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For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the most recent edition of the *BIOSIS Serial Sources* (Philadelphia, PA: Biosciences Information Service). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

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Tables may be prepared either with WordPerfect text or with the WordPerfect table formatting function. If text is used, then data should be assigned to columns by using all tabs or all spaces, but not a combination of the two.

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Jon A. Gibson (Biological Sciences Editor)
NMFS Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026 USA.

Research Communications Unit
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

STANDARD
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Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large area studies; synthesis reports for major resources or habitats; annual reports of assessment or monitoring programs; documentary reports of oceanographic conditions or phenomena; manuals describing field and lab techniques; literature surveys of major resource or habitat topics; findings of task forces or working groups; summary reports of scientific or technical workshops; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

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Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

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Northeast Fisheries Science Center Reference Document 03-06

36th Northeast Regional Stock Assessment Workshop (36th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

March 2003

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02-12 **Proceedings of the Fifth Meeting of the Transboundary Resources Assessment Committee (TRAC), Woods Hole, Massachusetts, February 5-8, 2002.** By R.N. O'Boyle and W.J. Overholtz, TRAC co-chairmen. [A report of Transboundary Resources Assessment Committee Meeting No. 5]. September 2002.

02-13 **Report of the 35th Northeast Regional Stock Assessment Workshop (35th SAW): Public Review Workshop.** [By Northeast Regional Stock Assessment Workshop No. 35.] September 2002.

02-14 **Report of the 35th Northeast Regional Stock Assessment Workshop (35th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments.** [By Northeast Regional Stock Assessment Workshop No. 35.] September 2002.

02-15 **Report of the Workshop on Trawl Warp Effects on Fishing Gear Performance, Marine Biological Laboratory, Woods Hole, Massachusetts, October 2-3, 2002.** [By Workshop on Trawl Warp Effects on Fishing Gear Performance, Marine Biological Laboratory, Woods Hole, Massachusetts, October 2-3, 2002.] October 2002.

02-16 **Assessment of 20 Northeast Groundfish Stocks through 2001: A Report of the Groundfish Assessment Review Meeting (GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8-11, 2002.** [By Groundfish Assessment Review Meeting, Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8-11, 2002.] October 2002.

03-01 **Manuscript/Abstract/Webpage Preparation, Review, & Dissemination: NEFSC Author's Guide to Policy, Process, and Procedure.** By J.A. Gibson, T.L. Frady, E.L. Kleindinst, and L.S. Garner. January 2003.

03-02 **Stock Assessment of Yellowtail Flounder in the Southern New England - Mid-Atlantic Area.** By S.X. Cadrin. [A report of Northeast Regional Stock Assessment Workshop No. 36.] February 2003.

03-03 **Stock Assessment of Yellowtail Flounder in the Cape Cod - Gulf of Maine Area.** By S.X. Cadrin and J. King. [A report of Northeast Regional Stock Assessment Workshop No. 36.] February 2003.

03-04 **Report of the 36th Northeast Regional Stock Assessment Workshop (36th SAW): Public Review Workshop.** [By Northeast Regional Stock Assessment Workshop No. 36.] February 2003.

03-05 **Description of the 2002 Oceanographic Conditions on the Northeast Continental Shelf.** By M.H. Taylor, C. Bascuñán, and J.P. Manning. March 2003.

Northeast Fisheries Science Center Reference Document 03-06

A Report of the 36th Northeast Regional Stock Assessment Workshop

36th Northeast Regional Stock Assessment Workshop (36th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

March 2003

Northeast Fisheries Science Center Reference Documents

This series is a secondary scientific series designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review but no technical or copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

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C. NORTHERN SHRIMP

MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 36th Northeast Regional Stock Assessment Workshop (36th SAW) was held in the Aquarium Conference Room of the Northeast Fisheries Science Center's Woods Hole Laboratory, Woods Hole, MA December 2-6, 2002. The SARC Chairman was Dr. Andrew Payne, CEFAS, UK (CIE). Members of the SARC included scientists from the NEFSC, the NMFS's Northeast Regional Office, the New England Fishery Management Council (MAFMC), Atlantic States Marine Fisheries Commission (ASMFC), State of Maryland, Canada's Department of Fisheries and Oceans (DFO), and the SEFSC's Beaufort NC laboratory (Table 1). In addition, 39 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. SAW-36th SARC Composition.

Andrew Payne (CEFAS, Lowestoft, UK; CIE), **Chairman**

Northeast Fishery Science Center:
Jon Brodziak
Chris Legault
Richard Pace
Anne Richards

Regional Fishery Management Councils:
Andy Applegate, NEFMC

Atlantic States Marine Fisheries Commission/States:
Laura Lee, ASMFC
Paul Piavis, MD

Other experts:
Jerome Hermsen, NMFS, Gloucester
Heath Stone, DFO, St. Andrews
John Wheeler, DFO, Newfoundland; CIE
Erik Williams, SEFSC, Beaufort

Table 2. List of Participants.

NMFS, Northeast Fisheries Science Center	MAFMC/ASMFC/States/Industry
Almeida, Frank	Carmichael, John - NC DMF
Boreman, John	Caruso, Paul - MA DMF
Burnett, Jay	Correia, Steve - MA DMF
Cadrin, Steve	Gamble, Megan - ASMFC
Col, Laurel	Glenn, Bob - MA DMR
Idoine, Josef	Hunter, Margaret - Maine DMR
Jearld, Ambrose	Kelly, Steve - REMSA
Mayo, Ralph	King, Jeremy - MA DMF
McHugh, Nancy	Kuzirian, Alan - MBL
Moser, Joshua	Lazar, Najih - RI DFW
Murawski, Steve	Lewis, Michael - ASMFC
Nitshcke, Paul	Lovett, Katie - NMFS
O'Brien, Loretta	McNamee, Jason - RI DEM
Serchuk, Fred	Munger, Lydia - ASMFC
Shepherd, Gary	O'Shea, Vincent - ASMFC
Smith, Pie	Quinlan, John - Rutgers IMCS
Smith, Terry	Sharov, Alexei - MD DNR
Sosebee, Katherine	Welch, Stuart - U.S.G.S
Sutherland, Sandra	
Terceiro, Mark	
Thompson, Michele	

Table 3. Agenda of the 36th Northeast Regional Stock Assessment Workshop (SAW-36) Stock Assessment Review Committee (SARC) Meeting

Aquarium Conference Room - NEFSC Woods Hole Laboratory
Woods Hole, Massachusetts
2 - 6 December, 2002

TOPIC	WORKING GROUP & PRESENTER(S)	SARC LEADER	RAPPORTEUR
MONDAY, 2 December (1:00 - 5:00 PM)........			
Opening			
Welcome	Terry Smith, SAW Chairman		P. Smith
Introduction	Andy Payne, SARC Chairman		
Yellowtail flounder (A)	SAW Southern Demersal Working Group		
	S. Cadrin	H. Stone	R. Mayo
TUESDAY, 3 December (8:30 AM - 5:00 PM)........			
SNE/MA winter flounder (B1)	ASMFC winter flounder technical committee		
	M. Terceiro	J. Wheeler	P. Nitschke
Gulf of Maine winter flounder (B2)	ASMFC winter flounder technical committee		
	P. Nitschke	E. Williams	M. Terceiro
Northern shrimp (C)	ASMFC northern shrimp technical committee		
	M. Hunter	L. Lee	R. Glenn
Informal reception (**6:00 PM**) at SWOPE Building (Marine Biological Laboratory)			
WEDNESDAY, 4 December (8:30 AM - 5:00 PM)........			
SNE/MA yellowtail flounder (A1)	SAW Southern Demersal Working Group		
	S. Cadrin	H. Stone	S. Wigley
Cape Cod yellowtail flounder (A2)	SAW Southern Demersal Working Group		
	S. Cadrin	A. Applegate	J. King
Atlantic striped bass (D)	ASMFC striped bass technical committee		
	A. Sharov/ S. Welch	P. Piavis	M. Gamble
THURSDAY, 5 December (8:30 AM - 5:00 PM)........			
Review Advisory Reports and Consensus Summary Sections for the SARC Report			
FRIDAY, 6 December (8:30 AM - 5:00 PM)........			
SARC comments, research recommendations, and 2nd drafts of Advisory Reports			
Other business		P. Smith	

The Process

The Northeast Regional Coordinating Council, which guides the SAW process, is composed of the chief executives of the five partner organizations (NMFS/NEFSC, NMFS/NER, NEFMC, MAFMC, ASMFC). Working groups assemble the data for assessments, decide on methodology, and prepare documents for SARC review. The SARC members have a dual role – panelists are both reviewers of assessments and drafters of management advice. As products of the meeting, the Committee prepares two reports: a summary of the assessments with advice for fishery managers known as the *Advisory Report on Stock Status*; and a more detailed report of the assessment, results, discussions and recommendations known as the *Consensus Summary of Assessments* (this report).

Assessments for SARC review were prepared at meetings listed in Table 4.

Table 4. SAW-36 Working Group meetings and participants.

Working Group and Participants	Stock/Species	Meeting Date
SAW Southern Demersal Subcommittee		
	Yellowtail flounder stock structure	August 29, 2002
Frank Almeida	NEFSC	
Jon Brodziak	NEFSC	
Steve Cadrin	NEFSC	
Hemant Chikarmane	MBL	
Laurel Col	NEFSC	
Alexandra Hangsterfer	MBL	
Jeremy King	MADMF	
Alan Kuzirian	MBL	
Chris Legault	NEFSC	
Ralph Mayo	NEFSC	
Tom Nies	NEFMC	
Loretta O'Brien	NEFSC	
Bill Overholtz	NEFSC	
Paul Rago	NEFSC	
Tim Sheehan	NEFSC	
Vaughn Silva	NEFSC	
Sandy Sutherland	NEFSC	
Mark Terceiro, chair	NEFSC	
Michelle Thompson	NEFSC	
Susan Wigley	NEFSC	

Table 4. (cont.) SAW-36 Working Group meetings and participants.

Working Group and Participants	Stock/Species	Meeting Date
	SNE/MA yellowtail flounder CC/GOM yellowtail flounder	Sept. 30 - October 4, 2002
Steve Cadrin	NEFSC	
Steve Correia	MA DMF	
Jeremy King	MA DMF	
Gary Shepherd	NEFSC	
Kathy Sosebee	NEFSC	
Mark Terceiro, chair	NEFSC	
ASMFC Winter Flounder Technical Committee		
	SNE/MA winter flounder GOM winter flounder	September 24-25, 2002
Jay Burnett	NEFSC	
Steve Cadrin	NEFSC	
Steve Correia	MA DMF, Chair	
Laura Lee	ASMFC, RIDMF	
Chris Legault	NEFSC	
Anne Mooney	NY DEC	
Lydia Munger	ASMFC	
Paul Nitschke	NEFSC	
Sally Sherman	ME DMR	
David Simpson	CT DEP	
Kathy Sosebee	NEFSC	
Mark Terceiro	NEFSC	
Susan Wigley	NEFSC	
ASMFC Northern Shrimp Technical Committee		
	Northern Shrimp	May 15, 2002 September 23-24, 2002
Robert Glenn	MA DMF	
Margaret Hunter, chair	ME DMR	
Josef Idoine	NEFSC	
Clare McBane	NH F&G	

Table 4. (cont.) SAW-36 Working Group meetings and participants.

Working Group and Participants	Stock/Species	Meeting Date
ASMFC Atlantic Striped Bass Tagging. Committee		Linthicum, MD July 23-24, 2002
Robert Beal	ASMFC	
Megan Gamble	ASMFC	
Bob Harris	VIMS	
Desmond Kahn	DE DFW	
Tina McCrobie	USFWS	
Kim McKown	NYS DEC	
Vic Vecchio	NYS DEC	
Beth Versak	MD DNR	
Stuart Welch	USGS, WVU	
ASMFC Striped Bass Technical Committee		Linthicum, MD September 10-12, 2002
Mike Armstrong	MA DMF	
Tom Baum	NJ DFW	
Robert Beal	ASMFC	
John Carmichael	NC DMF	
Vic Crecco	CT DMF	
Megan Gamble	ASMFC	
Mark Gibson	RI DFW	
Doug Grout	NH DFW	
Phil Jones	MD DNR	
Desmond Kahn	DE DFW	
Kim McKown	NYS DEC	
Gary Nelson	MA DMF	
Rob O'Reilly	VRMC	
Alexi Sharov	MD DNR	
Gary Shepherd	NEFSC	
Tom Squiers	ME DMR	

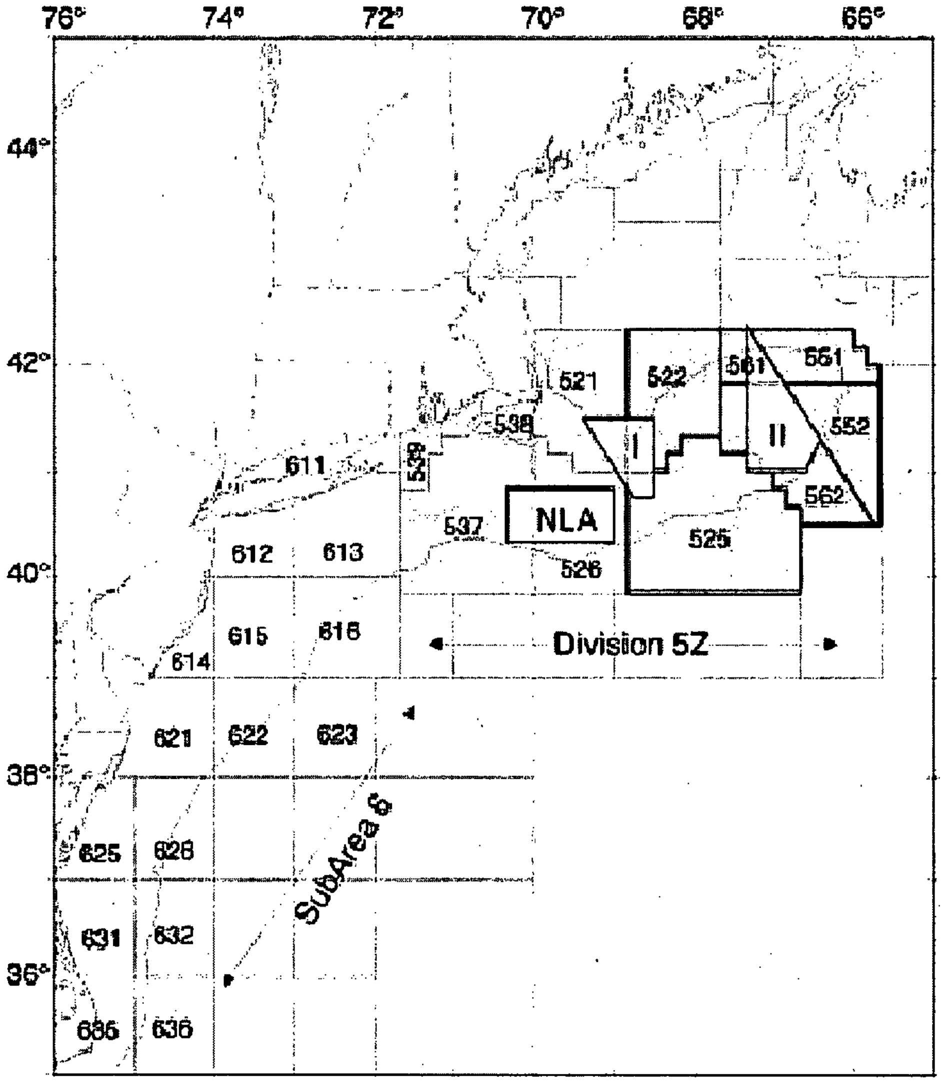
Agenda and Reports

The 36th SARC included presentations on assessments for yellowtail flounder (two stocks), winter flounder (two stocks), and northern shrimp as well as a presentation on assessment methodologies for striped bass. Prior to the presentation and discussion of individual yellowtail flounder stock assessments, the SARC discussed the issue of stock identification for the species. Information was offered by the SAW southern demersal group that led the SARC to conclude that, for assessment purposes, three stocks be classified: Southern New England/Mid-Atlantic (SNE/MA), Georges Bank, and Cape Cod/Gulf of Maine (CC/GOM). Assessments for the SNE/MA and CC/GOM stocks were then reviewed by the panel. The two winter flounder stocks assessed and reviewed by the panel are the Southern New England/Mid-Atlantic stock (SNE/MA) (as previously defined) and the Gulf of Maine stock (previously defined). The GOM winter flounder assessment was the first analytical assessment (VPA via ADAPT) offered for the stock. The winter flounder assessments were prepared by the ASMFC's winter flounder technical committee as was the assessment for northern shrimp. The striped bass information reviewed by the SARC was not an assessment, per se, but rather materials to address a set of questions (Terms of Reference) which related to specific issues of assessment methodology offered by the ASMFC.

SARC documentation includes two reports: one containing the assessments, SARC comments, and research recommendations (the Consensus Summary Report), and another produced in a standard format which includes information on stock status and management advice (Advisory Report). The draft reports were provided to the NEFMC, MAFMC and ASMFC in January. Presentations to the Councils and Commissions took place in January and February 2003 (MAFMC, 23 January, Atlantic City; NEFMC, 29 January, Portsmouth NH; ASMFC, 25 February, Crystal City VA). Following review by the Councils and Commission, the documents are finalized and published in the NEFSC Reference Document series as the *36th SARC Consensus Summary of Assessments* (this report) and the 36th *SAW Public Review Workshop Report* (which includes the final version of the Advisory Report).

A chart of US commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. A chart showing the sampling strata used in NEFSC bottom trawls surveys is presented in Figure 2.

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.



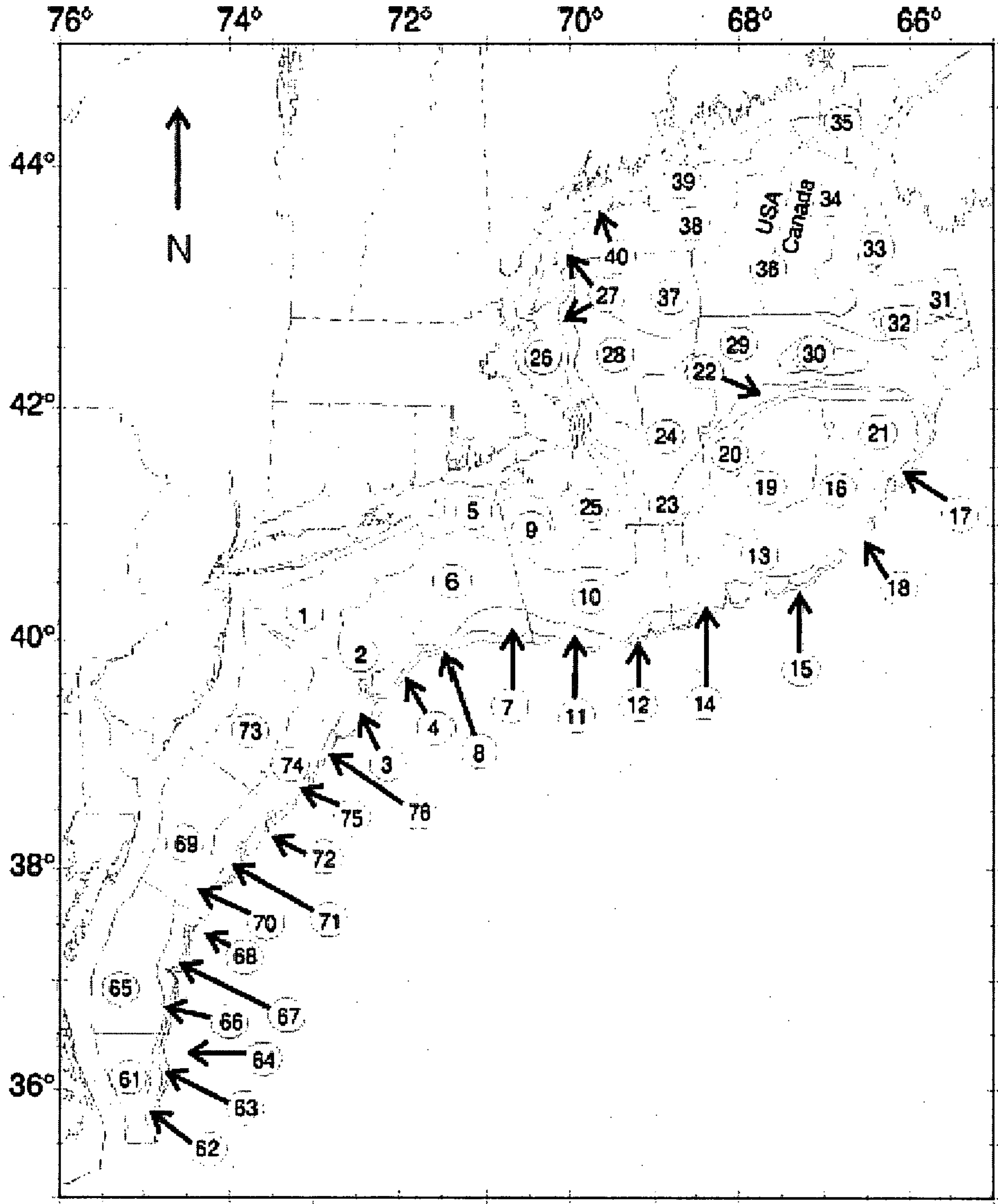


Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. YELLOWTAIL FLOUNDER

Stock Structure

The SARC reviewed a summary of available information on stock structure of yellowtail flounder in the Northwest Atlantic, with a focus on resources off the northeastern United States. Following an extensive review of the literature on stock identification, the SARC was presented with a summary of a series of studies covering spatial distribution patterns, geographic variation in growth and maturity, morphometric variation, and larval transport. At present, yellowtail flounder off the northeast coast of the United States are managed as four units: Georges Bank, Cape Cod, Southern New England, and Mid-Atlantic. In addition, the resource is distributed in the western Gulf of Maine, primarily in statistical area 513 adjacent to the Cape Cod management unit. Assessment of the Georges Bank, Southern New England, and Cape Cod stocks are carried out analytically through Virtual Population Analysis (VPA) and/or Biomass Dynamics Models (ASPIC), while the status of the Mid-Atlantic stock is evaluated using research survey index proxies. There has been no analytical assessment of the Gulf of Maine resource.

Most scientific evidence, including tagging studies, growth and maturity rates, and larval transport suggests that yellowtail flounder on Georges Bank are distinct from those in adjacent areas. However, there appears to be a considerable degree of mixing and similarities in biological characteristics between the southern New England and Mid-Atlantic stock units. In the past, the two units were considered to be a single stock, and were apparently split for ICNAF jurisdictional, rather than biological reasons. Although data on stock structure in the Gulf of Maine are sparse, the available information suggests that there is no basis to maintain a distinction between the Cape Cod stock unit and the remaining distribution of the resource in the Gulf of Maine.

The SARC then considered a proposal by the Southern Demersal Working Group to define three stock units: Georges Bank, Southern New England/Mid-Atlantic, and Cape Cod/Gulf of Maine.

Although the literature review and recent studies are comprehensive, there remain several areas of concern. Many conclusions were based on differences in biological characteristics that may simply reflect different environmental regimes in the various locations or changes in exploitation over time. Regardless of the mechanism, differences in growth and maturity are maintained because there is a significant degree of geographic isolation, particularly between the Georges Bank stock and those to the west. However, there are no such physical barriers between the southern New England and Mid-Atlantic areas and there appears to be substantial movement across the existing boundary between the management units for these two stocks.

The relevance of the historical tagging experiments is also an area of concern. The tag returns from these earlier studies were not adjusted for fishing effort, and the tag release sites (often on

Magnuson et al. 1990 (Chapters 4+6)

DECLINE OF THE SEA TURTLES CAUSES AND PREVENTION

Committee on Sea Turtle Conservation

Board on Environmental Studies and Toxicology

Board on Biology

Commission on Life Sciences

National Research Council

NATIONAL ACADEMY PRESS

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The project was supported by the Department of Commerce under contract number 50 DGNC 9 00080.

Cover: Loggerhead turtle. Photograph courtesy of the Florida Audubon Society.

Frontispiece: Thousands of fish and a loggerhead turtle caught in a shrimp trawl. The turtle is alive and apparently uninjured. The fish are dead. Photograph: Michael Weber, Center for Marine Conservation.

Photographs on chapter-opening pages are courtesy of Peter Pritchard and the Florida Audubon Society, and Michael Weber, Center for Marine Conservation.

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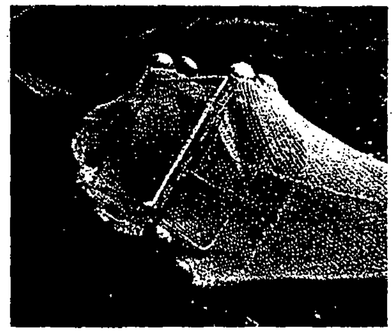
ɔarse in U.S. waters for trend analysis. ; to have increased somewhat over the umbers have been very low throughout.

ıumbers in the United States, principally erto Rico. Although records are too few rs do not appear to be declining. Inter- important Surinam and French Guiana population shifts as beaches erode and



4 Distribution of Sea Turtles in U.S. Waters

To understand the issues concerning the conservation of sea turtles in U.S. waters, we need to view their distribution along the Atlantic and gulf coasts on a broad spatial scale. That immediately makes apparent the wide extent of the complex conservation problem even in U.S. coastal waters. It also helps to identify, for example, which beaches should receive priority for protection of sea turtle nesting and where the distribution of sea turtles overlaps with human activity to cause mortality along the coasts at various water depths in different seasons. This chapter enlarges the general presentation on species distributions in Chapter 2 and provides a broad analysis of the distribution of sea turtles in U.S. waters in recent years. For our analysis, we have taken the most quantitative published information available or have reanalyzed the most extensive data bases available through the cooperation of individuals and government agencies.

SOURCES OF INFORMATION

Nesting Distribution

Information on distribution of nests of loggerheads, green turtles, and leatherbacks in the continental United States has been obtained from aeri-

al surveys and beach patrols. The committee's compilations are based on data from the U.S. Fish and Wildlife Service, North Carolina Wildlife Resources Commission, South Carolina Wildlife and Marine Resources Department, Georgia Department of Natural Resources, and Florida Department of Natural Resources. Additional data were obtained from the U.S. Recovery Plan. Density (nests per kilometer) varies from year to year, as does the intensity of beach surveys. Sufficient data are available, however, to indicate the general density of nesting on beaches from Maine to Texas.

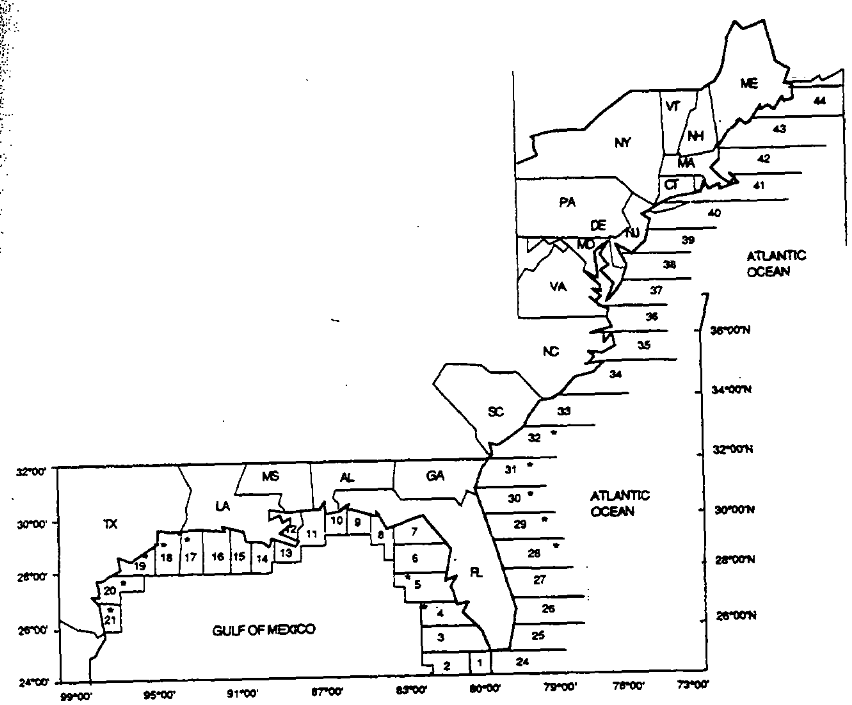
Pelagic Aerial Surveys

Aerial surveys documenting the distribution of sea turtles in the water have been conducted from Maine to the Mexican border. Data presented here are from N.B. Thompson (pers. comm., NMFS, 1989) and Winn (1982). Aerial surveys are valuable for surveying large areas in a short time. However, interpreting data from aerial surveys is difficult for several reasons: small turtles, particularly Kemp's ridleys, generally are not visible, and ocean conditions, such as water clarity and surface glare, can alter visibility and therefore affect the reliability of species identification and counts.

Sea Turtle Strandings

Volunteers in the Sea Turtle Stranding and Salvage Network (STSSN) attempt to document every sea turtle stranding on the U.S. Atlantic and gulf coasts. The date and location of each stranded turtle are recorded, as well as its species, size, and condition. Distribution of strandings provides information on the distribution of turtles. However, quantification of turtle distribution based on that data base is limited by several factors. First, the data base is not independent of the distribution of human-induced mortality factors, such as fishing, dredging, and boating. Second, temporal and spatial coverages are rarely uniform. Most beaches are surveyed by volunteers. Areas under contract for regular surveys since 1986 are fishing zones 17-21 (Texas), fishing zones 4 and 5 (gulf coast of south Florida), and fishing zones 28-32 (Atlantic coast of north Florida, Georgia, and South Carolina) (Figure 4-1). Shorelines formed by marsh or mangrove stands, such as large sections of the Louisiana coast and the northwestern coast of the Florida peninsula, are not surveyed. Third, because of current and wind patterns, dead turtles might float some distance before they strand or might never strand.

FIGURE 4-1 Shrimp-fishing zones along U.S. coasts of Atlantic Ocean and Gulf of Mexico.



NOTE: Asterisk indicates that zone has contractual arrangement for observing turtle stranding.

DISTRIBUTION

The capture of sea turtles in bottom trawls associated with commercial and experimental or exploratory fishing provides some information on depth and area distribution.

Nesting

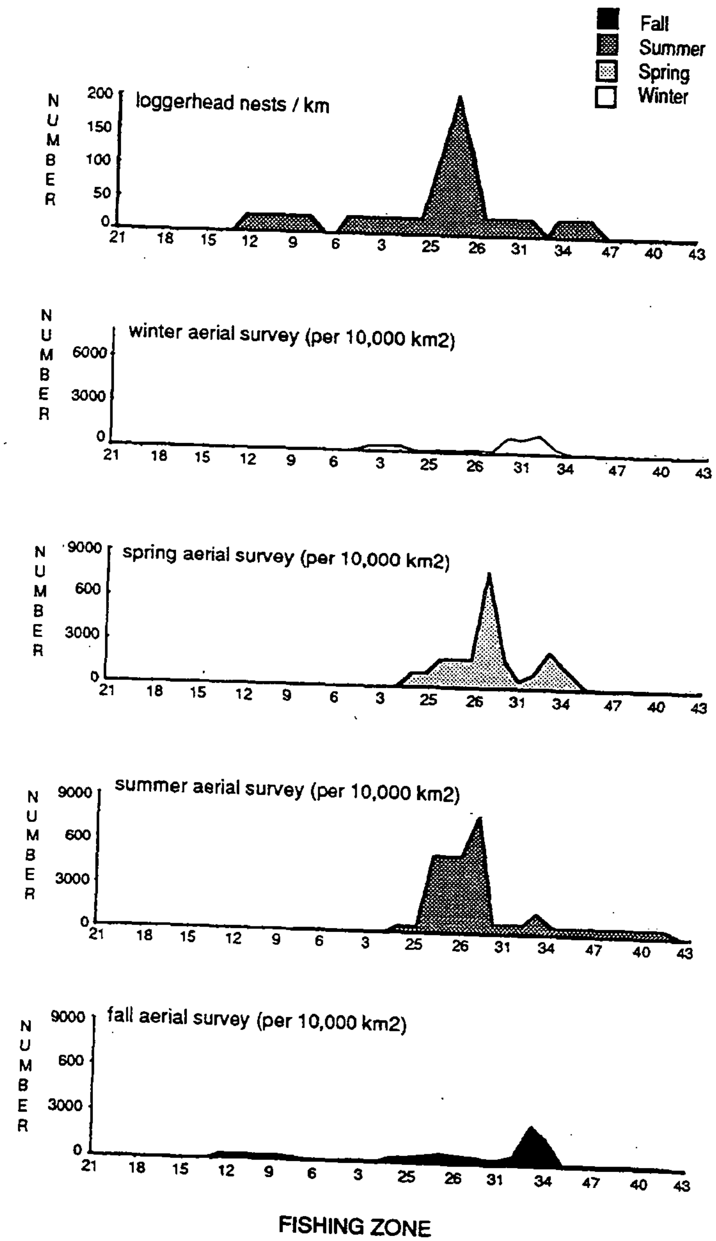
The southeastern United States supports one of the two largest rookeries of loggerheads in the world. Some nesting occurs from North Carolina to Louisiana, with outliers as far north as New Jersey and west to Texas (Figure 4-2, *top*); but the 330 km of beach on the Atlantic coast of Florida between St. Augustine and Jupiter supports by far the highest density of loggerhead nesting (Figure 4-2). In recent years, from 50 to more than 200 nests/km of beach are dug annually in this region, compared with only a few to 50 nests/km elsewhere (Figure 4-2, *top*). In addition, the same 330 km of beach is the only location where substantial (but much lower) numbers of green turtles and leatherbacks nest on the U.S. Atlantic and gulf coasts. Kemp's ridleys and hawksbills very rarely use U.S. continental beaches for nesting.

Aerial Surveys

Quantitative data are available for some regions to evaluate the seasonal changes in on/offshore distribution or the depth distribution of large individuals of the most abundant species, the loggerhead, along the Atlantic and gulf coasts of the United States. The most general picture comes from distributional maps compiled from aerial surveys taken in each quarter of the year for much of the Atlantic coast and portions of the gulf coast (Winn, 1982; Thompson, 1984; pers. comm., N.B. Thompson, NMFS, 1989). Other aerial surveys are more spatially restricted but provide useful information for selected sites off Florida, Louisiana, and Texas (Fritts and Reynolds, 1981; Fritts et al., 1983; pers. comm., R. Lohoefener, NMFS, 1989).

North of Cape Hatteras to the Gulf of Maine, large loggerheads were sighted from inshore to the offshore banks and shelf edge and continental slope (Winn, 1982). The distribution shifted from more inshore to more midshelf from spring to summer. From Cape Hatteras, North Carolina to St. Augustine, Florida, sea turtles, mostly large loggerheads with a few adult leatherbacks, generally appeared more abundant on the inshore

FIGURE 4-2 Distribution of loggerhead nesting (per km) and seasonal aerial surveys of loggerheads (per 10,000 km^2) in shrimp-fishing zones. Data from Appendix D.



halves of aerial transects than on offshore halves in spring and summer, but appeared less abundant on the inshore than offshore halves in fall and winter (Thompson, 1984). There are too many points on Thompson's maps to see any obvious difference in the Cape Canaveral region. South of Canaveral, large loggerheads appear more abundant in the inshore than offshore halves of the transects in all seasons of the year. In the Gulf of Mexico from Key West to the Mississippi River (pers. comm., N. Thompson, NMFS, 1989), sightings of large loggerheads seem more frequent in the inshore portions of aerial surveys than in the offshore portions in summer and autumn, and offshore in winter. Maps of the sightings of large loggerheads used in Lohoefener et al. (1988) in spring and autumn for all gulf locations show no obvious seasonality with respect to distance from shore, nor did Lohoefener (pers. comm., NMFS, 1989) observe any seasonal changes in depth distribution off Louisiana from the data used by Lohoefener et al. (1989).

Densities of large loggerheads (with a few adult leatherbacks) from aerial sightings can also be analyzed with respect to water depth over which the turtles were sighted within survey areas of 25,642 km^2 at two locations on the gulf coast of southern Florida in August (Fritts and Reynolds, 1981) and seasonally both for the Atlantic coast of Florida off the primary nesting beaches of loggerheads near Cape Canaveral and the gulf coast of southern Florida (Fritts et al., 1983). Other sites off Louisiana and Texas had too few turtle sightings to analyze for seasonality of on/offshore or depth distributions.

The primary conclusion of these two aerial surveys off Florida is that both in the Atlantic waters (Canaveral area) and the gulf waters of southern Florida, the aerial sighting densities of large loggerheads are higher throughout the year over water depths of 0-50 m than over depths from 50-1,000 m; few large loggerheads or leatherbacks were observed over waters from 50-1,000 m in any season. Averaged over all seasons, the sighting densities over waters 25 to 50 m deep were 78-82% of those over 0 to 25 m depths, but sighting densities over waters 50 to 100 m deep were 9-14% of those over 0 to 25 m depths. Because the depth contours drop off much more sharply at Canaveral than at the gulf site off south Florida, it also appears that the distributions of large loggerheads were related to water depth rather than to distance from shore. For both locations, the sighting density declines rapidly near the 50 m depth contour rather than at a fixed distance from shore. An alternative explanation might be that turtles spend more time below the surface in deeper water and that fewer are then sighted. However, the catch in trawls, presented below, also supports the conclusion of fewer large loggerheads and leatherbacks being found in deeper waters.

At both the Canaveral and the southern Florida gulf sites, large loggerheads remained abundant throughout the year at depths from 0 to 50 m. In waters less than 50 m deep, minimum sighting densities of large loggerheads observed in October and December averaged about 50% of those for February, April, June, and August.

Aerial surveys of coastal waters also demonstrate the high concentration of adult loggerheads off the primary nesting beaches along the Atlantic coast of Florida during spring and summer (Figure 4-2); sightings range up to about 7,900 per 10,000 km^2. Moderately high sighting densities, about 2,500 per 10,000 km^2, also were reported in the fall off North and South Carolina. Densities of sighted large loggerheads were low (about 30-100 per 10,000 km^2), along portions of the west coast of Florida, and decreased sharply off Louisiana and Texas (to 1-30 per 10,000 km^2). North of Cape Hatteras, loggerheads were absent in winter, low in summer (about 500 per 10,000 km^2, and very low (1-4 per 10,000 km^2) even in summer as far north as the Gulf of Maine.

Leatherbacks sighted in aerial surveys were uncommon throughout the entire Gulf of Mexico, averaging about 50 per 10,000 km^2 (Lohoefener et al., 1988) and were about one-hundredth as abundant as large loggerheads among identified sightings off the Atlantic coast south of Cape Hatteras (Thompson, 1984). In the Gulf of Maine, leatherbacks numbered only 7-8 per 10,000 km^2 during summer and fall; they were absent or very sparse in winter and spring.

Kemp's ridleys are not usually visible and identifiable from aerial surveys, so this survey method provides no information on their distribution.

Seasonality of sighting densities varies with the geographic location along the coast. Off the primary nesting beaches of Florida's Atlantic coast, sighting densities were about 15 times higher during spring and summer than during autumn and winter (Figure 4-2); the lowest sighting densities occurred in the winter, when they were about 2.5% of highest summer densities. That pattern reflects the aggregation of the mature loggerheads for breeding and access to the nesting beaches. Farther north, off North Carolina, sighting densities were not maximal during the summer nesting season, but rather were 2-4 times higher during spring and autumn than during winter or summer. Seasonal coverages of aerial surveys are insufficient to permit speculation about other regions.

Strandings

According to 1987 and 1988 data from the STSSN, the most common turtle carcasses found on the outer beaches from Maine to Texas were

those of loggerheads (1,522 and 1,150 in these years), followed by Kemp's ridleys (141 and 176), green turtles (105 and 150), leatherbacks (119 and 63), and hawksbills (22 and 20) (Appendix E). Those numbers understate the number of dead turtles in the area, in that many dead turtles do not drift ashore or are not found. The highest stranding rates of loggerheads occurred along 500 km of Atlantic beaches of Georgia and northern Florida (Figure 4-3). Other areas with many strandings of loggerheads were the beaches of Mississippi, Alabama, and Texas. Carcasses of Kemp's ridleys were found most frequently on beaches of Texas, the Atlantic coast of northern Florida, and North Carolina (Figure 4-3). Green turtles were stranded most frequently along the Atlantic coast of Florida; leatherbacks along the coasts of Delaware, New Jersey, and New York; and hawksbills along the coasts of Texas and Florida (Figure 4-3).

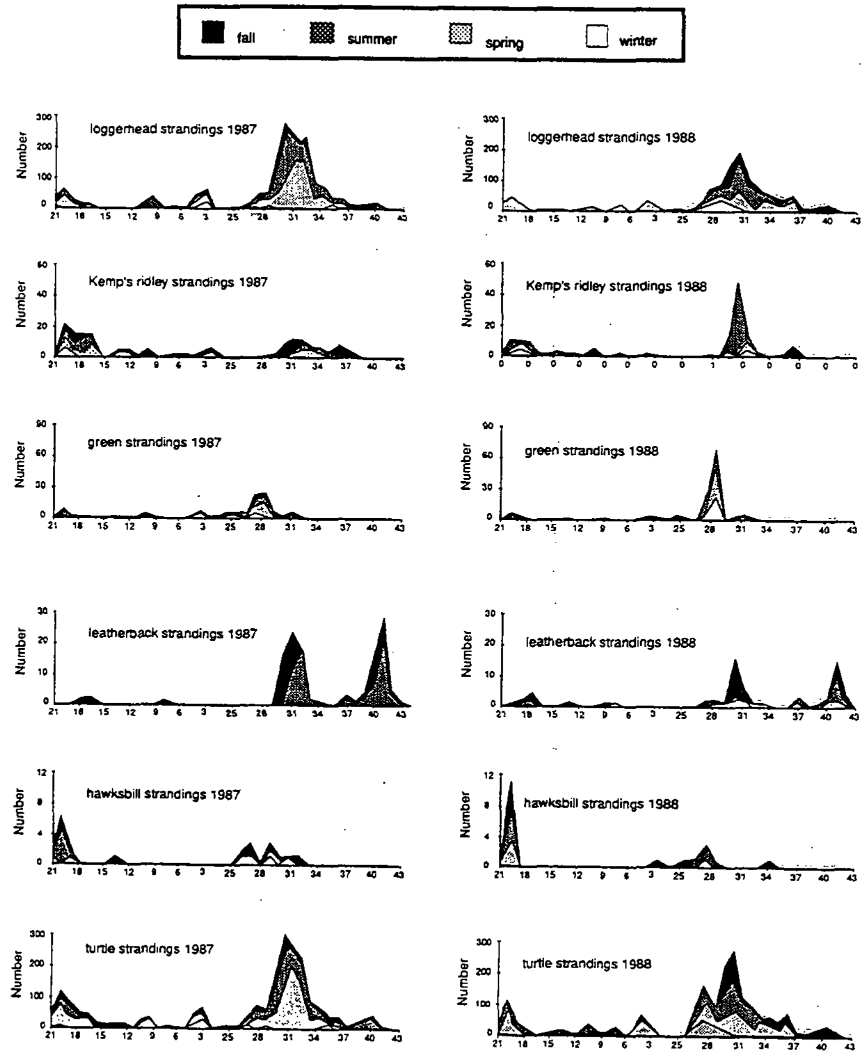
Seasonality of strandings differs with species of turtle and geographic region. Loggerheads strand most frequently in May-December on Atlantic beaches, in April and May on the Texas coast, and in May and June in Mississippi and Alabama. In some locations and seasons, few turtle carcasses are reported. In some areas, that is accounted for by the absence of beach surveys or by ocean current patterns; in others, it might be related to an overall lack of turtles in the region. For example, in northern Florida and Georgia, only 1.5% and 3.6% of the annual totals of loggerhead strandings in 1987 and 1988, respectively, occurred in winter (January-March) along the 500 km characterized by maximal strandings during May through September. That is consistent with the aerial survey data on turtles off this coastal region, where winter sighting densities were 2.5% of maximal summer sighting densities. In addition, few sightings in the region were on the inshore portions of the aerial surveys in winter, but many during the spring and summer (Thompson, 1984).

Seasonality of strandings of Kemp's ridleys also appeared to differ with region (Figure 4-3). On Texas beaches, stranding occurred in February-December, with maximums in April and May and again in August and September, but few strandings occurred on the Atlantic coasts of Florida to Maine in January-May.

ONSHORE, OFFSHORE, AND DEPTH DISTRIBUTION

Turtles caught in bottom trawls also provide information on depth distribution that is consistent with the marked decrease of large loggerheads and leatherbacks at increasing depths observed in the aerial surveys. Twenty-nine loggerheads were captured off Georgia and Florida (to Key West) in 1306 hours of trawling (Bullis and Drummond, 1978). The highest catches, about 0.0015-0.0045 turtles/hour of trawling, were taken in

FIGURE 4-3 Sea turtle stranding, by species, 1987-1988. Fishing zones are shown on horizontal axes (see Figure 4-1). Source: STSSN (see Appendix E).



0-40 m of water compared with catch rates of 0-0.0025 turtles/hour in 40-100 m. Thirteen sea turtles, mostly loggerheads and Kemp's ridleys, were caught in the Gulf of Mexico off Louisiana or the west coast of southern Florida in the NMFS observer program in 1988-1989. Catch rates were 0.006 turtles/hour (in 2,007 hours) at 0-27 m and 0.0008 turtles/hour (1,285 hours) at more than 27 m. Henwood and Stuntz (1987) also showed that the catch of sea turtles per net per hour was lower at depths of 27-99 m than 2-27 m. They had 976 trawling hours in the deeper water and 5,177 trawling hours in the shallowest water. They did not present data on catch rates of turtles by depth, but the catch per effort at depths greater than 27 m was less than the catch per effort for all but two of the other depth intervals. As with the aerial surveys, turtle abundance in deeper water appeared to be about one-tenth that in shallower water.

SUMMARY

Data on distribution of sea turtles come from observations of nesting turtles, aerial surveys, the STSSN, and incidental captures in fishing gear.

Nesting is most common on the Atlantic coast of Florida, and the loggerhead is the greatly predominant species. Loggerheads aggregate off the nesting beaches in spring and summer, and move up and down the coasts and a little more offshore in fall and winter. Some leatherback and green turtle nesting occurs in eastern Florida. According to stranding data, sea turtles in order of decreasing abundance in U.S. coastal waters are loggerheads, Kemp's ridleys, green turtles, leatherbacks, and hawksbills. Some strandings occur from the Gulf of Maine to all the states along the Gulf of Mexico. Adult turtles are apparently less abundant in deeper waters of the Gulf of Mexico than in waters less than 27-50 m deep, and they are usually uncommon near the shore off northern Florida in fall and winter. In the eastern gulf, turtles are less abundant inshore in winter than in summer, but even in winter they are common in inshore waters.

5
Natural Mortality and Critical Life Stages

This chapter summarizes current information on the causes and magnitude of natural mortality of sea turtles, and discusses how sea turtles at different life stages contribute to the population or to the reproductive value. Recent analyses of loggerhead populations and reproduction (Crouse et al., 1987) are especially useful for making decisions about conservation of sea turtles, because they help to identify life stages in which reduced mortality can have the greatest influence on the maintenance or recovery of endangered or threatened sea turtle populations.

From models developed by Frazer (1983a), female loggerheads probably first nest when about 22 years old, and survivors continue nesting every few years until they are about 54. Most mature female loggerheads nest every second or third year and deposit several clutches of eggs during a nesting season. Thus, an individual is estimated to lay on the average 80 eggs each year for 30 years. The eggs and hatchlings have high mortality rates, but as the survivors grow, natural mortality declines markedly. About 80% of the nesting females studied for many years at Little Cumberland Island survive from one year to the next. (Chapter 2 presented variations on the pattern of life history of the several species of sea turtles.) These general patterns of mortality and reproduction form a

6 Sea Turtle Mortality Associated with Human Activities

Sea turtles on nesting beaches are most susceptible to mortality associated with human activities at the egg, hatchling, and nesting female stages and in coastal waters at the subadult (including juvenile) and adult stages. They are vulnerable to diverse potentially lethal interactions with human activities, situations including direct predation and habitat modification, incidental capture or entanglement in fishing gear, and physical damage caused by dredging of shipping channels, collisions with ships and boats, and oil-rig removal or other underwater explosions. Each species in the pelagic environment is vulnerable to ingestion of plastics, debris, and petroleum residues. The species differ in behavior and habitat requirements, so they can be affected differently by various human activities.

The recognized sources of mortality related to human activities are listed in order of estimated importance in Table 6-1 for all life stages, and order-of-magnitude mortality estimates are presented in Table 6-2 for juvenile plus adult loggerheads and Kemp's ridleys. The latter table includes the committee's judgment of the certainty of the information on which the estimates were based and lists the preventive and mitigative measures that are in place or being developed. The preventive and mitigative measures are described and evaluated in detail in Chapter 7. The present chapter discusses the information on each mortality factor associ-

TABLE 6-1 A qualitative ranking of the relative importance of various mortality factors on juveniles or adults, eggs, and hatchlings with an indication of mortality caused primarily by human activities. Sources are listed in order of importance to juveniles or adults, because this group includes the life stages with greatest reproductive values.

		Life Stage		
Source of Mortality	Primarily Human Caused	Juveniles to Adults	Eggs	Hatchlings
Shrimp trawling	yes	high	none	unimportant
Other fisheries	yes	medium to low	none	unimportant
Non-human predators	no	low	high	high
Weather	no	low	medium	low
Beach development	yes	low	medium	low
Disease	no	low	unimportant	low
Dredging	yes	low	unimportant	unimportant
Entanglement	yes	low	unimportant	low
Oil-platform removal	yes	low	none	unimportant
Collisions with boats	yes	low	none	unimportant
Directed take	yes	low	medium	unimportant
Power plant entrainment	yes	low	none	unimportant
Recreational fishing	yes	low	none	unimportant
Beach vehicles	yes	low to unimportant	medium	unimportant
Beach lighting	yes	low to unimportant	unimportant	medium
Beach replenishment	yes	unimportant	low	low
Toxins	yes	unknown	unknown	unknown
Ingestion of plastics, debris	yes	unknown	none	unknown

ated with human activities first for eggs and hatchlings and then for juveniles through adults.

The analyses in Chapter 5 on the reproductive value of various life stages called attention to the mortality factors that are most important for juveniles and adults in the ocean and inshore marine habitats. The most important identifiable source of mortality for loggerhead and Kemp's ridleys is incidental capture in shrimp trawls (Table 6-2); other fisheries and fishery-related activities are also important, but collectively only one-tenth as important as shrimp trawling. Dredging, collisions with boats, and oil-rig removal are also important, but only one-hundredth as important as shrimp trawling. Mortality from entrainment in power plants and directed capture of juveniles and adults is believed to be generally low. Parasites,

TABLE 6-2 Order-of-magnitude estimates of human-caused mortality on juvenile to adult loggerhead and Kemp's ridley sea turtles, an index of the certainty of the mortality estimates, and a list of preventive or mitigative measures needed or in place for each type of mortality.

Source of Mortality Caused by Humans	Mortality (number/year)		Rank of Certainty of Estimate*	Preventive and Mitigative Measures in Place
	Loggerheads	Kemp's Ridleys		
Shrimp trawling	5,000-50,000	500-5,000	1	Turtle excluder devices, tow time, time and place restrictions
Other fisheries (trawl and release, passive gear, including entanglement in lost nets and debris)	500-5,000	50-500	3	Open and closed seasons and fisheries, and Marine Pollution International Protocol
Dredging	50-500	5-50	2	Seasons and turtle removal
Collisions with boats	50-500	5-50	3	None
Oil-rig removal	10-100	5-50	3	Surveys and turtle removal
Entrainment in power plants	5-50	5-50	1	Turtle removal with tended barrier nets
Directed take	5-50	5-50	3	Prohibition

*1 = most certain, 3 = least certain.

toxins, and ingestion of plastics and other debris also constitute problems, but present information does not allow quantitative estimates of annual mortality related to them.

MORTALITY OF SEA TURTLE EGGS AND HATCHLINGS

Beach Erosion and Accretion

Erosion of nesting beaches can result in loss of suitable nesting habitat. Erosion rates are influenced by dynamic coastal processes, including sea-level rise. Human interference with natural processes through coastal development and associated activities has resulted in accelerated erosion rates in some localities and interruption of natural shoreline migration. Accretion (deposition of beach sediments) also kills eggs in a nest.

Beach Armoring

Where beach-front development occurs, a site is often fortified to protect the property from erosion. Shoreline engineering is expensive and is virtually always carried out to save structures, not sandy beaches; it usually accelerates beach erosion (NRC, 1987). Several types of shoreline engineering, collectively referred to as beach armoring, include sea walls, rock revetments, riprap, sandbag installations, groins, and jetties. Those structures can cause severe adverse effects on nesting turtles and their eggs. Beach armoring can result in permanent loss of a dry nesting beach through accelerated erosion and prevention of natural beach and dune accretion, and it can prevent or deter nesting females from reaching suitable nesting sites. Clutches deposited seaward of the structures can be inundated at high tide or washed out by increased wave action near the base of them. As the structures fail and break apart, they spread debris on the beach, which can further impede access to suitable nesting sites and result in a higher incidence of false crawls (non-nesting emergences of females) and trapping of hatchlings and nesting turtles. Sandbags are particularly susceptible to rapid failure, which results in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts or to construct egg cavities of improper size and shape.

Groins are designed to trap sand during transport in longshore currents, and jetties might keep sand from flowing into channels. Those structures prevent normal sand transport and accrete beaches on one side of the structure while starving opposite beaches, thereby causing severe

erosion (NRC, 1987) and corresponding degradation of nesting habitat. Even widely spaced groins can deter nesting.

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand that moves along the beach and preventing excessive sand loss. They also protect dune systems by deterring public access. Because of their construction, improperly placed drift fences can impede nesting and trap emergent hatchlings.

Beach Nourishment

Beach nourishment consists of pumping, trucking, or otherwise depositing sand on the beach to replace what has been lost to erosion. Beach nourishment can disturb nesting turtles and even bury turtle nests during the nesting season. The sand brought in might differ from native beach sediments and can affect nest-site selection, digging behavior, incubation temperature (and hence sex ratios), gas-exchange characteristics in incubating nests, moisture content of a nest, hatching success, and hatchling emergence success (Mann, 1977; Ackerman, 1980; Mortimer, 1982b; Raymond, 1984; Nelson, 1986). Beach nourishment can result in severe compaction or concretion of the beach. The trucking of sand to protect beaches can itself increase compaction.

Significant reductions in nesting success on severely compacted beaches have been documented (Raymond, 1984). Nelson and Dickerson (1989a) evaluated compaction on 10 nourished east coast Florida beaches and concluded that five were so compacted that nest digging was inhibited and another three might have been too compacted for optimal digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches and that, although some might soften over time through erosion and accretion of sand, others can remain hard for 10 years or more. Nourished beaches develop steep escarpments in the midbeach zone that can hamper or prevent access to nesting sites. Nourishment projects involve use of heavy machinery, pipelines, increased human activity, and artificial lighting. They are normally conducted 24 hours a day and can adversely affect nesting and hatching activities. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, and so increase the incidence of false crawls. Increased human activity on a project beach at night might cause further disturbance to nesting females. Artificial lights along a project beach and in the nearshore area of the borrow site might deter nesting females and disorient emergent hatchlings on adjacent nonproject beaches.

Artificial Lighting

Extensive research has demonstrated that emergent hatchlings' principal cues for finding the sea are visual responses to light (Daniel and Smith, 1947; Hendrickson, 1958; Carr and Ogren, 1960; Ehrenfeld and Carr, 1967; Dickerson and Nelson, 1989). Artificial beachfront light from buildings, streetlights, dune crossovers, vehicles, and other sources has been documented in the disorientation of hatchling turtles (McFarlane, 1963; Philibosian, 1976; Mann, 1977; Fletemeyer, 1980; Ehrhart, 1983). The results of disorientation are often fatal. As hatchlings head toward lights or meander along the beach, their exposure to predators and likelihood of desiccation are greatly increased. Disoriented hatchlings can become entrapped in vegetation or debris, and many hatchlings have been found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that find the water might be disoriented after entering the surf zone or while in nearshore water. Intense artificial light can even draw hatchlings back out of the surf (Carr and Ogren, 1960; pers. comm., L. Ehrhart, University of Central Florida, 1989). In 1988, 10,155 disoriented hatchlings were reported to the Florida Department of Natural Resources.

The problem of artificial beachfront lighting is not restricted to hatchlings. Carr et al. (1978), Ehrhart (1979), Mortimer (1982b), and Witherington (1986) found that adult green turtles avoided bright areas on nesting beaches. Raymond (1984) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront light in southern Brevard County, Florida, and that nesting females avoided areas where beachfront light was most intense. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights might not be restricted to those placed directly on or near nesting beaches. The background glow associated with intensive inland light, such as that emanating from nearby large metropolitan areas, can deter nesting females and disorient hatchlings that are navigating the nearshore waters. Cumulatively, along the heavily developed beaches of the southeastern United States, the negative effects of artificial light are profound.

Beach Cleaning

Several methods are used to remove human-caused and natural debris from beaches, including mechanical raking, hand raking, and hand picking of debris. In mechanical raking, heavy machinery can repeatedly tra-

verse nests and potentially compact the sand above them; it also results in tire ruts along the beach that might hinder or trap emergent hatchlings (Hosier et al., 1981). Mann (1978) suggested that mortality within nests can increase when beach-cleaning machinery exerts pressure on soft beaches with large-grain sand. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb a sealed nest or might even uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried on the beach; this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches, hinder and entrap emergent hatchlings, and alter nest temperatures. Mechanical beach cleaning is sometimes the sole reason for extensive nest relocation.

Increased Human Presence

Resident and tourist use of developed (and developing) nesting beaches can adversely affect nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance of nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at all stages of the process. Murphy (1985) reported that beach disturbance can cause turtles to shift their nesting beaches, delay egg-laying, and select poor nesting sites. Davis and Whiting (1977) reported significantly higher rates of false crawls on nights when tagging patrols were active on an otherwise remote, undeveloped nesting beach. Nesting beaches heavily used by pedestrians might have low rates of hatchling emergence, because of compaction of the sand above nests (Mann, 1977), and pedestrian tracks can interfere with the ability of hatchling loggerheads to reach the ocean (Hosier et al., 1981). Campfires and the use of flashlights on nesting beaches disorient hatchlings and can deter nesting females (Mortimer, 1989).

Recreational Beach Equipment

Recreational material on nesting beaches (e.g., lounge chairs, cabanas, umbrellas, boats, and beach cycles) can deter nesting attempts and interfere with incubating egg clutches and the seaward journey of hatchlings. The documentation of false crawls near such obstacles is increasingly common as more recreational equipment is left in place all night on nesting beaches. There are also reports of nesting females that become entrapped under heavy wooden lounge chairs and cabanas on southern

Florida nesting beaches (pers. comm., S. Bass, Gumbo Limbo Nature Center, 1989; pers. comm., J. Hoover, Dade County Beach Department, 1989). Recreational beach equipment placed directly above incubating egg clutches can hamper emergent hatchlings and can destroy eggs by penetration directly into a nest (pers. comm., C. LeBuff, Caretta Research, Inc., 1989).

Beach Vehicles

The operation of motor vehicles on turtle nesting beaches is still permitted in many areas of Gulf of Mexico and Atlantic states (e.g., Florida, North Carolina, and Texas). Some areas restrict night driving, and others permit it. Driving on beaches at night during the nesting season can disrupt the nesting process and result in aborted nesting attempts. The adverse effect on nesting females in the surf zone can be particularly severe. Headlights can disorient emergent hatchlings and vehicles can strike and kill hatchlings attempting to reach the ocean. The tracks and ruts left by vehicles traversing the beach interfere with the ability of hatchlings to reach the ocean. The time spent in traversing tire tracks and ruts can increase the susceptibility of hatchlings to stress and predation during transit to the ocean (Hosier et al., 1981). Driving directly above incubating egg clutches compacts the sand and can decrease hatching success or kill pre-emergent hatchlings (Mann, 1977). In many areas, beach-vehicle driving is the only reason nests have to be relocated. Vehicular traffic on nesting beaches also contributes to erosion, especially during high tides or on narrow beaches, where driving is concentrated on the high beach and foredune.

Exotic Dune and Beach Vegetation

Non-native vegetation has been intentionally planted in or has invaded many coastal areas and often displaces native species, such as sea oats, beach morning glory, railroad vine, sea grape, dune panic grass, and pennywort. The invasion of such destabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation can also form impenetrable root mats, which can prevent proper nest-cavity excavation, and roots can penetrate eggs, cause eggs to desiccate, or trap hatchlings.

The Australian pine (*Casuarina equisetifolia*) is particularly detrimental. Dense stands of that species have taken over many coastal strand areas throughout central and southern Florida, causing excessive shading

of the beach. Studies in southwestern Florida suggest that nests laid in the shaded areas are subjected to lower incubation temperatures, which can alter the natural hatchling sex ratio (Marcus and Maley, 1987; Schmelz and Mezich, 1988). Fallen Australian pines limit access to suitable nest sites and can entrap nesting females. Davis and Whiting (1977) reported that nesting activity declined in Everglades National Park where dense stands of Australian pine took over native beach vegetation. Schmelz and Mezich (1988) indicated that dense stands of Australian pines in southwestern Florida affect nest-site selection and cause increased nesting in the middle beach area and higher ratios of false crawls to nests compared with areas of native vegetation.

MORTALITY OF SEA TURTLE JUVENILES AND ADULTS

Shrimp Fishing

Description of the Fishery

The shrimp fishery has the highest product value of any fishery in the United States. It also is the most important human-associated source of deaths of adult and subadult sea turtles. Sea turtles are captured in shrimp trawls towed along the bottom behind shrimping vessels. The vessels might tow one to four otter trawls. An otter trawl consists of a heavy mesh bag with tapered wings on each side that funnel shrimp into the cod end, or bag, of the net. To keep the trawl near the bottom and achieve horizonal opening of the mouth of the trawl, a weighted otter board is positioned at the front of each wing to serve as a hydrofoil. Turtles swimming, resting, or feeding on or near the bottom in the path of a trawl are overtaken and enter the trawl with the shrimp.

What is often perceived as the U.S. shrimp fishery is actually a number of fisheries. Seven species of shrimp are harvested in the fishery: brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), pink shrimp (*P. duorarum*), seabobs (*Xiphopenaeus kroyeri*), royal red shrimp (*Hymenopenaeus robustus*), rock shrimp (*Sicyonia brevirostris*), and trachs (*Trachypenaeus* sp.). Each shrimp species is taken by a distinct fishery, and the several fisheries are differentiated according to fishing depths, seasonal landings, vessel and gear, fishing localities, fishing techniques, and other characteristics.

The most valuable shrimp species in the United States are brown, white, and pink. For example, in 1985, U.S. commercial shrimp catches were 122,000 metric tons in the gulf and 13,000 metric tons in the south Atlantic. The white shrimp fishery is the most important in the U.S. south Atlantic; the brown shrimp fishery is more important in the gulf.

Brown shrimp range along the north Atlantic and Gulf of Mexico coasts from Martha's Vineyard, Massachusetts, to the northwestern coast of Yucatan. The range is not continuous, but is marked by an apparent absence of brown shrimp along Florida's west coast between the Sanibel and the Apalachicola shrimping grounds (Farfante, 1969). In the U.S. Gulf of Mexico, catches are highest along the coasts of Texas, Louisiana, and Mississippi. Brown shrimp can be caught at depths of 100 m or more, but most come from depths less than 50 m. The season begins in May, peaks in June and July, and declines to an April low (Gulf of Mexico Fishery Management Council, 1981).

White shrimp range along the Atlantic coast from Fire Island, New York, to Saint Lucie Inlet, Florida, and along the gulf coast from the mouth of the Ochlockonee River, in the Florida panhandle, to Campeche, Mexico. In the gulf, there are two centers of abundance: one along the Louisiana coast and one in the Campeche area. White shrimp are comparatively shallow-water shrimp; most of the catch comes from depths less than 25 m. The catch has a major peak in late summer and early fall, with an October high and a minor peak of over-winter shrimp with a peak in May. The largest catches occur west of the Mississippi River to the Freeport, Texas, area, although the catch is considerable along the entire north central and western gulf and south Atlantic. Pink shrimp range along the Atlantic from the lower Chesapeake Bay to the Florida Keys and around the gulf coast to the Yucatan peninsula. Major concentrations exist off southwestern Florida and in the southeastern part of the Gulf of Campeche. The two major pink shrimp grounds in the United States are the Tortugas and Sanibel grounds in southwestern Florida. The pink shrimp catch comes mainly from depths less than 50 m, with a maximal catch from 20-25 m. Most of the catch is taken off Florida and is greatest in the southwestern waters of the state. The catch is high from October through May.

In the south Atlantic, white shrimp account for the majority of landings in Georgia and the Atlantic coast of Florida. In South Carolina, small landings of white shrimp in the spring are augmented by a much larger catch in the fall. The spring white shrimp fishery is based on adults that have over-wintered, whereas the fall catch is based almost entirely on young of the year. White shrimp are caught in North Carolina principally during the fall, but the catch is much smaller than that of brown and pink shrimp (Calder et al., 1974). Brown shrimp predominate in the North Carolina fishery. During some years, catches of brown shrimp exceed those of white shrimp in South Carolina as well. The peak of the brown shrimp harvest occurs during the summer in all four south Atlantic states. Brown shrimp enter and leave the Florida east coast fishery earlier than in the other three states. In the south Atlantic, pink shrimp are of major

commercial significance only in North Carolina, where they account for about one fourth of the total shrimp landings. Fishing for pink shrimp usually begins in the spring and ends by midsummer.

Other minor shrimp species are often fished incidentally or during the offseasons of the major shrimp fisheries. A targeted rock shrimp fishery exists in the south Atlantic off northern Florida from August to January. In recent years, vessels in the western gulf have focused their effort on "trachs" during the late winter and spring months. The trach catch is primarily from depths of 20-50 m. The royal red shrimp fishery is relatively insignificant, occurring at depths of 250-550 m; harvesting and marketing obstructions have limited this fishery. Seabobs are caught most often in shallow waters at 13 m or less and in the open ocean; along the Louisiana coast, catch rates are highest in October-December.

The various fisheries share some similarities, in socioeconomic makeup and biology, but there are important contrasts, principally in depth of operation. The similarities and differences might have an important bearing on turtle bycatch. Many of the fisheries for shrimp, especially of the three major species, are timed and located in relation to the life histories of the shrimp. For example, several discrete fisheries constitute the "gulf brown shrimp fishery." Juvenile and subadult brown shrimp live in bays and estuaries and are harvested by the inshore fishery. The shrimping vessels used are usually small, from 6 to 30 m long; most are about 15 m long.

As the shrimp mature, they migrate offshore. Vessels fish near shore out to a depth of 25 m, especially for subadult and adult white and pink shrimp. The larger vessels of the gulf type begin almost exclusive harvest of the species (adult brown and pink shrimp) in water deeper than 25 m; these vessels are generally 20-30 m long. As the maturing brown shrimp continue to migrate into the deeper gulf waters, the smaller inshore vessels are limited, and only the larger vessels can gain access to the fishery. The offshore fishery provides the basis for the adult brown shrimp fishery.

The pink shrimp fleet off Florida uses a variety of vessels of different sizes but is associated primarily with larger offshore boats. White and brown shrimp are caught in bays and estuaries in some states by the smaller inshore vessels. Unlike the adult brown shrimp fleet, which uses larger vessels, the adult white shrimp fleet uses vessels of all sizes.

Distribution and Intensity of the Fishery

The distribution and intensity of fishing in inside waters were calculated from raw data and summaries provided to the committee by NMFS. For waters outside the coast, the information was taken from Appendix F. Fishing effort is measured in effort-days (24-hr days of towing time) per boat, regardless of variations in vessel size, the number and size of nets it tows, and water depth. That probably underestimates effort outside the coastal beaches, compared with bays, rivers, and estuaries, because offshore boats tend to be larger and tow more nets for longer periods than the inside boats. The unit of effort is used by NMFS in the Gulf of Mexico and the Atlantic Ocean and is estimated annually with the cooperation of individual state agencies. Quarterly effort in offshore waters is plotted by fishing zone from Texas to Maine for 1987 and 1988 (Figure 6-1). Data used are the best available currently from NMFS.

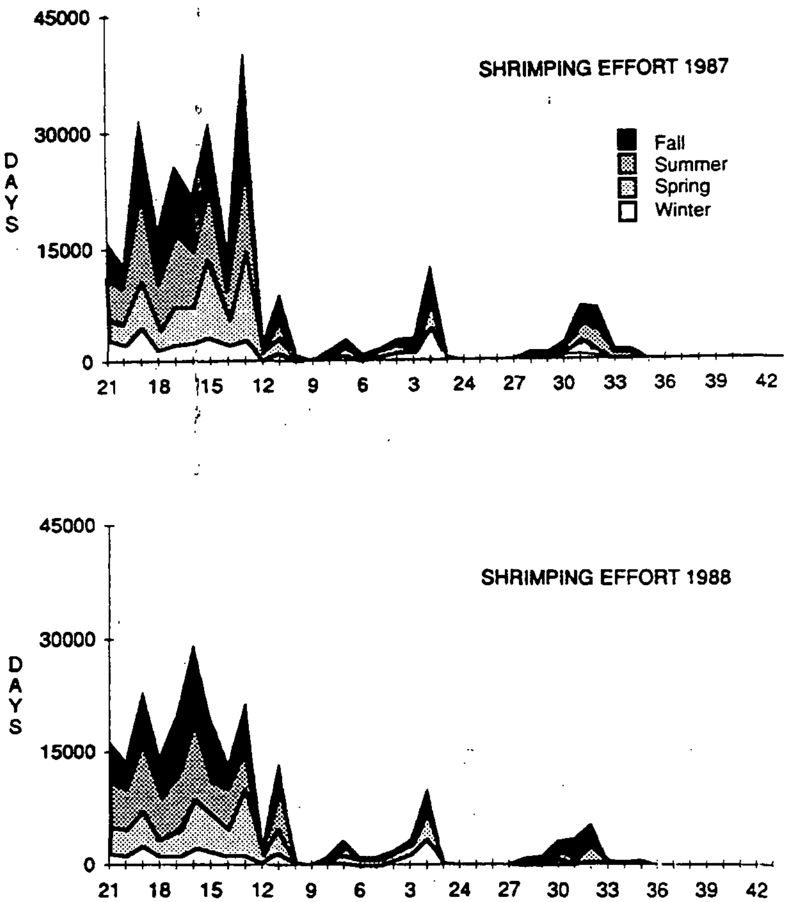
The shrimp fishery is intense, totalling about 373,000 24-hr days per year from the Mexican border in the gulf to Cape Hatteras in the Atlantic during 1987 and 1988. The intensity is much greater in the gulf—345,000 days—compared with the Atlantic's 28,000 days; 92% of the total effort is expended in the gulf. Most effort is offshore of the coastal beaches, about 249,000 days, or 67% (67% for the gulf and 68% for the Atlantic). The rest is expended in the bays, estuaries, and rivers, 33% of the total effort. The most intense fishery outside the coastal beaches is off Texas and Louisiana and includes 83% of the effort off the coastal beaches and 55% of the total effort from Maine to the Mexican border. Shrimp fishing off Mexico near the U.S. border has been low or absent in recent years.

Although fishing efforts in the bays, estuaries, and rivers are similar in the Atlantic and Gulf of Mexico, distinct differences occur in shrimping efforts directed toward offshore waters. Brown and pink shrimp are important fisheries in the Gulf; therefore, more shrimping effort is expended in deeper waters of the gulf than in the Atlantic, where white shrimp dominate the fishery. Statistical reporting procedures vary between the Atlantic and gulf data bases (pers. comm., J. Nance, NMFS, 1989). Areas of effort are reported by distance from shore in the Atlantic and by depth in the gulf. Because of differences associated with the slope of the gulf's continental shelf, a comparison of effort by distance from shore would be impractical; however, because white shrimp is the principal Atlantic fishery, effort focuses on a relative shallower and nearshore fishery.

For 1987 and 1988, NMFS data indicate that 92% of the Atlantic effort outside of coastal beaches was from 0 to 5 km, 3% was from 5 to 20 km, and 4% was farther than 20 km offshore. In contrast, in the gulf outside of coastal beaches, 65% of the effort was in water shallower than 27 m (a depth contour that ranges from approximately 14-50 km offshore), while 24% was between 27 m and 48 m; another 11% was deeper than 48 m.

Seasonally, effort for the fisheries outside of coastal beaches is greatest in summer and fall, lower in spring, and least in winter. In 1987 and

FIGURE 6-1 Shrimp-fishing effort, 1987-1988, by season. Fishing zones are shown on horizontal axis (see Figure 4-1). Data from Appendix F.



1988, 33% of the effort was in summer, 31% in fall, 24% in spring, and 12% in winter. This pattern largely represents that of the western gulf; local variations from this pattern occur. Off Georgia and the Carolinas, little fishing takes place in winter, whereas off the Atlantic coast of northern Florida, effort is more uniform through the year and includes significant winter fishing. Along the gulf coast of Florida, fishing is most intense in winter and spring.

Fishing effort in the gulf has grown steadily since 1960. The increase has been by a factor of about 2.5 in 30 years. The proportion of the effort in rivers, estuaries, and bays has remained about the same during this growth period. In the Atlantic, comparable data were not available, but from 1984 to 1988, total effort ranged from 24,000 to 34,000 24-hr days per year, reaching a maximum in 1986.

Seasonal Changes in Stranding, Shrimp-Fishing Effort, and Turtle Abundance

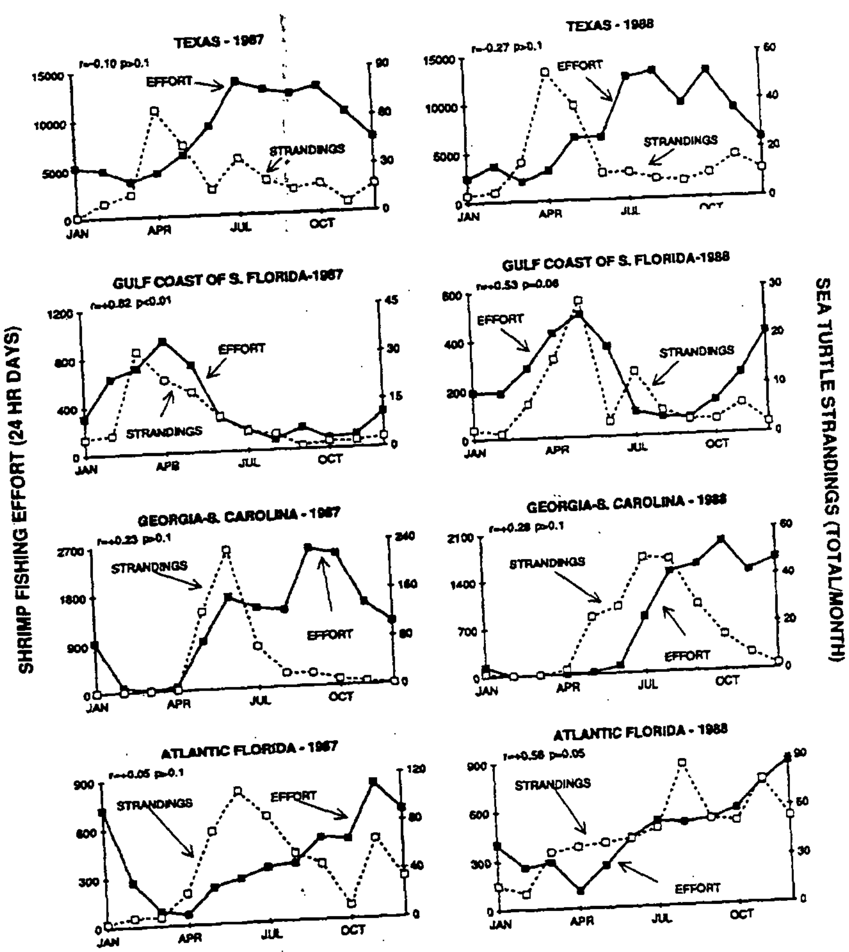
The recent abundance of stranded sea turtles and the intensity of shrimp fishing vary from the western Gulf of Mexico along the coast to the Gulf of Maine and from season to season. The distributions of strandings are complex interactions between trawling intensity and the abundance of sea turtles and other factors. The relationship between stranding and fishing intensity takes on a different perspective when viewed on short and long time and space scales. For example, the highest stranding rate does not occur off Texas and Louisiana (Figure 4-3), where shrimp fishing is now most intense (Figure 6-1); turtle abundance is lower there now than along the south Atlantic coast. Such broad-scale comparisons do not provide evidence of the present effects of trawling, because they do not account for historical changes in the abundance of turtles in relation to past shrimping and other mortality factors.

The relation between turtle stranding and fishing effort on an intermediate scale—i.e., seasonal changes in areas that differ in the ratio of turtle abundance to shrimping effort—permits an interesting, but speculative interpretation. Sites chosen for our analysis were those with NMFS contractual stranding surveys: Texas (zones 17-21), the gulf coast of Florida (zones 4 and 5), the northern Florida's Atlantic coast (zones 29-31), and Georgia-South Carolina (zones 31 and 32). Those four areas span a range of ratios of turtle abundance in aerial surveys (number of turtles sighted/10,000 km^2) to shrimp fishing effort (10,000 24-hr days of fishing) from about two for Texas to about 2,500 off Florida, or a factor of about 1,250 in the ratio of abundance of turtles to fishing effort in the two states.

In only two of the eight examples (Figure 6-2) was turtle stranding positively correlated with fishing effort ($p = 0.05$). One of those examples, from the Atlantic coast of Florida in 1988, was used by Schroeder and Maly (1989) as evidence for a direct relation between stranding and fishing effort. *The relation between stranding and effort is more complex than* the simple argument that more shrimping effort equals more turtle stranding.

Models of fishing-induced mortality have produced insights that can be applied to the present situation. Results of an examination of the season-

FIGURE 6-2 Seasonal changes in sea-turtle strandings on ocean beaches and shrimp-fishing effort offshore of ocean beaches at four locations along the Gulf of Mexico and the Atlantic coast for 1987 and 1988. The four areas differ greatly in the abundance of turtles sighted from aerial ocean surveys and shrimp-fishing effort. Texas (zones 18-21) had the fewest turtles per unit of shrimp fishing, followed by western Florida (zones 4-5), and Georgia and South Carolina (zones 31-32); the largest number of turtles per unit of shrimp-fishing effort was for Atlantic north Florida (zones 28-30). The correlations and p values are those for a simple linear regression. Data from Appendixes E and F.



al changes in fishing effort and stranding in each area and year (Figure 6-2) suggest an analogy with those models. In Texas, for example, stranding reached a maximum in April and then declined as effort increased; later in the summer, effort was high, but few turtles were stranded. One possible interpretation is that trawling has eliminated most of the turtles in that area by early summer. Alternative explanations could be that the turtles migrate through the area in the spring (Pritchard and Márquez M., 1973; Timko and Kolz, 1982) and that oceanic conditions in the spring differ from those in the other seasons and tend to bring more dead floating turtles to the beach than in other seasons (Amos, 1989).

A pattern with some similar features was observed on the gulf coast of southern Florida. The decline in strandings occurred while effort was high, as would be expected from fishing-induced mortality. Effort declined, but the decline in turtle stranding began before effort dropped to low levels.

In the Georgia-South Carolina region, stranding was greatest as the fishing effort was increasing early in the season, but later declined as effort continued to increase. That pattern is consistent with the interpretation that fishing effort locally depleted the turtles by middle to late summer.

Finally, on the Atlantic coast of northern Florida, stranding reached a maximum as effort increased and then began to decline—sharply in 1987, marginally in 1988. That pattern is also consistent with the effects of fishing-induced mortality on a fixed or limited population size. The only case of no major decline when effort was high was the northern Florida example of Schroeder and Maley (1989). That area has the most turtles per unit of shrimping effort among the four locations examined and would be the most likely to support a direct relation between stranding and effort over an extended period with modest levels of fishing effort relative to the standing stock of sea turtles.

We cannot eliminate the alternative hypotheses from the existing data on turtle migration and ocean currents. However, these observations are consistent with models of fishing-induced mortality, and that suggests that this is a likely hypothesis. It might explain the lack of a significant positive correlation between seasonal fishing effort and turtle stranding in all but two of the eight examples: the relationship between fishing effort and abundance of the fished species often are out of phase.

We note that neither significant positive nor nonsignificant negative correlations between seasonal changes in stranding and shrimping effort are by themselves enough to reveal the influence of shrimping on stranding. The relationships are more complex on these broad temporal and spatial scales in response both to shrimping effort and to changes in turtle abundance. The influence of shrimping on turtles cannot be excised

from the seasonal patterns only by a simple linear regression analysis. More incisive analyses, as presented below, are needed to tease apart the relationship.

Strong Evidence of Shrimp Trawling as an Agent of Sea Turtle Mortality

One central charge of this committee is to evaluate available evidence to assess whether incidental catch of sea turtles during shrimp trawling is indeed a cause of sea turtle mortality and, if so, to estimate the magnitude and importance of this mortality. Sea turtles are undoubtedly caught in large numbers during shrimp trawling. For example, the primary source of tag returns from female Kemp's ridleys tagged at the nesting beach at Rancho Nuevo (84% of 129 returns) has come from incidental capture of the turtles and reporting of tag numbers by cooperative shrimpers (Pritchard and Márquez M., 1973; Márquez M. et al., 1989). Furthermore, observers on vessels conducting commercial shrimp trawling have reported large numbers of sea turtle captures (Hillestad et al., 1978; Roithmayr and Henwood, 1982).

Even if individual fishermen catch few turtles, the size of the shrimp fleet and the effort exerted result in a collective catch that is "large," although not all sea turtles that are caught in shrimp trawls necessarily die as a result. In a recent review, 83% of 78 papers on the incidental capture of all Atlantic sea turtle species in fishing operations inferred that shrimp trawling is a major source of mortality (Murphy and Hopkins-Murphy, 1989).

We consider below five observations that, when taken together, constitute a compelling demonstration that incidental capture during shrimp trawling is the proximate cause of mortality of substantial numbers of sea turtles.

Relation Between Sea Turtle Mortality in Trawls and Tow Time The most convincing data available to assess whether shrimp trawling is responsible for sea turtle deaths come from NMFS studies relating the time that a trawl was allowed to fish (tow time) to the percentage of dead sea turtles among those captured. Henwood and Stuntz (1987) published a linear equation showing a strong positive relation between tow time and incidence of sea turtle death. They concluded that "the dependence of mortality on tow time is strongly statistically significant ($r = 0.98$, $p < 0.001$)."

The committee analyzed the data set used by Henwood and Stuntz to clarify in detail the relationship between tow times and mortality. Death rates are near zero until tow times exceed 60 minutes; then they rise rapidly with increasing tow times to around 50% for tow times in excess

of 200 minutes. That pattern is exactly what would be expected if trawling were causing the drowning of an air-breathing animal. Death rates never reach 100%, because some turtles might be caught within 40-60 minutes of lifting the net from the water. The data provide the functional relation between other correlative relations, namely, between fishing activity and dead turtles or population trends.

Under conditions of involuntary or forced submergence, as in a shrimp trawl, sea turtles maintain a high level of energy consumption, which rapidly depletes their oxygen store and can result in large, potentially harmful internal changes. Those changes include a substantial increase in blood carbon dioxide, increases in epinephrine and other hormones associated with stress, and severe metabolic acidosis caused by high lactic acid concentrations. In forced submergence, a turtle becomes exhausted and then comatose; it will die if submergence continues. Physical and biological factors that increase energy consumption, such as high water temperature and increased metabolic rates characteristic of small turtles, would be expected to exacerbate the harmful effects of forced submergence because of trawl capture.

Drowning can be defined as death by asphyxiation because of submergence in water. There are two general types of drowning: "dry" and "wet." In dry drowning, the larynx is closed by a reflex spasm, water is prevented from entering the lungs, and death is due to simple asphyxiation. In wet drowning, water enters the lungs. For nearly drowned turtles, the wet type would be more serious, because recovery could be greatly compromised by lung damage due to inspired seawater. The exact mechanism of sea turtle drowning is not known, but a diagnostic condition of the wet-drowning syndrome—the exudation of copious amounts of white or pink froth from the mouth or nostrils—has been observed in trawl-captured turtles.

Turtles captured in shrimp trawls might be classified as alive and lively, comatose or unconscious, or dead. A comatose turtle looks dead, having lost or suppressed reflexes and showing no sign of breathing for up to an hour. The heart rate of such a turtle might be as low as one beat per 3 minutes. Lactic acid can be as high as 40 mM, with return to normal values taking as long as 24 hours. It takes 3-5 hours for lactic acid to return to 16-53% of peak values induced by trawl capture. Although the fate of comatose turtles directly returned to the sea is unknown, it is reasonable to assume that they will die (Kemmerer, 1989).

In 1989, NMFS conducted a tow-time workshop to analyze data on tow times and turtle conditions from seven research projects. The projects spanned 12 years, during which 4,397 turtles were encountered. The numbers of dead and comatose turtles increased with tow time (Figure 6-

3). Small increases in tow time between 45 and 125 minutes resulted in large, steep increases in the numbers of dead and comatose turtles. For most tow times, there were more comatose than dead turtles. Few turtle deaths were related to tow times of less than 60 minutes. Tow times are thus a critical element in determining turtle mortality associated with shrimp trawls.

Coincidence of Opening and Closing of Shrimp Season with Changes in Turtle Stranding on Adjacent Beaches in Texas and South Carolina Murphy and Hopkins-Murphy (1989) used the data on sea turtle stranding in South Carolina in 1980-1986 to seek a temporal relation between the opening of the ocean shrimp fishery and the rate of stranding. In South Carolina, the Sea Turtle Stranding and Salvage Network (STSSN) has provided complete and reliable coverage of the ocean beaches for several years. The opening of the ocean shrimp fishery took place between May 16 and June 26 and varied from year to year. The 7-year total number of strandings (190 carcasses) in the 2-week periods just after the opening of the fishery was 5 times as large as the number of strandings in the 2-week periods immediately before the opening (38 carcasses). Although that does not conclusively demonstrate a causal relationship, repetition of the

FIGURE 6-3 Relation between the percentage of dead or dead and comatose loggerheads as a function of tow time of trawls. Total number of turtles captured was 4,397. Compiled by the committee from raw data provided by NMFS that were the basis for Henwood and Stuntz's (1987) calculations.

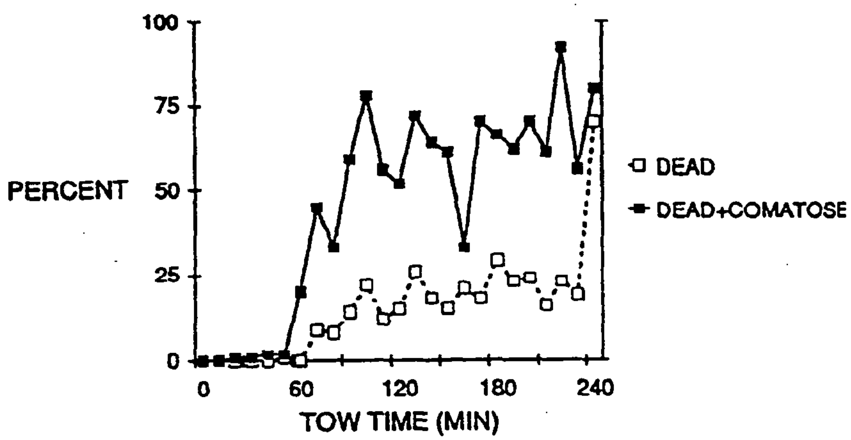
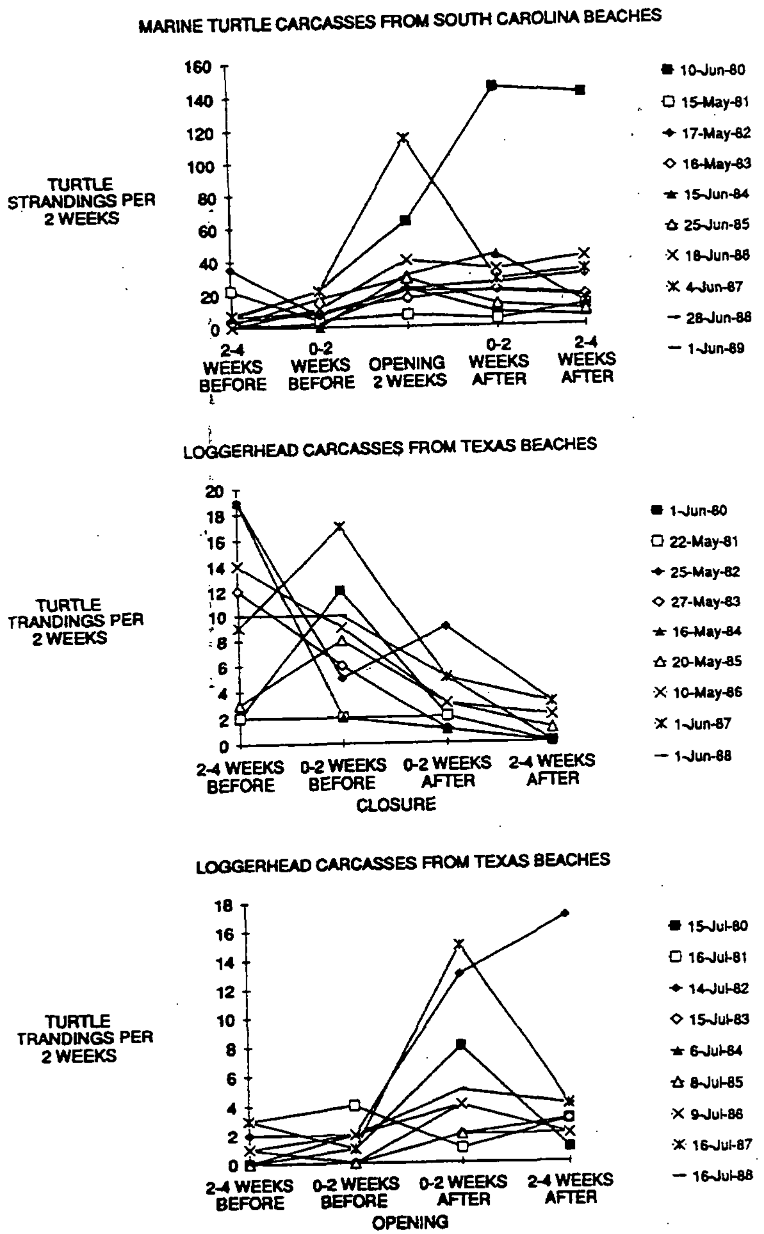


TABLE 6-3 Changes in the number of stranded sea turtles before and after the opening and closing of shrimp fishing seasons using data from STSSN.

Examples	Years	Mean Number of Strandings* 2-4 Weeks Before a	0-2 Weeks Before b	0-2 Weeks After c	2-4 Weeks After d	Significance of Differences Probability Level† a to b	b to c	c to d
South Carolina Opening	1980-1989	8	10	37	34	0.48	0.006	0.96
Texas Opening	1980-1988	1	1	6	4	0.58	0.04	0.36
Texas Closure	1980-1988	10	8	3	1	0.56	0.03	0.008

*Loggerheads or, for South Carolina, mostly loggerheads
†Two-tailed Wilcoxon matched-pair, signed rank test

FIGURE 6-4 Sea turtle strandings on beaches before and after opening or closing of shrimping seasons in South Carolina and Texas. Statistical analysis of differences is in Table 6-3. (Compiled from NMFS data.)



large increase in stranding after the beginning of shrimping, despite variation in the date of the beginning of shrimping, strongly suggests that shrimp trawling is the proximate cause of the large increase in dead sea turtles found on South Carolina beaches after the opening of shrimp season.

To evaluate further the potential effect of shrimp trawling on the numbers of sea turtles found dead on South Carolina beaches, we followed the lead of Murphy and Hopkins-Murphy (1989) and segregated stranding data into two-week intervals (the first and second halves of each month, because of how the data were compiled) for the 10-year STSSN data base (1980-1989). The 2-week interval in which the fishery opened was designated as the "2 weeks after opening," unless the opening occurred at the end of the 2 weeks, in which case the next 2-week interval was called the "2 weeks after opening." We compiled the strandings not only for the 2-week intervals before and after opening of the shrimp season, but also for the 2-week periods before and after that 4-week period, for a total of four 2-week periods (Table 6-3, Figure 6-4). We then used the Wilcoxon signed-ranks test (a paired-sample nonparametric test) to compare strandings in each pair of successive 2-week periods. The 3.7-fold increase in turtle strandings that occurred in the 2 weeks after opening has a two-tailed probability of 0.006 of occurring by chance. No other contrast between successive 2-week intervals had a probability of less than 0.10. This analysis thus implies that shrimp trawling was indeed responsible for the increase in turtle strandings. It is an especially strong analysis, in that the increase observed with the opening of the fishery was independent of seasonal changes (the date of opening varied widely—from May 16 to June 26).

We also used the STSSN data base for Texas beaches for the 9 years of 1980-1988 to evaluate the effects of fishery closing and opening on stranding of loggerheads (Table 6-3, Figure 6-4). The changes in four consecutive 2-week periods were compared and analyzed as for the South Carolina data. The application of the nonparametric tests demonstrated that the sixfold increase in loggerhead stranding between the 2 weeks before and the 2 weeks after opening of the Texas brown shrimp fishery had a two-tailed probability of 0.04 (Table 6-3). Differences between 2-4 weeks before and 0-2 weeks before intervals were not statistically significant. As in the South Carolina case, the statistical tests suggest that loggerhead stranding increased significantly when shrimp trawling opened in Texas.

Finally, we analyzed in the same manner how stranding rates changed at the time of closing of the Texas brown shrimp fishery (Table 6-3, Figure 6-4). Loggerhead stranding decreased between the 2 weeks before and the 2 weeks after closing by a factor of 2.7. The probability that that

decrease occurred by chance with a 2-tailed test was 0.01 (Table 6-3). The contrast between the first two periods (2-4 weeks before versus 0-2 weeks before closing) had a probability of 0.56. A decline in stranding did occur between 0-2 weeks after and 2-4 weeks after closing, p=0.008. Consequently, although a large and statistically significant decline in loggerhead stranding had occurred after closing of the Texas brown shrimp fishery, the decline continued to occur between the last two periods. Given the uncertainty as to how long it takes for dead turtles to reach the beach, those results are consistent with either an effect of brown shrimping on sea turtle stranding or a general decline in sea turtle stranding during the period for other reasons. Because the dates of closure varied from May 10 to June 1, we interpret the decline to be fishery related.

Stranding in the three cases—South Carolina opening, Texas opening, and Texas closing—changed by factors of 3.9, 5.0, and 4.5, based on the 4 weeks before and 4 weeks after opening. We conclude that, in those locations and at those times, approximately 70-80% of the stranded turtles were caught in shrimp trawls. Taken along with the results on tow time given above, these results provide strong evidence of the crucial role of shrimp fishing on turtle mortality.

Relation Between Loggerhead Populations and Shrimping Effort Along the southeastern Atlantic coast, loggerhead populations are declining where shrimp fishing is intense off the nesting beaches. They are not declining, however, where shrimping effort is low or absent. Nesting populations in South Carolina and Georgia (Figure 3-1*c,d*) are declining, whereas those in central and southern Florida are not and might even be increasing (Figure 3-1*e,f*). Shrimping effort declines markedly to the south at Cape Canaveral (Figure 6-1) so, for example, the population at Hutchinson Island is subject to essentially no shrimp fishing off the nesting beach (fewer than 17 effort-days per year) whereas the populations at Little Cumberland Island, Georgia, and Cape Island, South Carolina, have intense fisheries (about 400-7,000 days per year per fishing zone). Further evidence of the relation between shrimping effort and turtle population declines is found in the lower stranding rates of loggerheads in fishing zones 26-28 at Canaveral and south, where effort is low, even though these zones have the highest density of nesting loggerheads (Figure 4-2). Shrimping effort declines from about 1,000 effort-days per year in zone 28 to almost none in zones 27 and 26. In contrast, effort increases irregularly north of zone 28 to a maximum of 5,000-7,000 in zone 32, off South Carolina. Because the turtles aggregate off the nesting beaches during the nesting seasons between their multiple nestings, the absence of the fishery would be expected to reduce mortality and contribute to the maintenance or growth of local nesting populations, as was observed south but not north of Canaveral.

Quantification of Sea-Turtle Mortality in Shrimp Trawls Incidental catch and mortality of sea turtles in shrimp trawls have been estimated on the basis of interviews with vessel captains (Anon., 1976; Anon., 1977; Cox and Mauerman, 1976; Rabalais and Rabalais, 1980; Rayburn, 1986) and direct observation by fishery observers on commercial shrimping vessels (Hillestad et al., 1978; Ulrich, 1978; Roithmayr and Henwood, 1982; Henwood and Stuntz, 1987). Henwood and Stuntz (1987) provide the most complete assessment of sea turtle capture and mortality for the south Atlantic and Gulf of Mexico shrimp fisheries. Their study, based on more than 27,000 hours of observed trawling, estimated an annual incidental capture of approximately 47,000 sea turtles, with an estimated mortality of about 11,000. The study suffers from the a posteriori approach of estimating capture and mortality from programs not specifically designed for that purpose and, therefore, is limited in its ability to account for possible differences in capture and mortality related to such variables as species, season, depth, and geographic location. Although the statistics have been debated (Clement Assoc., 1989; Murphy and Hopkins-Murphy, 1989), the estimates are conservative because of the approach taken. Points of contention with the estimates of mortality include the use of data from a research study of the use of turtle excluders on trawlers, the representativeness of fishing distribution between research studies and commercial shrimping, the precision of mortality estimates based on the method used to calculate mortality rate, the magnitude of mortality estimates based on the assumption that all comatose sea turtles survive, and the magnitude of mortality estimates based on the complete omission of inside waters (waters landward of the barrier islands, including bays, sounds, etc.) (Table 6-4).

The objective of the trawler excluder study was to design and use an apparatus that would effectively prevent the incidental capture of sea turtles in existing shrimping gear. Shrimp fishermen fished with commercial fleets in both the Gulf of Mexico and the south Atlantic. Sixty-two percent of the trips were in the south Atlantic, where 95% of the loggerheads and 78% of the Kemp's ridleys were caught (Table 6-5). Georgia, fishing zone 31, accounted for 74% of the total south Atlantic trips and 58% of the catch of loggerheads and 71% of the catch of Kemp's ridleys in the south Atlantic. For the south Atlantic, the estimated catch rate for the trawler excluder study was strongly influenced by the catch rate off Georgia; the Georgia catch rate was lower than the other zones sampled. Similarly, in the gulf, the catch rates reflected activity off Texas and Louisiana, which comprised 75% of the effort. Eliminated from consideration in this study

TABLE 6-4 Points of contention and potential sources of bias to estimated mortality as calculated by Henwood and Stuntz (1987).

Contention/Potential Bias	Impacts on Estimate
Use of trawl excluder study provided a biased sample because fishermen fished where turtles were.	Fishermen fished with fleet and were not controlled by contracting agency. A sea turtle "hot spot" (Cape Canaveral channel) (see Figure 4-1) was eliminated from study. Georgia (fishing zone 31 (see Figure 4-1)) accounted for the majority of the study effort and catch in south Atlantic; Texas and Louisiana (fishing zones 15-19 (see Figure 4-1)) accounted for the majority of the study effort in the Gulf of Mexico. The study was used to calculate catch rates for the south Atlantic and the gulf. Overall catch (and hence, mortality) was estimated by multiplying catch rates by commercial fishing effort as determined separately by NMFS for the gulf and south Atlantic. No significant bias was detected.
Fishing effort in study did not reflect true commercial fishery. Data were biased.	In the Gulf of Mexico, 65% of the commercial effort was exerted in waters ≤27 m (1988), whereas 84% of the effort reported in the study was in waters ≤27 m. If catch rates are partitioned by depth (≤27 m and >27 m), based on sea turtle distribution (see Chapter 4), the 19% oversampling of water ≤27 m results in an overestimate of catch (and mortality) of about 24% for the gulf.
Precision of mortality estimates is erroneous. Methods used did not incorporate variability of mortality rate into variability of estimated mortality. (Product estimated captures times mortality rate.)	Reported limits of confidence intervals would be widened, thus increasing the uncertainty about the estimated mortality.
All comatose sea turtles were assumed to survive. This produces an underestimate, because not all comatose sea turtles do survive.	If all comatose turtles died, the estimate of mortality would increase from about 11,000 to about 32,000.
Captures in inside waters were not included, thus reported estimates are low.	Reported mortality estimates are underestimates due to omission of inside waters data. Approximately 37% of total shrimping effort occurs in inside waters. Depending on species, total estimated mortality might be higher by a factor of 1.6 or from 11,000 to 18,000.

TABLE 6-5 Distribution of effort (number of tows) and capture of loggerhead and Kemp's ridley sea turtles from trawler excluder study.

Statistical Zone	Tows (no.)	Loggerheads (no.)	Kemp's Ridleys (no.)
1	93	3	
2	476	3	
3	60	2	
15	160	0	
16	111	0	1
17	110	1	
18	1,340	5	2
19	169	1	1
Total Gulf of Mexico	2,519	14	4
30	308	50	
31	3,024	161	10
32	527	41	4
33	209	23	
Total Atlantic	4,068	275	14

Source: Partial data set from Henwood and Stuntz (1987) and W. Stuntz (pers. comm.)

were the catch and effort data from the Cape Canaveral ship channel and surrounding area (approximately 24 km). This local area harbors large concentrations of sea turtles throughout the year, and high turtle catch rates there do not reflect those occurring outside the Canaveral area (Henwood and Stuntz, 1987). Elimination of those data provided conservative estimates of catch rates for the south Atlantic.

Distribution of effort by depth in the Gulf of Mexico in the Henwood and Stuntz (1987) study is biased toward shallower waters than are usual or typical for the commercial shrimp fleet. The commercial fleet exerted 65% of total offshore shrimping effort in 27 m or less in 1988 (pers. comm., E. Klima, NMFS, 1989), whereas 84% of the total effort reported by Henwood and Stuntz (1987) was in 27 m or less. Statistically significant differences in capture rates among depths were not found in these data, and the data were pooled to provide the best estimates of capture rates in the Gulf of Mexico. However, information discussed in Chapter 4 strongly suggests that turtle abundance is negatively correlated with depth.

The confidence intervals associated with estimates of mortality in Henwood and Stuntz (1987) do not incorporate the uncertainties associated with the estimated mortality rate, so they portray a lower level of uncertainty than is reflected by the data. Incorporating that uncertainty would broaden the confidence intervals about the estimates of mortality.

Henwood and Stuntz (1987) restricted their analysis of mortality rate (number of dead turtles per unit of tow time) to turtles classified as dead; they excluded turtles classified as comatose. Recent work (pers. comm., P. Lutz, University of Miami, 1989; Stuntz and Kemmerer, 1989) indicates that some comatose sea turtles die even after proper resuscitation techniques have been applied and the turtle becomes active. Internal injuries that are not visible in turtles landing on deck and are not initially totally debilitating are considered a factor in delayed mortality of trawl-caught sea turtles (pers. comm., D. Owens, Texas A&M University, 1989). If some or all comatose sea turtles die as a result of trawling, the Henwood and Stuntz study underestimates sea turtle mortality by a factor of as much as 3 (Figure 4-3).

A final underestimate results from the Henwood and Stuntz (1987) study having considered only shrimping effort in waters outside the coastal beaches. Because 33% of the total shrimping effort in 1987 and 1988 occurred in rivers, estuaries, and bays and because sea turtles (especially young Kemp's ridleys) are found in these waters, total mortality from the shrimp fishery could be higher than the Henwood and Stuntz estimates by a factor of as much as 1.6. That possibility is based on the assumption that the abundance of turtles is the same inside and outside and the assumption that a unit of effort is equal inside and outside; neither of those assumptions is precisely true (nor known, for that matter).

The limitations of the data and the criticisms of methods used do not detract from the basic findings of the Henwood and Stuntz study. With its assumption that all comatose turtles survive and its omission of all turtle capture and mortality estimates for inside waters, the approach taken by Henwood and Stuntz results in a marked underestimate of total sea turtle mortality associated with the shrimp fishery.

Relation Between Sea Turtle Stranding and Spatiotemporal Pattern of Shrimp Trawling in North Carolina The northern limit of the geographic zone of ocean shrimp trawling occurs at Ocracoke Inlet, North Carolina. Data compiled by Street (1987) on sea turtle stranding on ocean beaches in North Carolina exhibit a spatiotemporal pattern that closely matches that of trawl fishing in the ocean offshore of that state. South of Ocracoke Inlet, where offshore shrimp trawling continues from about May through September, 86% of the 545 sea turtle strandings observed in 1980-1986 occurred in those months. In contrast, north of Ocracoke Inlet, where no shrimp trawling occurs, but where a winter trawl fishery for flounder exists, 85% of the 456 sea turtle strandings recorded on ocean beaches in 1980-1986 occurred during the October-April period (Street, 1987). The spatiotemporal switch in the season and location of apparent

sea turtle mortality suggests that shrimp trawling causes substantial mortality of sea turtles south of Ocracoke Inlet in North Carolina. The winter mortality of sea turtles to the north might be caused by groundfish trawling or by temperature shocks in the colder-water biogeographic province north of Cape Hatteras.

Other Fisheries, Discarded or Lost Gear, and Marine Debris

Turtles are caught and killed in finfish trawls, seines, pompano gill nets in Florida (pers. comm., L. Ehrhart, University of Central Florida, March 1990), various kinds of passive fishing gear (such as gill nets, weirs, traps, and long lines), lost fishing gear, and other debris. We conclude that the mortality associated with these and related factors is about one-tenth that associated with shrimp trawling (Table 6-2). Collectively, the nonshrimp fisheries constitute the second largest source of mortality of juvenile to adult sea turtles. That statement is based on the observations documented below by region.

The assessment of sea turtle mortality attributed to entanglement in stationary or fixed fishing gear is difficult, because of the disparity and discontinuity of reliable data. It is fair to assume that in some localities and with some types of fishing gear, entrapment and entanglement occur fairly often, but the resulting turtle deaths might not be as consistent. Most of the entangled or entrapped turtles are subadults and adults. Fishermen appear to be reasonably cooperative in efforts to set live sea turtles free. However, dead turtles are set adrift and might later be accounted for as strandings. The ratio of dead turtles set adrift to those counted as stranded is not adequately documented. If the approximate 4:1 ratio documented by Murphy and Hopkins-Murphy (1989) is considered valid, some total estimate of mortality can be made. On the basis of yearly stranding data with mortalities directly associated with encounters with fixed fishing gear, a yearly estimate of a maximum of 45-400 sea turtle deaths is reasonable. That is only a crude estimate; more research and monitoring are necessary to document and understand the interaction of sea turtles with fixed fishing gear.

Estimates of worldwide losses and discards of commercial fishing gear—including plastic nets, lines, and buoys—range from 1,350 to 135,000 metric tons of gear per year (Merrell, 1980; Welch, 1988). Recreational fishing in the United States is undoubtedly another important source of marine debris, including bait bags and lost and damaged gear (Pruter, 1987). NMFS recreational fishing statistics indicate that more than 81 million recreational fishing trips are made annually to marine waters (NMFS, 1986a,b).

It is especially difficult to document the deaths caused by this source or to separate them from deaths caused by fixed but unattended fishing gear. Yet, sea turtles (and other marine life) are particularly vulnerable to commercial fishing gear that has been lost or abandoned at sea. Such gear continues to catch and entangle marine life indiscriminately, causing injury, strangulation, starvation, and drowning (Carr, 1987; Laist, 1987; McGavern, 1989; Gregg, 1988). Deaths of green turtles, hawksbills, loggerheads, Kemp's ridleys, and leatherbacks have been caused by entrapment and entanglement in fishing gear (Mager, 1985). Monofilament line is the most common type of debris to entangle turtles. Other debris includes rope, trawl netting, gill netting, plastic sheets, and plastic bags. Fishing-related debris is involved in about 68% of all cases of sea turtle entanglement (O'Hara and Iudicello, 1987). Other stationary or passive fishing gear that has caused deaths of turtles includes pound nets, long lines, sturgeon nets, and nylon and monofilament gill nets (Van Meter, 1983). Leatherbacks and green turtles are prone to entangling their front flippers and heads in buoy ropes or discarded twine (O'Hara et al., 1986; O'Hara and Iudicello, 1987). The largest authenticated leatherback ever recorded became entangled in whelk-fishing lines and drowned; fishermen cut the dead turtle loose, and the carcass washed up the next day on a beach in Wales (Morgan, 1989).

Sea turtle entanglement in monofilament fishing line is a common problem. It is not usually related to active fishing; rarely is a fishhook reported attached to the line. In several cases, a turtle was entangled on line snagged on underwater structures or reefs, which caused constriction and necrosis of the limbs or drowning (O'Hara et al., 1986).

Balazs (1985) acquired reports of 60 cases worldwide of turtle entanglement involving monofilament line, rope, netting, and cloth debris. Of the 60 cases, 55 (92%) involved single animals, and 38% of all the turtles were dead or died later. Five species from 10 locations worldwide were reported; Kemp's ridleys were not included. Green turtles accounted for 19 (32%) of the 60 cases, and immature turtles were affected more often than adults in all the species represented except the leatherbacks. Only adult leatherbacks were reported entangled; immature leatherbacks are rarely reported anywhere. Monofilament line, with no fishhooks attached, accounted for 20 (33%) of the cases; segments or snarls of rope, 14 (23%); pieces of trawl or webbing, 12 (20%); and monofilament net, 8 (13%). Fishing-related debris was involved in 41 (68%) of all the cases.

New England

Leatherbacks and Kemp's ridleys become entangled in lobster gear (O'Hara et al., 1986). Balazs (1985) reported a dead leatherback from Rhode Island that had a longline hook embedded in its flipper, with rope

attached. Although there have been no reports of sea turtle entanglement in gill nets in New England, reports of leatherbacks with cuts, severed limbs, or chafing marks suggest the possibility. Fretey (1982) published an extensive inventory of flipper injuries among leatherbacks in the large French Guiana nesting colony; some of these animals are known to come from feeding grounds in the northeastern United States. Balazs's (1985) compilation of worldwide incidence of sea turtle entanglement indicated that 11% of the 55 cases investigated involved monofilament net (O'Hara et al., 1986).

New York Bight

Turtle mortalities have resulted from lobster-pot lines and pound nets. Between 1979 and 1988, 58 stranded sea turtles reported in the New York Bight exhibited signs of entanglement with debris or inactive or fixed fishing gear. The Okeanos Ocean Research Foundation in New York reported two dead leatherbacks entangled in lobster gear in 1986 (O'Hara et al., 1986). Lobster-pot floatlines are a major source of entanglement, because they can be more than 180 m long in offshore waters and virtually undetectable below the surface. Six of 10 leatherbacks were caught in lobster-pot lines, and one entangled and drowned (Balazs, 1985; Sadove and Morreale, 1989).

In Long Island Sound, fixed pound-net gear traditionally captures the most sea turtles, predominantly Kemp's ridleys, but also green turtles, leatherbacks, and loggerheads (Morreale and Standora, 1989). The Okeanos Ocean Research Foundation has accumulated numerous reports of sea turtles, especially Kemp's ridleys, entrapped in pound nets in eastern Long Island. Surveyed fishermen indicate catching 10-20 turtles per year. That might be important, because more than 100 licensed fishermen were using pound nets in the region in 1986. It might not constitute a mortality problem, if the turtles are simply enclosed in the heart or head of the net until released, but deaths can occur if the turtles get tangled in the hedging or stringers (Balazs, 1985; Sadove and Morreale, 1989). Documented cases from 1986 include seven Kemp's ridleys, four loggerheads, and two green turtles captured; all but four were released alive (O'Hara et al., 1986). Balazs (1985) reported a leatherback that was found dead, tangled in rope. Debris in the water column or at the surface, such as floating line, can entangle turtles during normal activities, such as surfacing to breathe (Balazs, 1985; Sadove and Morreale, 1989).

Mid-Atlantic and Chesapeake Bay

The principal fishery-caused mortality in the mid-Atlantic and the Chesapeake Bay is in the pound-net fishery in the bay during the summer and the finfish trawl fishery for flounder off the coast in the winter. Doc-

umentation is best for the effects of the pound-net fishery. Other fishery-related mortality results from gill nets, crab-pot lines, and occasionally even rod-and-reel fishing. Some deaths in gill nets occur off Delaware (O'Hara et al., 1986).

Almost all turtle stranding during October and November in Virginia and adjacent waters of North Carolina occurred on the ocean front where heavy flounder trawling takes place off the coast. Some of the stranded turtles showed net marks and might have drowned in fish trawls. The seasonality of stranding in North Carolina north and south of Cape Hatteras implicates the flounder fishery as the source of mortality. Low-temperature deaths also might have contributed to the stranding. Further evaluation of this fall or winter mortality is warranted (Barnard et al., 1989).

An estimated 50-200 sea turtles strand from all causes in and around the Chesapeake Bay each year (Keinath et al., 1987; personal communication., D. Barnard and J. Keinath, Virginia Institute of Marine Science, October 1989). Stranding data for 1979-1988 were analyzed by Barnard et al. (1989) and D. Barnard and J. Keinath (pers comm., Virginia Institute of Marine Science, 1989). Of the turtles examined, 20% had definite net marks indicating death by pound net, gill net, or other fishing gear; 47% had no outward sign of injury or were very decomposed. The 20% figure is lower than previously estimated by Bellmund et al. (1987) and Keinath et al. (1987). Crab-pot lines and pound-net leads probably contributed to many of these deaths.

Stranding of dead turtles in and around Chesapeake Bay typically begins in mid-May. That pattern coincides with the deployment of pound nets in May. However, pound nets are in use through October, whereas strandings tend to cease by early July. The higher number of strandings early in the season might be related to the emaciated or weakened state of turtles entering the bay after a long migration (Bellmund et al., 1987; pers. comm., D. Barnard and J. Keinath, Virginia Institute of Marine Science, October 1989).

Many pound-net deaths might be related to the inability of sick or injured turtles to avoid fixed nets during periods of strong tidal flow (Musick, 1988; Barnard et al., 1989). Pound-net hedging or leaders with stringers produced the highest mortality rates for turtles, 0.7 per net, especially in strong currents. Pound-net leads composed of small mesh from top to bottom were associated with insignificant mortality rates. The turtle entanglement was 0.4 per net for open-water nets, compared with 0.1 per net for embayments and protected areas; the difference might be the result of the stronger currents in open water (Bellmund et al., 1987). In areas with weak currents, live turtles caught in pound nets apparently can move in and around the nets without becoming entangled (Bellmund et al., 1987), as evidenced by live turtles marked and released from one net

that have later been recaptured in the same or a nearby net and by the observation of a few loggerheads crawling out over the head netting as the net was being worked (Lutcavage, 1981).

It is unlikely that stranded turtles without visible constrictions were killed in pound nets. Entangled turtles in pound nets die and begin to decompose in situ; they do not drift free to strand on shore (Bellmund et al., 1987). None of five dead turtles entangled in pound-net hedging during 1984 came loose over 5 weeks. However, the rotting turtle eventually bloats; as it decomposes, it tears free, floats away, and strands (Lutcavage, 1981). One dead and marked loggerhead from pound-net hedging stranded 5 days later 10 km from the net.

Various reports have assessed the sources of mortality of dead sea turtles stranded on inshore beaches and shores in and around the Chesapeake Bay. A total of 645 dead turtles, including 527 loggerheads and 28 Kemp's ridleys, stranded between May 1979 and November 1981. Necropsies of some loggerheads implicated enteritis and drowning (Lutcavage and Musick, 1985). A sample of 71 turtles from 1979 included 25 with a determinable cause of death; seven of the deaths were caused by pound nets. Of the 57 turtles sampled in 1980, 21 had a determinable cause of death, and 19 deaths were caused by pound nets. In addition to pound-net deaths, one turtle died in a haul seine, one after being caught on a long line, and two in crab-pot lines (Lutcavage, 1981). Of the 124 turtles sampled in 1981, 11 had determinable deaths, and four deaths were caused by pound nets (Lutcavage and Musick, 1985). Confirmed netting deaths from 1979 to 1983 numbered 53 (19% of the determinable deaths); only four turtles (1.4%) died as a result of non-net fishing gear. Of the 83 dead stranded turtles examined in 1984, 10 (12%) had evidence of constriction, and 20 (24%) were in pound or gill nets (Bellmund et al., 1987). Definite net-related deaths in the Chesapeake Bay during some summers from 1979 to 1984 ranged from 3% to 33% of the total number of stranded turtles (Lutcavage and Musick, 1985).

Early reports indicated that the cause of death could be determined for about half the 980 stranded sea turtles recorded between 1979 and 1987 and that almost 40% could be attributed to entanglement in gill or pound nets (Keinath et al., 1987). However, reanalysis of the data available for 1979-1988 determined that fewer turtle deaths (approximately 20%) could be definitely attributed to entanglement in pound or gill nets, or other fishing gear (Barnard et al., 1989).

South Atlantic

Sea turtle deaths other than those caused by shrimp fishing have occurred in the south Atlantic in association with oceanic gill nets, large ocean set nets, and tuna and billfish long lines.

Turtle mortality associated with gill-net fisheries in the Carolinas starts in early spring and is maximal in April. The South Carolina Wildlife and Marine Resources Department reported that oceanic gill net fisheries for Atlantic sturgeon, shad, and shark have caused the deaths of loggerheads, Kemp's ridleys, and green turtles (pers. comm., S. Murphy, S.C. Wildlife and Marine Resources, 1989). In 1980-1982, about 217 turtles stranded in the early spring in connection with large ocean nets used to catch Atlantic sturgeon. In 1983-1985, the sturgeon season was closed in mid-April, and the carcass count decreased to about 106 turtles. In 1986, there was no sturgeon season, and only about 18 turtles died in the spring. Illegal drift nets for the shad fishery and shark fishery were probably responsible for most of the 36 carcasses reported in May 1989, including eight leatherbacks.

Sea turtles are caught infrequently on long lines in the gulf and Atlantic (Swordfish Management Plan, 1985). On the basis of data from the 1979 Japanese long-line observer program, 12 turtles (including two leatherbacks) were caught in the gulf and 17 (including nine loggerheads) were caught in the Atlantic. During 1980, the same observer program reported 10 turtles captured. The greatest number were captured in January-March in the gulf and in September-January in the Atlantic. Seven percent of the turtles captured died in gulf long-line fishery and 30% in incidental captures in the Atlantic (O'Hara et al., 1986). One unidentified turtle in 1987 and one leatherback in 1988 were hooked, as reported by observers on Japanese long-line vessels fishing in the northwest Atlantic fishery conservation zone (FFOP, 1988, 1989). Leatherbacks tend to get hooked (either in the mouth or the flipper area), whereas loggerheads are prone to entanglement in the ganglion lines attached to the main line.

In Florida, there were five recent confirmed sightings by divers of sea turtles entangled in monofilament fishing line on reefs and wrecks (pers. comm., J. Halusky, N.E. Florida Sea Grant Extension, May 1989). Two of them were rescued and released, and three were dead.

Balazs (1985) reported 10 cases of turtle entanglement in Florida in 1978-1984: one green turtle, alive; five loggerheads, including three dead; and five hawksbills, alive. Balazs also reported a dead loggerhead in Georgia. Of the 11 cases, six involved monofilament fishing line, two involved rope, two involved gill or other netting, and one involved both line and netting.

Gulf Coast

A study along the Texas coast during 1986 and 1987 encountered entanglement of 25 turtles in discarded net and monofilament line. Entanglement was identified as the probable cause of death of seven; the remainder were stranded alive. Nine of the 25 turtles were Kemp's ridleys, and the others were loggerheads, hawksbills, green turtles, and leatherbacks. The turtles were entangled in fishing line and hooks, shrimp trawls, onion sack, net and rope, tar, crab trap, and trot line. The study concluded that the probability that a sea turtle in Texas coastal waters would come into contact with marine debris is high, and that commercial and recreational fishermen and their discarded gear were responsible for most of entanglements (Plotkin and Amos, 1988; Ross et al., 1989).

Balazs (1985) reported five entangled turtles in Texas in 1977-1983, including one live green turtle, three live hawksbills, and one dead hawksbill. Four of the entanglements involved monofilament fishing line, the other a piece of plastic onion bag. Amos (1989) reported that, in 77 recorded strandings of hawksbills in Texas since 1972, the incidence of entanglement in plastic was high—22% of those in which such information was recorded. The most common form of entanglement occurred when turtles' necks or limbs were caught in woven plastic produce sacks. Monofilament fishing line wrapped around limbs has also been recorded. No entanglements of recent posthatchlings have been noted, only entanglements of yearlings.

An anecdote from Paul Raymond of the NMFS Law Enforcement Division provides a dramatic example of the problem. An abandoned pompano trammel net (three panels) of monofilament was seized on October 16, 1989, off the beach (near shore) near Wabasso, Florida (Indian River County). It had been set 6 days before and left unchecked. In it were 10 juvenile green turtles and one juvenile loggerhead, all entangled and drowned. Pompano trammel nets are tethered in very shallow water near shore by fishermen in small boats. The industry is not well organized or documented as to size, season, or distribution. Nets set inshore (behind the coastal regulation lines) must be attended, but that is not required by Florida for nets outside the line. The net in question here had been abandoned. An unattended but not abandoned net can also kill turtles.

Dredging

Dredging of harbors and entrance channels can kill sea turtles (Hopkins and Richardson, 1984). A comprehensive survey of records and project reports recognized 149 confirmed incidents of sea turtles entrained by hopper dredges working in two shipping channels from 180 to 1990 (Table 6-6) (pers. comm., J.I. Richardson, University of Georgia, April 1990). Only verifiable records of fresh kills or live turtles were included in this table, explaining the slight difference in total counts between this survey and other reports (Rudloe, 1981; Joyce, 1982). Three species of sea

TABLE 6-6 Reported sea turtle incidents by species during dredging activities from 1980 to 1990.

Site	Year	Loggerhead	Green Turtle	Unidentified*	Total
Cape Canaveral Entrance Channel	1980	50	3	18	71
	1981	1	1	1	3
	1984-85	3	0	6	9
	1986	5	0	0	5
	1988	8	2	18	28
	1989-90	0	6	1	7
Totals		67	12	44	123
King's Bay Entrance Channel, Georgia and Florida	1987-88†	7	1	1	9
	1988	3	0	2	7‡
	1989	9	0	1	10
Totals		19	1	4	26

*Fragments of sea turtle carcasses not identified to species. It is assumed that most are loggerheads.
†Initial construction dredging for Trident submarine base.
‡Two Kemp's ridleys caught in 1988 at Kings's Bay, Georgia.

Source: Richardson, 1990.

turtles were taken, including two individuals of the endangered Kemp's ridley. Although some entrained specimens were identified, it is estimated that 90% or more of the incidents involved the loggerhead. Nearly all sea turtles entrained by hopper dredges are dead or dying when found, but an occasional small green turtle has been known to survive.

Entrapment and death of turtles by hopper dredges first became an issue of concern at the Port Canaveral Entrance Channel, Florida, in 1980 after unusually high concentrations of loggerheads were noted in the area (Carr et al., 1981). Seventy-seven loggerheads were reported killed in 1980 during the removal of 2.5 million cubic yards (1.9 × 106 m^3) of sediment from the channel (Rudloe, 1981; Joyce, 1982). The rate of turtle take varied among dredges, ranging from 0.038 turtle entrained per hour (dredge *McFarland*) to 0.121 turtle entrained per hour (dredge *Long Island*) (Joyce, 1982). The very high number of turtles taken was not repeated in subsequent years for several reasons. First, the *Long Island*, because it seemed to pose the greatest threat, was transferred immediately to other areas. Second, a program of gear modification to the drag heads was initiated at that time. Finally, the loggerheads did not seem to use the Canaveral Channel *in the same numbers* in later years. By 1989, the rate of sea turtle capture in surveys in the channel were about one-tenth the rates recorded in 1978-1983 (pers. comm., A. Bolten, University of Florida, 1989).

Although the most serious loss of turtles in hopper dredges occurs within the Port Canaveral Entrance Channel, smaller numbers have been taken at King's Bay Entrance Channel. Twelve turtles (10 juvenile loggerheads, one adult loggerhead, one juvenile green turtle) were taken during some 20,000 hours of construction dredging (Slay and Richardson, 1988). The rate of capture was less than 0.001 turtle per dredge hour.

The loss of turtles to hopper dredges in other entrance channels is not yet known, but other entrance channels from North Carolina to Florida will be surveyed by NMFS to assess any potential effects on sea turtles (pers. comm., J. Richardson, University of Georgia, 1990). Data are being gathered through additional observer programs to answer the question, and the numbers of sea turtles taken are expected to be considerably smaller than observed at Port Canaveral. The data are not available, but it would not be unusual for 1,000 hours of maintenance dredging to be needed per channel per year.

Collisions with Boats

Another source of mortality to sea turtles associated with human activity is collision with vessels. The regions of greatest concern are those with high concentrations of recreational-boat traffic, such as the southeastern Florida coast, the Florida Keys, and the many shallow coastal bays in the Gulf of Mexico. Of the turtles stranded on the gulf and Atlantic coasts of the United States, 6% of 1,847 strandings in 1986, 7% of 2,373 in 1987, and 9% of 1,991 in 1988 had boat-related injuries for an average of about 150 turtles per year (Schroeder, 1987; Schroeder and Warner, 1988; Teas and Martinez, 1989). In most cases, it was not possible to determine whether the injuries resulted in death or were postmortem injuries.

In the Chesapeake Bay region, boat-propeller wounds accounted for approximately 7% of the deaths of sea turtles stranded in 1979-1988 whose causes were determinable (Barnard et al., 1989), or about five to seven turtles per year.

If we assume that half the boat-collision injuries documented by the STSSN were the primary causes of death of the stranded sea turtles in 1986-1988, and only about 20% of the dead turtles wash ashore, about 400 turtles are killed by boat collisions each year along the gulf and Atlantic coasts of the United States outside of coastal beaches. That estimate might be low, because the strandings include only the ocean beaches (boat collisions with turtles also occur in inside waters), and an animal with an open wound has an increased probability of predation and thus a further reduction in probability of stranding. The estimate might be

high, because more than half of the turtles might have been hit when they were already dead from other causes and were floating.

Petroleum-Platform Removal

The use of explosives in removal of petroleum structures became controversial with respect to turtle mortality in 1986. From March 19 to April 19, 1986, 51 turtles, primarily Kemp's ridleys, were found dead on beaches of the upper Texas coast. Ten petroleum structures in the nearshore area of the strandings had been removed with explosives during the period. Shrimping was at a seasonal low, and circumstantial evidence suggested that at least some of the strandings were due to underwater explosions used in removal of the structures (Klima et al., 1988). Further evidence of the serious effects of the explosions included the stranding of 41 bottlenose dolphins (*Tursiops truncatus*) and large numbers of dead fish (Klima et al., 1988).

After those incidents, attention focused on the possible effects of petroleum-platform removal. In July 1986, 11 sightings of at least three turtles (two loggerheads and one green turtle) occurred during the removal of a platform 30 miles south of Sabine Pass, Texas. What appeared to be a dead or injured turtle drifting with the current 10 feet below the surface was reported 1.5 hours after detonation of explosives (Gitschlag, 1989). Six sightings of loggerheads were reported at five other removal sites, and a green turtle was observed at another location. Those sightings and strandings resulted in a consultation under Section 7 of the Endangered Species Act of 1973 between NMFS and the Minerals Management Service (MMS). Oil and gas companies wishing to use underwater explosives were thereafter required to submit permit requests to MMS. Obtaining a permit requires use of qualified observers to monitor sea turtles near platforms and in some cases to remove turtles to a safe location away from the potential impact of explosive charges.

Data collected by NMFS since 1986 support an association between turtles and some offshore platforms. Divers have reported that turtles commonly associate with offshore structures (Rosman et al., 1987). Gitschlag (1989) reported that 36 turtle sightings near platforms scheduled to be removed were made during 1987-1988 by the NMFS observer program. Another 30 turtles were observed during that period at structures not scheduled for removal (personal communication, G. Gitschlag, NMFS, 1989). A recent NMFS observer effort indicated that turtle concentrations near a petroleum platform could be large. Twelve turtles were collected and removed from one structure off Texas in September 1989 (pers. comm., G. Gitschlag, NMFS, 1989).

Additional reports confirm the association of turtles with offshore platforms. Lohoefener (1988) used aerial surveys and found hard-shelled sea turtles (cheloniids) to be associated with platforms offshore of the Chandeleur Islands (Louisiana), although their study did not indicate an association of sea turtles with platforms in the western Gulf of Mexico. They determined the daytime probability of one or more cheloniids near a platform off the Chandeleur Islands to be about 0.27 within 500 m of the structure, 0.50 within 1,000 m, and 0.65 within 1,500 m. West of the Mississippi River, the probability of one or more cheloniids within 500 m of a randomly selected platform would be about 0.04, within 1,000 m about 0.08, and within 1,500 m about 0.13. Only larger turtles and only turtles on or near the surface are usually seen by aerial surveys, so the figures given should be considered low.

Although information on association of sea turtles with energy platforms is sparse, the potential for mortality must be considered genuine. It is difficult to document a cause-effect relation between turtle deaths and offshore explosions, because no dead animals have been recovered at removal sites and freshly killed turtles sink and might drift a long way by the time putrefaction causes them to float. Association of turtles with the structures is not random; platforms apparently provide a resting place or a location where food is readily available (Klima et al., 1988). From March 1987 through 1988, 69 platforms and 39 caissons or other single-pile structures were removed in gulf waters of Louisiana and Texas. MMS estimated that there were 3,434 platforms in the federal outer continental shelf as of December 1986 and predicted that 60-120 structures would be removed each year for the next 5 years (MMS, 1988). Continuing research should identify more specifically the negative effects of explosive removal of offshore structures. Safeguards for protection of turtles near structures scheduled for removal are essential.

To estimate the numbers of sea turtles that might be killed or injured by explosions in the future, we assumed that the injury and mortality zone will extend no farther than 1,000 m from the structure being removed (Klima et al., 1988). For the Chandeleur Islands area, where the highest densities were seen, Lohoefener et al. (1988) used aerial surveys and estimated a 0.5 probability that a turtle would be visible within 1,000 m of a given structure during the day. If about 100 platforms in gulf waters of Louisiana and Texas will be removed each year over the next 10 years, a total of 8-50 turtles each year could be killed or injured without protective intervention. That estimate is biased downward for two reasons: first, an aerial survey samples only during the day, when turtles are known to forge away from resting sites. Second, turbidity in the Gulf of Mexico may reduce visibility from the air, especially west of the Mississippi. Yet, Klima et al. (1988) estimated higher densities of turtles in this

region during the observer programs. If only half of the turtles are seen during aerial surveys, the estimate could reach as high as 100 turtles possibly affected each year over the 10-year period.

Other uses of explosives also might have an effect. Petroleum seismographic exploration and military maneuvers can use explosives. Their impact on turtle mortality has not been measured, but it might exist. In contrast, turtles nesting in areas adjacent to military bombing activities (e.g., on eastern Vieques Island, Puerto Rico) might actually benefit, because the control of human access and the danger of unexploded rounds greatly reduce the presence of egg poachers (pers. comm., P. Pritchard, Florida Audubon Society, October 1989).

Entrainment of Sea Turtles in Power-Plant Intake Pipes

Sea turtles can become entrained in intake pipes for cooling water at coastal power plants. The best-documented case is that of St. Lucie unit 2 in southeastern Florida. At that facility, nets are constantly set and monitored in the intake canal to remove sea turtles. In 1976-1988, 122 (7.5%) of the 1,631 loggerheads and 18 (6.7%) of the 269 green turtles entrapped in the canal were found dead, for an average of about 11 turtles per year (Applied Biology Inc., 1989a). Four Kemp's ridleys were found dead during the same period. No dead leatherback or hawksbill has been found there (Applied Biology Inc., 1989a). Deaths resulted from injuries sustained in transit through the intake pipe, from drowning in the capture nets, and perhaps from causes before entrainment.

At four other power plants in Florida (Port Everglades, Turkey Point, Cape Canaveral, and Riviera Beach), 21 turtles (loggerheads, green turtles, and one hawksbill) were entrained in the systems from May 1980 through December 1988. Of the 21, seven were found dead (four of which were loggerheads), for an average of about one per year. At the Port Everglades plant, 25-30 hatchlings were also entrained in the system, and a few of them died (Applied Biology Inc., 1989b).

Other turtle deaths at coastal power plants have been reported in New Jersey (Eggers, 1989), North Carolina, and Texas (pers. comm., T. Henwood, NMFS, 1989; pers. comm., B. Schroeder, Florida Department of Natural Resources, 1989). They were sporadic and apparently involved few turtles. For example, the Delaware Bay Power Plant in New Jersey entrapped 38 turtles in 9 years—26 loggerheads (18 dead) and 12 Kemp's ridleys (six dead); for an average of about three per year.

Two factors cause an unusually high entrainment rate at the St. Lucie unit 2 power plant in Florida. First, the continental shelf is narrow in that area, and that seems to cause the normally high density of turtles passing

along the coast to be concentrated near the shore, where the coolant-water intake tube is. Second, that part of the coast appears to be on the main coastal migratory route for turtles in the region. Therefore, mortality rates for this power plant should be considered separately. A total mortality estimate of about 11 turtles per year might be expected in the future at current population densities: about 9.4 loggerheads, one green turtle, and 0.3 Kemp's ridley.

For other power plants, far less is known. According to the Edison Electric Institute (1987), 98 power-generating facilities use ocean or estuarine water for their cooling systems along the gulf and Atlantic coasts of the United States. If we assume that rates of turtle capture from the five power plants discussed above (excluding the St. Lucie facility) are typical for the remaining coastal facilities between New York and Texas, we can estimate an annual mortality of 48 loggerheads and 13 Kemp's ridleys (loggerheads, 98 power plants × 0.48 per year; Kemp's ridleys, 98 power plants × 0.13 per year). Adding in the estimates from the St. Lucie plant raises the loggerhead to 57 per year and Kemp's ridley to 13 per year. An important consideration for the future is that, as turtle populations increase, we would expect an increase in the number of animals entrained in the facilities, and as human populations increase, more power plants might be built.

Directed Take

Directed take of sea turtles and their eggs is illegal in the United States and along the Caribbean and gulf coasts of Mexico. Some illegal take does occur in the United States and Mexico, but the numbers are probably negligible. Loss of eggs and adult Kemp's ridleys at Rancho Nuevo is minimal, because protection has been provided. Although directed take of sea turtles is widely considered to affect populations, at least locally (Pritchard, 1980), the committee was unable to quantify the extent of the problem.

Toxicology

Tissues and eggs from several species of sea turtles in the southeastern United States, Ascension Island in the South Atlantic, the coast of France, and other geographic regions have been analyzed for organochlorine compounds, heavy metals, hydrocarbons, and radionuclides (Hillestad et al., 1974; Thompson et al., 1974; Stoneburner et al., 1980; Clark and Krynitsky, 1980, 1985; Witkowski and Frazier, 1982; Bellmund et al.,

1985). Turtles were found to be contaminated to various degrees in all the studies cited. However, because of the lack of data on physiological effects of the pollutants in sea turtles, their effect on survival cannot be estimated. Additional studies are needed to determine extents of contamination and the physiological effects of the contaminants.

Ingestion of Plastics and Other Debris

About 24,000 metric tons of plastic packaging is dumped into the ocean each year (Welch, 1988). Nationwide 10-20% of beach debris is expanded polystyrene foam and 40-60% is other plastic (McGavern, 1989). An estimated 1-2 million birds and more than 100,000 marine mammals and sea turtles die from eating or becoming entangled in plastic debris each year, including netting, plastic fishing line, packing bands, and styrofoam (Welch, 1988; McGavern, 1989; Sanders, 1989).

Sea turtles ingest a wide variety of synthetic drift items, including plastic bags, plastic sheeting, plastic particles, balloons, styrofoam beads, and monofilament fishing line. Specific reports have been related to green turtles in Hawaii, Florida, and Texas; loggerheads in Georgia, Florida, Texas, and Virginia; hawksbills in Florida and Hawaii; and leatherbacks in New York, New Jersey, Massachusetts, and Texas (Wallace, 1985; O'Hara et. al., 1986). Turtles can mistake plastic bags and sheets for jellyfish or other prey. Ingestion of those items can cause intestinal blockage; release toxic chemicals; reduce nutrient absorption; reduce hunger sensation; inhibit feeding and mating activity; diminish reproductive performance by leaving the turtle unable to maintain its energy requirements and cause suffocation, ulceration, intestinal injury, physical deterioration, malnutrition, and starvation (Wehle and Coleman, 1983; Wallace, 1985; O'Hara et al., 1986; Bryant, 1987; Farrell, 1988; Gramentz, 1988; Welch, 1988; McGavern, 1989).

Absorption of toxic plasticizers (such as polychlorinated biphenyls) is also possible as a result of ingestion. Some plasticizers can concentrate in tissues, and the toxic ingredients can cause eggshell thinning, tissue damage, and aberrant behavior (Wehle and Coleman, 1983; O'Hara et al., 1986).

Plastic bags blocked the stomach openings of 11 of 15 leatherbacks that washed ashore on Long Island during a 2-week period. Ten had four to eight quart-sized bags, and one had 15 quart-sized bags (*San Francisco Chronicle*, 1983; Balazs, 1985; O'Hara et al., 1986). In South Africa Hughes extracted a ball of plastic from the intestine of an emaciated leatherback; when unraveled, it measured 9 × 12 ft, or 2.7 × 3.7 m (Bal-

azs, 1985; Coleman, 1987). In September 1988, the largest leatherback ever recorded (914 kg) was found dead on a beach in Wales. The cause of death was listed as drowning due to entanglement, but a tightly compacted piece of plastic (15 × 25 cm) blocked the entrance to the small intestine and might have contributed to death (Eckert and Eckert, 1988).

Accumulation of pollutants and plastic debris found in sargassum driftlines might be a source of mortality of turtles through ingestion (Mager, 1985). Floating debris is concentrated by natural processes along lines of convergence between discrete water masses, in the core of major current gyres, or on beaches and submerged rocky outcrops. Driftlines along margins of small temporary eddies or areas of downwelling can accumulate floating debris and provide feeding areas for turtles. Young turtles are passive migrants in offshore driftlines and can contact buoyant debris.

In 1979-1988 in the New York Bight area, necropsies were performed on 116 sea turtles. Various amounts of synthetic materials were found in 10 of 33 leatherbacks, three of 35 loggerheads, one of four green turtles, and none of 44 Kemp's ridleys. Most prevalent were plastic bags, small pieces of plastic sheeting, monofilament line, small pieces of variously colored plastic, and numerous small polystyrene balls. There was strong evidence in some animals that ingestion of synthetic materials caused their deaths. There is little information on the residence times and cumulative effects of synthetic materials in marine animals. These observations are not well suited to quantify the frequencies of ingestion (Sadove and Morreale, 1989).

Studies conducted along the Texas coast in 1986-1988 documented the effects of marine debris on sea turtles (Plotkin and Amos, 1988; Stanley et al., 1988; Plotkin, 1989). They were significantly affected by ingestion of, and to a smaller extent entanglement in, marine debris. Necropsies of Kemp's ridleys, loggerheads, and green sea turtles revealed that the intestines of at least 65 of 237 turtles examined contained marine debris, such as plastic bags, styrofoam, monofilament fishing line, polyethylene beads, aluminum foil, tar, glass, and rubber. In a 22-month study, plastic was found in nearly 80% of the turtle stomachs that contained debris and in turtles from about 97% of the beaches surveyed (Stanley et al., 1988). All five species found in the Gulf of Mexico had eaten or were ensnared by debris.

Reports of debris ingestion by species indicated that green turtles had the highest incidence (32%) followed by loggerheads (26%), leatherbacks (24%), hawksbills (14%), and Kemp's ridleys (4%). For all species except the leatherback, immature turtles were involved more frequently than adults. The distribution of debris types was as follows: plastic bags and sheets (32.1%), tar balls (20.8%), and plastic particles (18.9%).

NMFS scientists, on the basis of the results of autopsies conducted

since 1978, estimated that one-third to one-half of all turtles have ingested plastic products or byproducts (Cottingham, 1988).

Mortality associated with ingestion of plastics and debris cannot be accurately quantified from available data. Of the turtles examined, green turtles ingested plastic debris most frequently, followed by loggerheads and leatherbacks. Research is needed to develop accurate postmortem techniques to determine the role of plastic ingestion on turtle deaths. However, many reported stranded turtles are in an advanced state of decomposition, so it is difficult to determine exact causes of death, although indigestible stomach contents might still be identifiable. It is possible that the enactment of Annex V of the International Convention for the Prevention of Pollution from Ships (called MARPOL for "marine pollution") might affect the amount of plastic that sea turtles are likely to encounter in the future; but, considering the life span of plastic and the amount already present in the oceans, the possible deleterious effects of plastic on sea turtles and other wildlife will be present for generations to come.

SUMMARY

Sea turtles are susceptible to human-caused deaths through their entire life, from nesting females, eggs, and hatchlings on beaches to juveniles and adults of both sexes in offshore and inshore waters.

The committee found that the most important source of mortality on eggs and hatchlings at present on U.S. beaches is from non-human predators, whose abundance is often associated with human disturbance, but other factors are beach development, directed take, beach vehicles, and beach lighting. The most important source of mortality for juveniles to adults in the coastal zone is shrimp trawling. Other factors judged to be of significance for juveniles and adults are other fisheries and entanglement in lost fishing gear and marine debris.

Order-of-magnitude estimates of human-caused mortality on juvenile to adult loggerheads and Kemp's ridleys were made by the committee. Shrimp trawling accounts for 5,000-50,000 loggerhead and 500-5,000 Kemp's ridley mortalities per year. Other fisheries and discarded fishing gear and debris account for 500-5,000 loggerhead and 50-500 Kemp's ridley mortalities. Dredging, collisions with boats, and oil-rig removal each account for 50-500 loggerhead and 5-50 Kemp's ridley deaths. Entrainment in electric power plants and directed take each account for fewer than 50 turtle deaths per year. Based on the committee's evaluation, about 86% of the human caused mortalities on juveniles and adults result

from shrimp trawling. The committee recognized the possible effects of plastic ingestion and marine debris but was unable to quantify them.

The strong evidence that shrimp trawling is the primary agent for sea turtle mortality caused by humans comes from five lines of analysis and information. First, the proportion of sea turtles caught in shrimp trawls that are dead or comatose increases with an increase in tow time from 0% during the first 50 minutes to about 70% after 90 minutes. Second, the numbers of turtles stranding on the coastal beaches consistently increased in a steplike fashion when the shrimp fishery opened in South Carolina and Texas and decreased when the fishery closed in Texas. Because the openings and closings were on different dates in different years, the change in strandings can be ascribed to the fishery rather than to date per se. The change in stranding rate indicates that 70 to 90% of the turtles stranded at those times and places were killed in shrimp trawls. Based on analysis of data from loggerheads, these stranded turtles were also in the life stages with the highest reproductive values. Third, loggerhead nesting populations are declining in Georgia and South Carolina where shrimp fishing is intense, but appear to be increasing farther south in central to southern Florida where shrimp fishing is low or absent. Fourth, the estimate in the literature of 11,000 loggerheads and Kemp's ridleys killed annually by shrimp trawling was judged by the committee to be an underestimate, possibly by a factor of three to four, because that estimate accounted for neither mortality in bays, rivers, and estuaries nor the likely deaths of most comatose turtles brought onto the deck of shrimp trawlers. Many of the comatose turtles will die even when released back into the water. Fifth, in North Carolina, turtle stranding rates increase in summer south of Cape Hatteras when the shrimp fleet is active and north of Cape Hatteras in winter when the flounder trawling is active.

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10 Diving Physiology

Molly E. Lutcavage and Peter L. Lutz

CONTENTS

10.1 INTRODUCTION

Sea turtles are among the longest and deepest diving of the air-breathing vertebrates. In the wild, most sea turtles spend as little as 3 to 6% of their time at the surface, where energetic and predation costs may be high, and can thus be considered truly subaquatic. The central features of their diving ability involve an efficient oxygen transport system and an extraordinary tolerance of hypoxia which allows maximal use of limited oxygen stores. Many of the physiological traits that support this breath-hold mode of life, such as intermittent breathing patterns, adjustable metabolism, and hypoxia tolerance, are common reptilian features and undoubtedly were present in the land-dwelling reptilian ancestors of the sea turtle.[1,2] However, sea turtles have distinctive modifications in morphology and physiology that allow them to fully exploit the marine environment in unique ways, and interesting parallels can be made with the aquatic adaptations shown by marine mammals.[3]

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For efficient underwater locomotion the sea turtle body plan includes limbs modified as hydrofoils, a reduction in carapace mass, shortened neck, and body streamlining. They have nasal passages that close upon diving, orbital salt glands for salt excretion (see Chapter 14), and some (leatherbacks) can conserve body heat sufficiently to allow them to forage in cold temperate waters[4] (see Chapter 11). However, the most important respiratory adaptations for successful breath-hold diving are those that facilitate efficient and rapid gas exchange when the turtles are on the surface, and maximize oxygen storage and tissue oxygen delivery while they are submerged. The important metabolic adaptations that enhance diving prowess include having an increased anaerobic scope and an enhanced tolerance of hypoxia.

10.2 NATURAL DIVE PATTERNS

Sea turtles show a wide range in diving depth and duration, although records for some species such as the Australian flatback, *Natator depressus*, are lacking, and we have no information on adult males of most species (Table 10.1). Deepest dive depths have been recorded from adult female leatherback turtles, *Dermochelys coriacea* (>1000 m),[16] followed by the olive ridley, *Lepidochelys olivacea* (290 m, sex unknown),[11] and adult female loggerheads, *Caretta caretta* (233 m).[5] Although hawksbills, *Eretmochelys imbricata*,[15] green, *Chelonia mydas*,[13] and Kemp's ridley turtles, *L. kempi*,[8-10] tend to remain in shallow water (from 20 to 50 m), a record of 110 m has been given for a green turtle.[14] Hawksbill turtles make the longest routine dives reported so far (56.1 min, sex unknown),[15] followed by internesting female olive ridleys (54.3 min),[11] who made longer dives than breeding or post-breeding males (28.6 and 20.5 min, respectively).[11] The longest reported voluntary dives in sea turtles range from 2 to 5 h.[8] In the olive ridley, diving and surface times of turtles tracked for extended periods with satellite transmitters varied in relation to reproduction and migration activities.[11] Similarly, satellite-tagged juvenile loggerhead and Kemp's ridley turtles showed different mean dive depths and surface intervals, depending on whether they were located in shallow coastal areas, (short surface intervals) or in deeper, offshore areas (longer surface intervals).[8-10]

In most cases, there seems to be little relation between maximum dive depth and dive duration. For example, a dive to 211 m by a satellite-tracked loggerhead off Japan required only 10 min,[5] while dives by loggerheads in shallow areas of Chesapeake Bay are considerably longer.[8,9] Perhaps surprisingly, the largest and deepest-diving sea turtle, *D. coriacea*, appears to have the shortest routine dives (4 to 11 min).[16-20] Possibly the price of having higher body temperatures and metabolic rates is that oxygen stores are expended more quickly than in smaller, slower-paced chelonid sea turtles (see Chapter 11).[21]

Despite the brevity of their respiratory phases, sea turtles sometimes spend as much as 19 to 26% of their time at the surface, engaged in surface basking, feeding, orientation, and mating.[8,11,18,19] The wide variation evident both within and across species reminds us that sea turtle diving and surface habitats are a reflection not only of their size and physiological attributes, but of their ecology, environment, and life history.

TABLE 10.1
Sea Turtle Dive Records from Published Sources

Species	Dive depth (meters)		Dive length (min)		% Time submerged
	Maximum	Routine	Maximum	Routine	
Loggerhead *(Caretta caretta)*					
fpn[5,6]	211–233	9–22		17–30	
fpn[6]	99	13.5–16.6		14.8–20.5	
Subadult[7,8]		9–22		19–30	80–94
Kemps ridley *(Lepidochelys kempi)*					
Subadult[7,8]		<50	300	12.7–18.1	96
fpn[10]			167	16.7	
Pacific ridley *(L. olivacea)*					
fpn[11]	290[11,12]			54.3	
mb[11]				28.6	
Green turtle *(Chelonia mydas)*					
?[14]	110				
Subadult[13]		<20	66	9–23	
Hawksbill *(Eretmochelys imbricata)*					
inf, d 15			73.5	56.1	
Leatherback *(Dermochelys coriacea)*					
fpn[16]	>1000		37	4–11	
fpn[17]	475	50–84	37.4	10–14.5	
fpn[18]			2–11		
Subadult[19]			7.7		74–91

Note: Abbreviations: fpn, post-nesting female; inf, internesting female; mb, breeding male; d, daytime; ? not given.

* Misidentified as *C. mydas* in original report.

10.3 LUNG STRUCTURE AND FUNCTION

During the short time they are on the surface, active breath-hold divers must eliminate all of the CO_2 accumulated during the previous dive and take on sufficient oxygen for the next dive. Lung adaptations to handle rates of gas exchange that are much more rapid than those needed by terrestrial relatives should have a high selection value.

10.3.1 VENTILATORY PATTERNS

Sea turtles only require a few breaths lasting less than 2 to 3 sec to empty and refill their lungs, even after being submerged for long periods.[22-24] However, there is a tendency for the number of breaths per breathing episode to increase with submergence time, regardless of activity.[25,26]

Increased ventilatory frequency is seen during nesting activity and when swimming at high speeds. For example, in leatherback turtles the breathing frequency

increased from 1.0 to 3.3 breaths min^{-1} between the egg deposition and sand-throwing phases,[27,28] and the ventilatory frequency increased sevenfold over resting values when juvenile greens swam at 0.4 m sec^{-1} in a swimming tunnel.[26] Breathing hypoxic or hypercapnic-inspired gases caused a shift in breathing patterns in both green and loggerhead turtles, going from intermittent single breaths to clusters of multiple breaths, shortened breath holds, and eventually, nearly continuous breathing.[26,29-32]

Sea turtle tidal volumes are highly variable, and are strongly influenced by the physical conditions the measurements are made under, i.e., whether the animal is swimming in water, held on land, or placed in a supine position.[24,32] Values range from 4 to 14 ml kg^{-1} in *D. coriacea*,[27] 33 to 49 ml kg^{-1} in *Caretta caretta*,[25,31,33] and 24 to 187 ml kg^{-1} in *Chelonia mydas*, [33] which represent 27% to over 80% of the total lung volumes for these species. These tidal volumes are much greater than those found in other reptiles (e.g., *Trachemys scripta*, 6.9 ml kg^{-1},[35] *Crocodylus niloticus*, 11.0 ml kg^{-1})[36] and allow the sea turtle nearly complete exchange of lung gases in a few respiratory bouts. Most marine mammals also have much greater tidal volumes than their terrestrial relatives.[37,38]

10.3.2 Lung Structure

Sea turtles have wedge-shaped lungs that lie under the carapace within the pleuroperitoneal cavity and are firmly attached to the dorsal body wall along the vertebral axis.[23,32,39,40] The lungs are spongy and multicameral like those of other highly aerobic reptiles such as *Varanus*,[41] but early anatomical work identified unique structures not found in reptilian lungs. These structures include strongly reinforced, large-diameter airways, and an intrapulmonary bronchus subdividing into reinforced secondary airways that branch from the primary bronchus and taper gradually in diameter toward the peripheral margins of the lung.[39] More recent histologic studies on loggerhead and green turtle lungs showed that cartilage occurs in all but the central leaflet of respiratory bronchioles, and all airways contain smooth muscle in close association with an elastic fiber matrix.[42-44] The parenchyma is homogenous, fibrous connective tissue and prominent myoelastic bundles occur proximal to the alveoli.[42-44]

In the marine mammals similar structural features facilitate high ventilatory flow rates by providing mechanical support against airway collapse from hydrostatic pressure, and it is very probable that the same function is provided in sea turtles.[37,45,46] Maximum expiratory flow rates in sea turtles are indeed at least an order of magnitude higher than those reported in other reptiles and are only slightly below the range reported for marine mammals.[23,24] For example, during spontaneous breathing on land, expiratory flow in an adult *Chelonia mydas* reached 120 ml sec^{-1} kg^{-1}, or nearly 12 l sec^{-1}.[23] Swimming juvenile green and loggerhead turtles resting on land had peak flow rates of 57 and 16 ml sec^{-1} kg^{-1}, respectively,[24,47] much higher than those reported in the semiaquatic turtle *T. scripta* (0.23 ml sec^{-1} kg^{-1}).[35]

Unlike mammals, sea turtles lack a diaphragm, and pelvic, gular, and pectoral muscles are recruited to ventilate the lung.[48] In consequence, both inspiration and expiration are active, and the respiratory muscles perform work, improving the

respiratory pump capacity beyond that of the passive elastic properties of the lung itself. The ventilation costs associated with large tidal volumes are further offset by the compliant lung and potential energy stored in the elastic recoil properties of lung tissue.[24,41]

10.3.3 Pressure and the Respiratory System

Despite reinforcement with connective and myoelastic tissue, the respiratory system compliance of the sea turtle (C_T = 11 ml cm H_2O^{-1} kg^{-1}, *Caretta caretta*)[24] closely reflect the pressure-volume characteristics of the body wall, and is only slightly less than reptiles having simple, less structurally modified lungs (e.g., *Gecko* 16 ml cm H_2O^{-1} kg^{-1}).[49] In deep divers, compliant chest walls prevent "thoracic squeeze" during lung collapse, a condition that could impede central circulation.[46] Complete lung collapse is believed to occur in deep-diving sea turtles at pressures equivalent to depths ranging from 80 to 160 m.[14] Also in sea turtles and other deep-diving mammals, the ratio of nonrespiratory airway volume to residual lung volume is large, so that at depth a considerable volume of gas will remain only in the reinforced airway.[24,37,50] The confinement of lung gas to nonrespiratory areas during deep dives will help prevent nitrogen supersaturation of tissues, commonly known as the "bends".[24,37,50]

However, there is some evidence that sea turtles are not completely protected against the bends, at least under accelerated decompression produced in some laboratory studies. Gas emboli have been seen in the capillaries of green sea turtles that died after rapid ascent from pressure chamber dives of over 14.5 atms.[14] Indeed, it has been suggested that bends-related damage accounts for an apparent avascular necrosis seen in the long bones of extinct sea turtles and mososaurs.[51,52] However, similar sequelae have not been identified in bones taken from extant sea turtles.[52] Given its relatively small and collapsible lung, there seems to be no compelling evidence that the sea turtle is normally at risk of decompression sickness. A further protection may be provided by vascular modifications. All sea turtles examined so far have a thickened muscular area (bulbous arteriosis) of the pulmonary artery that may constrict during deep diving and invoke a right to left shunt.[53] A diving-related increase in pulmonary vascular resistance[14,50,54] and a shift of circulation away from the pulmonary circuit may offer additional protection against the bends.

10.3.4 Pulmonary Gas Exchange

Sea turtles have the highest rates of oxygen consumption and the greatest aerobic scopes of any reptile. For example, green and leatherback sea turtles can increase resting oxygen uptake rate by 8- to 15-fold and attain maximal rates comparable to the resting rates of most mammals.[21,28,32,34] This aerobic scope is facilitated by the extensively subdivided respiratory surface. Sea turtle lungs provide a comparatively much greater area for gas exchange, and lower resistance to gas transfer, than seen in most reptiles. For example, the diffusion capacity of the loggerhead lung (0.11 ml min^{-1} kg^{-1} $Torr^{-1}$ at 25°C) is about twice that of nonvaranid reptiles and almost 25% of values for the resting mammal.[43] A high pulmonary diffusion capacity would

be of advantage during prolonged submergence, when sea turtles deplete lung, arterial, and venous O_2 stores. A low-resistance lung would also support the high metabolic rates seen in maximally exercising sea turtles by maintaining high saturation levels in arterial blood.[32,33,43]

10.3.5 Pulmonary Perfusion

Blood flow patterns can change dramatically during diving. In juvenile greens during ventilatory bouts swimming at speeds of 4 m sec^{-1}, pulmonary blood flow increased and heart rate nearly doubled.[26,47] The increase in cardiac output was mainly brought about through an elevated heart rate with only minor changes in cardiac stroke flow.[26] In green sea turtles, vascular resistance falls during ventilation and exercise and increases during diving.[26,47,54]

Intracardiac shunting has been seen in force-dived freshwater turtles and in the green sea turtle.[25,47,54,55] But intracardiac shunts appear to be of minor significance during short aerobic dives in green and loggerhead sea turtles.[26,47,54] However, right to left and left to right shunts, which would result in a substantial redistribution of blood away from or to the pulmonary circuit, could account for the observed wide variations in the depletion of lung and arterial PO_2 (see below). There is also evidence of pulsatile flow to the lungs during resting nonventilatory periods in *Chelonia mydas*[26] and in fresh water turtles,[56] believed to be caused by vagally mediated vasoconstriction in the pulmonary artery.

Pulmonary perfusion has been measured in loggerhead and green sea turtles. Using gas dilution techniques (25°C) the values for *Caretta caretta* (86 ml min^{-1} kg^{-1})[43] are significantly greater than those found for *Chelonia mydas* (24 ml min^{-1} kg^{-1}),[54] the latter being in agreement with measurements using flow probes in juvenile green turtles (26.5 ml min^{-1} kg^{-1}).[26] This suggests that loggerheads may have a higher blood convection requirement and therefore a small arterial-venous O_2 content difference as compared to that of *C. mydas*.[43]

10.3.6 Nonrespiratory Functions

Many aquatic reptiles appear to regulate the volume of air in their lungs to adjust buoyancy while diving. In shallow-diving loggerhead turtles the breath hold lung volume is close to the value predicted for neutral buoyancy[57,58] and a fine scale control of buoyancy may be achieved by shifting air between pulmonary compartments.[39] Although the pulmonary musculature of loggerhead embryos is fully present at hatching,[44] like other turtles, initially they can only dive to a few meters, and appear to require several months to develop full buoyancy control.[57,59,60] Diving depth and breath-hold duration increase with the size of the lung oxygen store (which increases with biomass), the maturation of the oxygen transport system, and structural development of the lung.

It is important to note that in addition to its roles in gas exchange and buoyancy regulation, the sea turtle lung may serve other purposes. Because the lung lies directly under the carapace, it has been suggested that during surface basking blood circulated through the lung may be used to transport radiant heat from the sun to other regions

of the body.[61] Nesting leatherback turtles sometimes produce quite audible growling sounds, but the role of the respiratory system in vocalization is not well documented in the sea turtles.

10.4 OXYGEN TRANSPORT

10.4.1 Oxygen Consumption

The dive duration of sea turtles is a function not only of the total oxygen store, but also of the metabolic rate during the dive, and the latter is dependent on size, activity, temperature, and hormonal and dietary status. Wide differences in oxygen consumption ($\dot{V}O_2$) are found according to activity levels. Because of difficulties associated with sampling, metabolic rates are hard to measure on freely diving sea turtles, and most $\dot{V}O_2$ rates during diving are interpolated from land or laboratory studies. For example, in leatherback turtles $\dot{V}O_2$ increased 15-fold between egg-laying and sand-throwing activity ($\dot{V}O_2$ = 0.25 ml min^{-1} kg^{-1} egg laying,[27] 3.7 ml min^{-1} kg^{-1} sand-throwing).[28] A threefold increase has been recorded in juvenile green turtles going from rest (1.98 ml min^{-1} kg^{-1}) to a swimming speed of 0.6 m sec^{-1} (5.6 ml min^{-1} kg^{-1})[47] and a threefold increase has also been seen in loggerheads from rest (1.0 ml min^{-1} kg^{-1}, 25°C) to moderate swimming activity.[31] In other studies $\dot{V}O_2$ rates for *C. mydas* range from 1.1 to 2.4 ml min^{-1} kg^{-1} (rest)[62] to 4.5 ml min^{-1} kg^{-1} (sand-throwing).[34,62] Leatherback hatchlings swimming continuously had $\dot{V}O_2$ rates (4.7 ml min^{-1} kg^{-1} at 24°C)[63] comparable to and even slightly higher than maximal rates recorded in hatchling green turtles.[64]

In the sea turtle, increases in oxygen uptake are brought about through increases in the respiratory frequency, tidal volume, and the amount of oxygen extracted from lung air. The efficiency of oxygen extracted from lung air is estimated by measuring the air convection requirement (ACR), the ratio of lung ventilation to oxygen uptake ($\dot{V}_E / \dot{V}O_2$). Although ACR values range widely in sea turtles (e.g., loggerhead 16 to 120,[31] green turtles 17.3 to 42.2,[47,54] nesting leatherbacks 37.1),[27,28] there appears to be a general tendency for the ACR to decline with increased activity and with a decrease in temperature.[26,29-31] Changes in respiratory frequency account for most increases in V_E, yet tidal volumes also vary somewhat with activity.[24,27,32,34]

10.4.2 Oxygen Store

It has been suggested that diving birds and mammals typically store oxygen in the blood and tissues, while amphibians and reptiles use the lungs as the major oxygen store.[38,56,65] However, consideration of the functional aspects of breath-hold diving indicates that diving strategies may rest on adaptational rather than phylogenetic grounds, centering around the different demands of shallow vs. deep diving.[65-67]

Shallow divers (coastal, estuarine, and freshwater inhabitants) typically inhale before a dive and depend upon the lung as a major oxygen store. This set of animals includes most aquatic turtles,[65] the duckbill platypus,[68] the sea otter,[38] manatees,[69] and dolphins.[38] By contrast, the more oceanic species (e.g., the large cetaceans, some of the pinnipeds, and the leatherback sea turtle) who dive deeply rely more upon

blood and tissue stores for oxygen and accordingly have a different set of adaptations. For example, in the loggerhead sea turtle some 72% of stored oxygen is carried in the lungs and tissue oxygen stores are of minor importance.[33] On the other hand, the deep-diving leatherback turtles have a distinctly different oxygen store strategy compared to chelonid sea turtles.[21,27] The hematocrit, hemobglobin, and myoglobin concentrations of the leatherback are among the highest recorded for reptiles, and approach levels found in diving mammals. The blood and tissue oxygen store of the leatherback (15.2 ml kg^{-1}) is larger than that of the lung (12.2 ml kg^{-1}), whereas in other sea turtles the lung store is larger by at least a factor of two (Figure 10.1).[21,27,33] Female leatherback turtles routinely dive to depths that would result in complete lung collapse, whereas in shallow-diving turtles the lung would remain partially inflated throughout the dive.[27,65] However, despite differences in distribution, total oxygen stores calculated for loggerhead turtles (22.2 ml O_2 kg^{-1})[33] and the leatherback (27.4 ml O_2 kg^{-1})[21] are surprisingly similar. Based on oxygen consumption measurements and estimates of total oxygen stores, aerobic dive limits of 33 and 70 min have been calculated for a 20-kg loggerhead[33] and the adult leatherback,[21] respectively, encompassing the ranges of dive duration seen in nature.

10.4.3 Blood Gases During Breath-Hold Dives

The blood gas transport systems of terrestrial vertebrates normally function within narrow ranges of alveolar PO_2, PCO_2, and blood pH. In contrast, one would expect that during a dive the sea turtle blood must be able to operate effectively in the face of intensified hypoxia and hypercapnia.

Unfortunately, there are few blood gas measurements in voluntarily diving sea turtles. In subadult loggerhead turtles, studied under laboratory conditions, a steady decline in arterial PO_2 was seen during dives, starting from initial values of 112.4 Torr PO_2 and falling to 3.9 Torr after 25 min of breath-hold diving.[25] Interestingly, the concomitant increases in PCO_2 were relatively small, typically <10 Torr for 20-min dives, suggesting that an efficient CO_2/bicarbonate and ionic exchange system was operating. Arterial pH, in consequence, did not decline by more than 0.03 to 0.1 pH units, even during long dives, and sometimes even increased slightly.[25] Such dives are probably fully aerobic, since blood lactate values obtained from comparably sized loggerheads under similar conditions were less than 0.2 to 0.4 m*M*.[31] Indeed, most voluntary dives are terminated at or before the arterial PO_2 reaches about 20 Torr in freshwater turtles,[55,56,70] crocodiles,[71] sea snakes,[1] and diving birds.[65] On the other hand, in a 15-min dive by a tethered adult green turtle, arterial PO_2 fell to below 30 Torr and arterial saturation declined from 90 to 45%, there was a substantial decrease in blood pH, and a tenfold increase in blood lactate concentration.[54] In the stress of trying to escape, oxygen stores had been used up rapidly and anaerobic glycolysis had been activated.

10.4.4 Blood Oxygen Transport

For sea turtles (and also marine mammals) the respiratory properties of blood may depend upon whether oxygen is primarily stored in the tissues or in the lung during

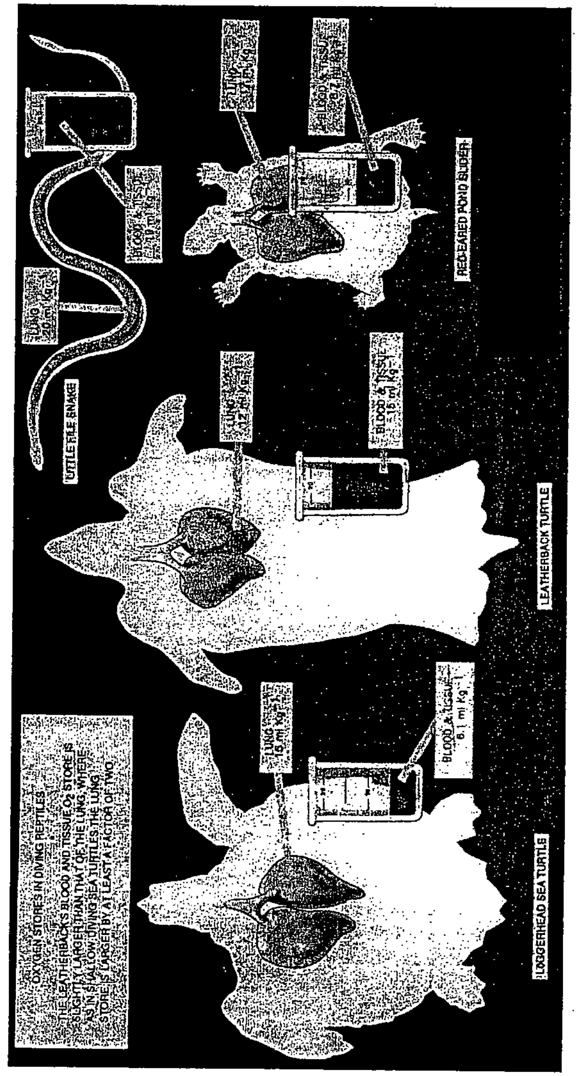

FIGURE 10.1 Oxygen stores in diving reptiles are divided between the lung, blood, and tissues.

the dive, as the problems of blood oxygen transport are quite different in either case.[3,67,70,72,73] For example, marine mammals and the leatherback sea turtle that store oxygen in the blood often have comparatively high hematocrits, which increase the blood oxygen-carrying capacities (Table 10.2). The deep-diving leatherback, for example, has the greatest hematocrit values of any reptile (32 to 38%).[27] But elevated hematocrits cause increased blood viscosity, which can make lung to tissue oxygen transport energetically much more expensive.[3] For both adult and hatchling green turtles, Wells and Baldwin[76] found an exponential increase in blood viscosity at hematocrits over 30%, and calculated that the optimal hematocrit for this species is around 30%.

TABLE 10.2
Blood Oxygen Affinity and Transport Properties of Diving Reptiles and Mammals

	Leather-back[27]	Logger-head[63]	Green turtle[63]	Crocodile[74]	Killer-whale[72]	Weddell seal[72]
Maximum dive depth (m)	>1000	233	110	<30	260	600
Hematocrit (%)	39	29	30	28	44	58
Hemoglobin (g dl⁻¹)	15.6	9.8	8.8	8.7	16.0	17–22
Myoglobin (mg g⁻¹)	4.9	2.9[33]				44.6[75]
O_2 carrying capacity (vol%)	21		7.5–11.9	12.4 8.8	23.7	31.6
P_{50} (Torr)	40	47	29 18.2[53]	22	31	29
pH at P_{50}	7.52	7.45 7.6[53]	7.45	7.5	7.4	7.4
Bohr effect	–0.34	–0.34 –0.59[53]	–0.30	–0.43	–0.74	–0.61
Hill number	2.7	2.8 2.8[53]	2.7	2.6		

Note: P_{50} is the PO_2 at 50% saturation. Hill number is the slope of the line describing the relationship between blood saturation log (S/100 – S) and partial pressure of oxygen, log PO_2.

By contrast, for animals that use the lung as an oxygen store, the blood must continue to pick up oxygen as the dive progresses, in face of declining lung PO_2 and blood pH. Here, a large Bohr effect would be disadvantageous for oxygen binding, since the lung PO_2 is falling concurrently with pH. Loggerhead and green sea turtles not only have Bohr values at the low end of the reptilian range, but, more significantly, the Bohr effects decline substantially at low saturation levels, i.e., at the operating region towards the end of a dive when the lung pH and blood PO_2 are lowest.[33] The shapes of the oxygen binding curves in both species are also favorable

for oxygen extraction from the lungs during a dive, in that they are steep rather than sigmoidal at low saturation levels (Hill n coefficient approaches 1).[33,65] Indeed, the kinetics of the oxygen-hemoglobin interaction in the green sea turtle would appear to favor oxygen uptake rather than oxygen release.[77] These adaptations allow oxygen to be stripped from the lung in the sea turtle to almost below detectable limits.[22,77,78]

Interestingly, the variation in blood oxygen affinities between different species is very wide (Figure 10.2). The highest affinity is seen by the green turtle (P_{50} = 27 Torr PO_2 at pH 7.4),[65] the leatherback turtle has a P_{50} of 40 Torr PO_2 at PCO_2 of 4.8%,[27] and the loggerhead turtle has the lowest affinity reported (PO_2 = 49 Torr at pH 7.4).[33,65,79] The adaptive significance of such a wide range on oxygen affinities is not at all clear, since all animals including the leatherback have basically the same mode of living, i.e., breath-hold diving. By contrast to greens and loggerheads, the slope of the oxygen dissociation curve of the leatherback at low saturation is shallow.[27]

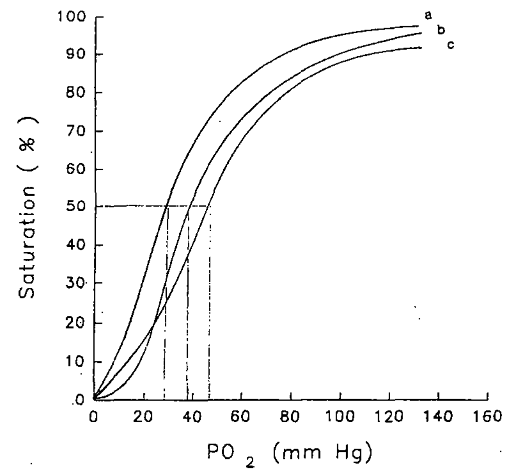

FIGURE 10.2 Comparison of blood oxygen binding curves in the (b) leatherback (25°C, pH = 7.52, 4.8% CO_2),[21] and in the green (a) and loggerhead (c) sea turtles (25°C, pH = 7.45, PCO_2 = 37 Torr).[65] The dotted lines indicate position of P_{50}.

Green and loggerhead hemoglobins appear to be adapted to a role in O_2 delivery in that they have an oxygen binding site that remains strained under all physiological conditions.[77,78] The dominance of the strained "T state" acts to preserve the hemoglobins of the sea turtle from uncontrolled stripping of oxygen, allowing modulation to be dictated by the partial pressure of O_2 at the tissue level.[78]

It appears that sea turtle hemoglobins are affected less by changes in temperature than other reptilian species. In one study, purified hemoglobin from *C. mydas* showed

an increase in O_2 binding with increased temperature, and adult loggerhead hemoglobin, plus cofactors, displayed only a slight decrease of O_2 affinity with temperature, suggesting that in sea turtles, hemoglobin-mediated oxygen delivery is independent of temperature.[77,78,80] However, the functional significance of such temperature independence is not clear, since the loggerhead is unlikely to experience marked gradients in body temperatures, and the effect may relate more to the interdependency of factors that influence hemoglobin oxygen affinity.[80]

Interestingly, while the oxygen affinity of the green turtle hatchling is similar to that of the adult, the oxygen affinity of pupified (or stripped) hatchling hemoglobin is much greater than that of the adult.[76,79] The reason appears to be that while the erythrocyte organic phosphates act to decrease the oxygen affinity of the hatchling embryonic hemoglobin (HbE), they have little effect on the affinity of adult hemoglobin (HbA). Hematocrit and hemoglobin concentrations in Kemp's ridley, green, loggerhead, and olive ridley turtles appeared to increase with age.[82] In *L. kempi*, there was a substantial increase in these parameters by 7 months, but adult levels were not reached until 16 months.[82]

10.5 FORCED-DIVING RESPONSES

While most voluntary dives appear to be aerobic, showing little if any increases in blood lactate and only minor changes in acid-base status, the story is quite different in forcibly submerged turtles, where oxygen stores are rapidly consumed, anaerobic glycolysis is activated, and acid-base balance is disturbed, sometimes to lethal levels.

It is now recognized that the "classic" dive response, which was identified in early studies on enforced submergence in marine mammals and reptiles,[83–85] is essentially an emergency reaction to special circumstances and rarely occurs during routine dives.[38,65] In the "classic" dive response, underwater endurance is maximized through circulatory adjustments (a rapid onset of bradycardia and severe peripheral ischemia) which spare oxygen and aerobic substrates for the brain and heart, while other tissues become anaerobic. The cost, however, is that the animal incurs an oxygen debt, which must be repaid when breathing is resumed.[38,65]

In forcibly submerged adult green turtles the heart rate declined sharply from 20 to 30 b min^{-1} to less than 1 beat min^{-1};[14] after 90 min the lung oxygen was virtually zero, and no oxygen was measurable in the blood after 5 h.[22] In these experiments no increase in blood lactate was seen until the first 30 to 60 min of enforced submergence, when blood lactate reached 90 to 100 mg ml^{-1}.[22] Recovery to predive levels required 15 h or more. A somewhat different pattern was seen in forcibly submerged loggerhead turtles. In these animals, blood oxygen was depleted to negligible levels in less than 30 min, and venous pH fell from 7.5 to 6.9 within 90 min.[33] Blood lactate increased from 9.9 m*M* in 30 min to 18 m*M* in 90 min forced dive. Following 30- to 90-min dives, loggerhead and green turtles hyperventilated for up to 30 min, yet remained acidotic for hours.[33] The increase in blood lactate occurring during prolonged forced dives in juvenile loggerheads appeared to be slightly more severe than that reported in adult green turtles. In the latter case, lactate concentration remained low until rapidly released as a spike upon initiation of breathing.[22]

It is most likely that the rapidity and extent of the internal changes that occur during forced or emergency dives are functions of the intensity of underwater struggling activity as well as the length of submergence. For example, oxygen stores were depleted within 15 min in tethered green sea turtles diving to escape.[54] Under such circumstances survival could be compromised if the animal remains trapped underwater, caught up in gear such as a shrimp trawl. Indeed, accidental drowning in shrimp trawls, driftnets, longlines, and other fishing gear has been identified as the most important source of turtle mortality in the U.S.[86] In a field study examining the effects of shrimp trawl tow times on sea turtle survival, there was a strong positive correlation between tow time and sea turtle deaths.[87] There is also evidence that trawl capture can cause a rapid and severe disturbance in acid-base balance. Juvenile Kemp's ridley turtles subjected to experimental trawls lasting a maximum of only 7.3 min (27°C) showed a marked metabolic acidosis (a sixfold lactate increase from pretrawl conditions) and increased breathing frequency nearly tenfold upon emergence.[88] Loggerhead turtles captured in shrimp trawls with tow times of less than 30 min showed severe metabolic acidosis with blood lactate values ranging from 8.8 to 16.2 m*M*.[89] Lactate recovery times were long, taking as much as 20 h in loggerheads and Kemp's ridleys, indicating that turtles are probably more susceptible to lethal metabolic acidosis if they experience multiple captures, because they would not have had time to process lactacid loads.[25,88,89]

Additional factors such as size, activity, water temperature, and interspecific differences also bear directly on metabolic rates and aerobic dive limits and will also influence trawl endurance times.[25] For example, larger sea turtles are capable of longer voluntary dives than small turtles. Juvenile sea turtles therefore may be more vulnerable to the stress of enforced submergence than adults, especially during the warmer months when routine metabolic rates are higher.[25] Disease factors and hormonal status may also play a role in anoxic survival in forced submergence. For instance, green turtles afflicted with fibropapillomas or spirorchidaisis may be especially vulnerable to trawl stress. Hematocrits as low as 25% of normal values occur in afflicted turtles, which would cause a reduction in the blood oxygen transport capacity. In freshwater turtles, thyroid hormones appear to have a role in setting metabolic rate, suggesting that hormones may also influence the metabolic status of a sea turtle.[90]

10.6 ANOXIC TOLERANCE AND HIBERNATION

Characteristically, the vertebrate brain has an absolute dependence on oxygen and dies with a few minutes of its absence. This is true of the marine mammal, and maintaining an adequate supply of oxygen to the brain is probably the ultimate determinant of dive endurance. However, the brains of a few species of freshwater turtle, and at least the loggerhead sea turtle, have the extraordinary ability to survive many hours of anoxia, indicating that these species can remain underwater without breathing for greatly extended periods.[91]

The mechanisms that protect their brains from anoxic failure have been the subject of several recent reviews.[92,93] In essence, the anoxic turtle brain is able to maintain ATP levels and ionic homeostasis by severely reducing its metabolic

demands to a level that can be fully met by anaerobic glycolysis. Factors involved include an increase in the concentration and release of inhibitory neurotransmitters such as gamma aminobutyric acid and the cofactors such as adenosine and gamma butyric acid, and a reduction in the concentration of excitatory neurotransmitters such as glutamate.[93,94]

The ability to tolerate complete anoxia may allow some freshwater turtle species such as *Chrysemys picta* to hibernate in frozen-over anoxic freshwater pools.[95] For sea turtles its use is not so clear. There are a few reports of possible hibernation in sea turtles. Felger et al.[96] described an assemblage of overwintering green turtles, *Chelonia agassizi*, in the Gulf of California, partially buried in the sandy bottom and believed to have been resident from 1 to 3 months (presumably without eating or breathing) at water temperatures below 15°C.[96] Torpid sea turtles have also been recorded off central Florida and coastal Georgia. In the winter of 1977 to 1978 large numbers of loggerheads were caught by trawling in the Cape Canaveral ship channel.[97] These animals were stained black by the anoxic sediments, suggesting that they had been lodged in the channel mud for a long period. Laboratory studies also indicate a dramatic reduction in activity in seawater temperatures below 11 to 15°C.[31,98] However, it has not been established that cold ocean waters actually cause sea turtles to become apneic and completely inactive for days. Indeed, there is evidence from satellite tracking studies that migrating loggerhead and Kemp's ridleys remain active below 10°C and as low as 6°C.[9] Loggerhead turtles subjected to seasonal low water temperatures off Tunisia reduce activity, but continue to forage.[99] Apart from incidences of cold stunning of young juveniles in New England waters,[100] it is likely that as winter approaches most sea turtles living in temperate waters start to migrate towards warmer tropical waters and do not experience severely cold temperatures.

10.7 CONCLUSIONS

From recent studies we have started to gain an appreciation as to how sea turtles and other divers manage breath-hold dives. This involves fairly radical adaptations in the lung, blood, and tissue compared to other reptiles. Interesting parallels between marine mammals and sea turtles in respiratory system structure and in deep diving vs. shallow diving strategy provide fascinating examples of convergent evolution. Yet much remains to be learned about the integration of physiological and cognitive responses to diving. For example, heart rate, pulmonary, and peripheral circulation may change abruptly in anticipation of surfacing or diving, and also change with activity during a dive, suggesting that the central nervous system coordinates and modulates the dive response.[14,26,65,101] The details of these responses in free-diving animals remain elusive.

We most especially need to know the characteristics and scope of the physiological responses of the sea turtle in the field. Huge gaps in our knowledge include how natural respiratory and cardiovascular patterns and alterations in blood gases relate to underwater activity, and how these variables change in relation to diurnal activity and season. Very recently, newly developed physiological sensors and miniaturized computers that record heart rate, swim velocity, and blood flow information on free-ranging pinnipeds and diving birds have been deployed on sea turtles. Satellite telemetry has also opened new avenues of research on the pelagic behavior of sea turtles, but how the different sea turtle species and their diving habits are affected by environmental changes such as cold snaps is poorly documented. Finally, it is a goal of sea turtle conservation efforts worldwide to reduce sea turtle deaths in fishing gear, identified as the greatest single threat to their survival (see Chapter 13). We must then fully understand how enforced submergence produces lethal stress in animals better known for their anoxic tolerance and durability.

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11 Thermal Biology

James R. Spotila, Michael P. O'Connor, and Frank V. Paladino

CONTENTS

11.1 INTRODUCTION

The biology of sea turtles is intimately tied to the thermal constraints of their environment. From the time a hatchling enters the water, a sea turtle lives in an environment that is thermally stable in any given place, but that can vary in temperature through time, with depth, and with geographic location. In general, it is only the female sea turtle that comes onto land and only when she is nesting. Nevertheless, temperature plays an important role in the biology of the nesting process as well. Sea turtles are unusual among reptiles because their large body size allows adults to use insulation and blood flow to alter or control body temperature (T_b). Therefore, there is a large difference in the ability of hatchlings, juveniles, and adults to thermoregulate actively.

The environmental constraints on the thermal energetics of sea turtles were reviewed by Spotila and Standora,[1] and recent advances were reviewed by Spotila.[2] Considerable progress has been made in the last 10 years in determining the thermoregulatory mechanisms of sea turtles. This has been accomplished by laboratory studies and by the application of sophisticated physiological techniques to field conditions. In this chapter we will review the basic biophysical constraints on the thermal biology of sea turtles, the thermoregulation of sea turtles on land and in the water, and the role of body size and metabolism in thermoregulation. For a review of early research on the thermal biology of sea turtles see Mrosovsky.[3]

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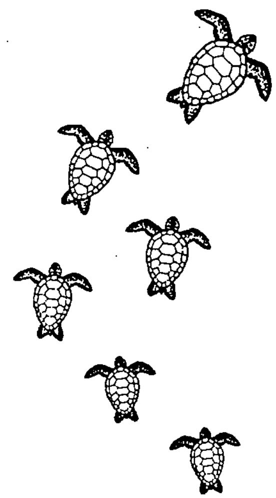

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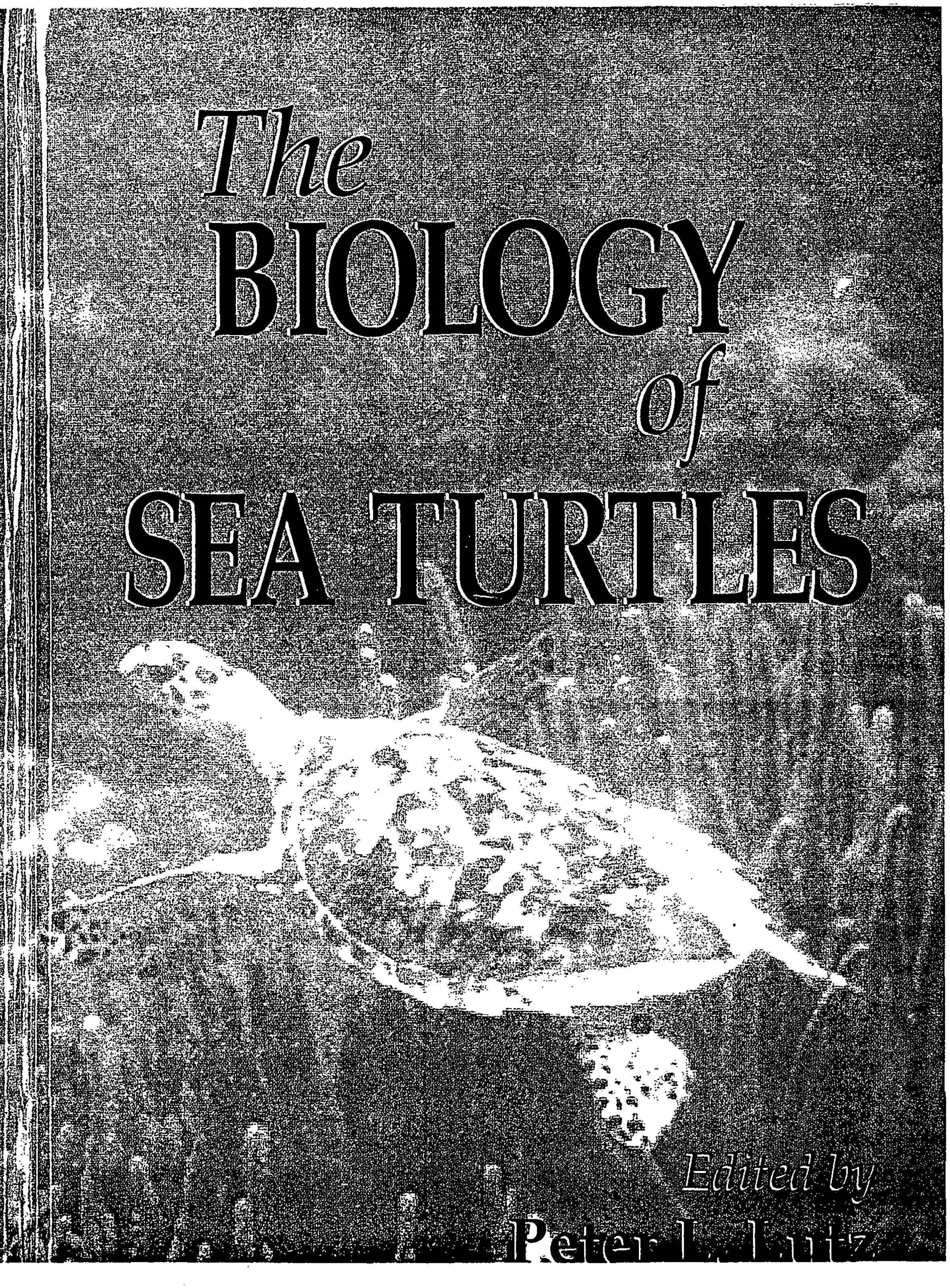
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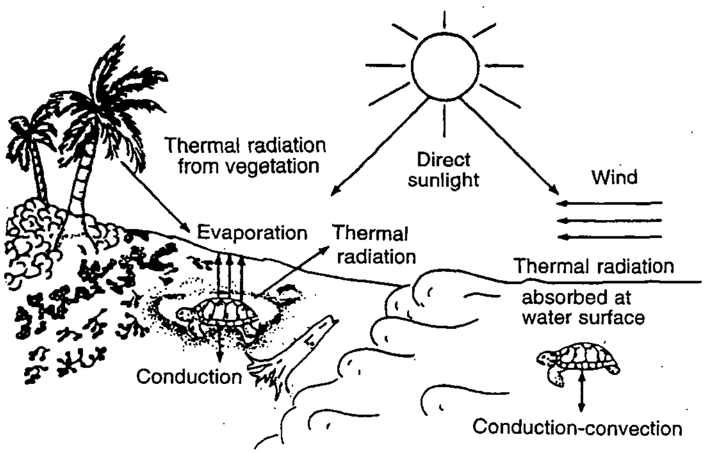

FIGURE 11.1 Heat exchange between sea turtles and their environment. On land, heat transfer occurs via radiation, convection (wind), evaporation, and conduction. In water, heat transfer occurs by conduction-convection. (From Spotila, J. R. and Standora, E. A., *Copeia*, 1985, 694, 1985. With permission.)

11.2 BIOPHYSICAL CONSTRAINTS

Energy exchange controls the T_b of sea turtles. Chemical energy from food drives metabolism, which in turn provides an internal source of heat. However, in all but the largest animals, energy exchange with the environment is the main source of heat for a sea turtle whether it is on land or in the water. On land, heat energy exchange is by radiation, convection, evaporation, and conduction.[4] In water, thermal radiation is absorbed near the surface and heat exchange is primarily by conduction and convection[5,6] (Figure 11.1). In his classic book, *Energy Exchange in the Biosphere*, Gates[7] explained the energy environment in which we live and detailed heat transfer by radiation and convection. His basic message was that

$$\text{HEAT IN} = \text{HEAT OUT} + \text{HEAT STORED}$$

By using simple steady-state or equilibrium equations, he indicated how to calculate the energy balance of an organism. The heat storage term is ignored in steady-state analysis. Following the convention of Gates,[8] this steady-state energy budget equation is given as:

$$Q_{abs} + M = R + C + E + G \qquad (11.1)$$

where:
Q_{abs} = radiation absorbed by the surface of the animal from the sun (solar radiation) and the surroundings (thermal radiation) ($W \cdot m^{-2}$)
M = metabolic heat production ($W \cdot m^{-2}$)
R = thermal radiation emitted by the surface of the animal ($W \cdot m^{-2}$)
C = heat energy lost by convection ($W \cdot m^{-2}$)
E = heat energy lost by evaporation of water or heat energy gained by condensation of water ($W \cdot m^{-2}$)
G = heat energy lost or gained by conduction through direct physical contact of the animal with soil, water, or substrate ($W \cdot m^{-2}$)

Using this equation we can predict the T_b of a plant or animal if we know its heat transfer properties and the thermal energy environment to which it is exposed. Details of the mechanisms of heat transfer in animals are presented by Spotila et al.[9] and do not need to be repeated here.

Porter and Gates[4] apply this approach to animals to produce climate space diagrams. These diagrams give thermal limits for birds, mammals, and reptiles. While useful for small animals, climate space diagrams are less useful for large reptiles because large crocodilians and sea turtles have high internal heat storage capacities and therefore large thermal inertia.[6,10] Therefore, climate space diagrams indicate long-term or average limits on the thermal biology of these large animals. Of more interest for sea turtles are transient energy budgets. The reason for this is that we need to predict body temperature of a sea turtle through time in order to understand its thermal biology.

Equilibrium and transient energy budget equations make different assumptions, are solved by different methods, and provide answers to different questions. Equilibrium equations provide information about the thermal environment of the animal. The T_b computed from Equation 11.1 is the T_b that a sea turtle would come to if the turtle stayed in one place for a long time and neither the environment nor the turtle changed. Since most sea turtles have large thermal inertia and, thus, seldom equilibrate with environmental conditions, their T_b tends to average out the changing environmental temperature over several hours or days. As the thermal environment changes, the turtle T_b is also changing (Figure 11.2). It approaches the environmental temperature with a lag due to its large heat capacity. Environmental temperature reaches a peak and starts to drop while the body core of the sea turtle is still warming up. Body temperature reaches a peak while environmental temperature is dropping, and then follows it down. In essence, the T_b of the turtle is chasing the effective temperature of the environment. Even so, the turtle should respond behaviorally to a changing thermal environment because it senses changes in skin temperature. The turtle has to anticipate changes in environmental heat load before they occur to avoid overheating due to its own internal heat transfer lag. A good example of this problem is reported by Colbert et al.,[11] who found that when they removed an alligator from the sun as its T_b approached the lethal value, T_b continued to rise for some time, and the alligator died of heat stress despite being in the shade for hours. Thus, we

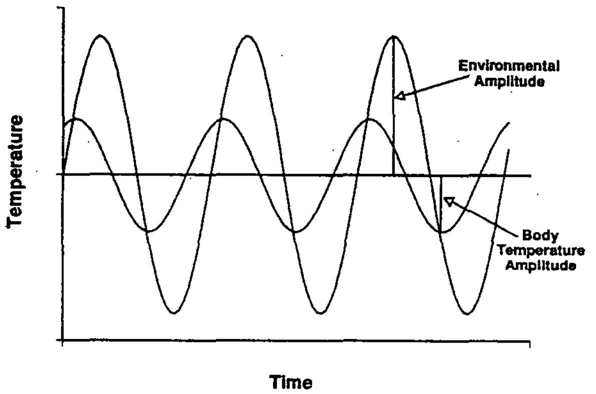

FIGURE 11.2 An idealized relationship of body temperature (T_b) change to environmental temperature change in a variable environment. Environmental temperature is the operative environmental temperature T_e (see text). In a large animal such as a sea turtle, the core T_b never comes to equilibrium with the T_e if that temperature fluctuates rapidly. The T_b is moderated or dampened and changes more slowly and less dramatically than the T_e. It appears as if the T_b chases, but never catches the T_e. Thus, a large sea turtle has a more constant temperature than its environment because of its thermal inertia. (From Spotila, J. R., O'Connor, M. P., Dodson, P., and Paladino, F. V., *Mod. Geol.*, 16, 203, 1991. With permission.)

need to have a means to study the instantaneous response of sea turtles to their thermal environment and we need to have a means to study transient heat transfer, because this determines T_b at any given time.

We can study the equilibrium and instantaneous energy exchange of a sea turtle by making use of the concept of operative environmental temperature (T_e) as defined by Bakken and Gates,[12] Bakken,[13] and Bakken et al.[14] The T_e is a temperature that indicates the heat load that the environment places on the surface of an animal. It averages the effect of solar radiation, heat radiation from the surroundings, and convection into a single temperature value. This is the temperature of a darkened environmental chamber with black walls that would provide the same thermal environment (heat load) as that experienced by the animal under the conditions in which the T_e is being measured. The T_e can be computed from Equation 11.1 or can be measured with an operative temperature model that has the same size, shape, and radiative properties as the real animal in question. Thus, Standora et al.[15] used a large hollow copper model of a sea turtle to measure the T_e of green turtles, *Chelonia mydas*, on the beach at Tortuguero, Costa Rica. The use of such a model would allow a detailed study of phenomena such as the basking of green turtles at French Frigate Shoals in the North Pacific.[16] Caution must be applied with this technique, however, because it is not a "cure all" for all biophysical studies of animals. Many poorly conceived and executed studies have produced unclear data because the investigators did not take the time to understand the intricacies of the T_e concept.

Bakken[17] provided a summary and critical review of the uses and measurements of T_e. We do not repeat that analysis here. Potential users of this technique would be well advised to consult this and other papers by Bakken to develop clearly their question and methodology before carrying out a T_e study of sea turtles.

Most importantly, before using a T_e model one must understand that such models (particularly for large animals) have several limitations. (1) Models must have the same heat exchange properties (radiation, convection) as the real animal. It is not sufficient to take a piece of copper pipe or a large sphere and paint it some color that appears to look like a sea turtle, and then assume that the model represents the turtle. The visual color may have little relevance to the absorptivity of the surface to visible and near-infrared solar radiation, because the near infrared is a large component of the total absorbed radiation, and our eyes cannot see it. (2) The T_e models do not account for metabolism and do not model evaporation effects very well, unless you cover the model with a wet surface, but that would change the radiative properties as well. Of course, sea turtles do not have wet skins, so that is less of a problem than for amphibians. (3) Models must be assessed in the same thermal environment as that experienced by the animal. For example, a sea turtle model needs to be in the same position as the sea turtle on the beach. If it is a green turtle model for a nesting turtle, then it needs to be in a body pit. (4) A model of a large animal such as a sea turtle may have problems with gradients among its parts. That is, the top surface (carapace) will be hotter than the true T_e of the animal, while one of the limbs will be another temperature, etc. The gradients in T_e may be real or may be an artifact of the model. It is possible that the T_e of the carapace is different than the real T_e of the plastron or front limb because those parts of the turtle experience different heat loads, or those differences may be due to a problem of air circulation in the model. That would have to be determined by more complicated modeling and computational efforts. In using a T_e model of an animal, we are looking for the average T_e of the whole animal. Therefore, the true T_e will be best estimated by the internal air temperature of the model. If the regional differences in T_e are very troublesome, it may be necessary to put a small fan into the model to assure good air circulation. (5) By design, a T_e model is not supposed to measure T_b. It is designed to measure the heat load on the surface of the animal. That is why we do not fill it with water or some other substance. We do not want it to respond with the same time constant as the real animal. We are measuring the heat exchange at the surface, not the T_b of the animal.

Transient energy budget equations predict how the T_b of an animal will change with time. If the animal is already at its equilibrium T_b and the environment is stable, no change in T_b is predicted. Thus, the equilibrium energy budget equation is a special case of the transient energy budget equation with the heat storage term = 0. The transient model is more generalized. While the equilibrium equation can be solved as an algebraic equation, the transient model involves the solution of a differential equation. There are standard solutions for transient energy budget equations,[8,18] and transient models have proven useful for consideration of heat transfer in large reptiles, including sea turtles[19] and dinosaurs.[20–22] The basic conclusion of these studies is that as body size of an animal increases, fluctuations in core T_b are reduced on hourly to daily time scales. For example, calculations by Spotila et al.[22]

indicate that the T_b of the dinosaur *Compsognathus* (1.96 kg) would vary with fluctuations in T_e of a few hours, like a large green iguana, while T_b of *Deinonychus* (75 kg) would vary with fluctuations on the order of less than a day, like an olive ridley turtle (*Lepidochelys olivacea*) on land, and T_b of *Tenontosaurus* (624 kg) would vary with T_e changes on the order of a week, like a leatherback turtle (*Dermochelys coriacea*) on land (Figure 11.3). Of course, sea turtles in water would be exposed to more rapid heat transfer at the surface of the skin (see below). Thus, differences in body size alone, both within and between species, result in different thermoregulatory problems for sea turtles. Sea turtles can only thermoregulate within the constraints placed upon them by the interaction of their physiological, behavioral, and physical characteristics and the physical characteristics of their environment. Within those constraints biological interactions, for example, predation by sharks, will further limit the ability of sea turtles to thermoregulate.

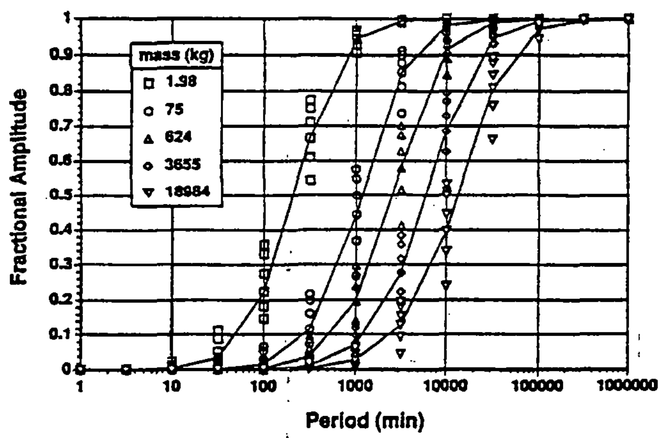

FIGURE 11.3 Predicted responses of dinosaur body temperatures (T_b) to variations in the thermal environment. Fractional amplitudes predicted for various-sized dinosaurs when exposed to fluctuations in the thermal environment with periods ranging from 1 min to 10^6 min (approximately two years). Fractional amplitudes are changes in T_b expressed as a fraction of the total difference in T_b between one equilibrium T_b and another. Thus, a fractional amplitude of 0.5 indicates that T_b would change half the way from one equilibrium temperature to another. Different symbols and lines represent different masses. Multiple symbols for a particular mass and period represent the effect of varying cardiac output from 20% of the predicted resting flow rate to 10 times the resting rate. Values are presented for 0.2, 0.5, 1.0, 2.0, 5.0, and 10.0 times resting flow rates. Lines go through values for 1.0 times resting flow rate. In all cases, lower cardiac outputs result in lower predicted fractional amplitudes, indicating that core T_b would change less in response to changing environmental temperature with lower rates of blood flow. Increases in body size and decreases in blood flow isolate core T_b from environmental temperature. (From Spotila, J. R., O'Connor, M. P., Dodson, P., and Paladino, F. V., *Mod. Geol.*, 16, 203, 1991. With permission.)

11.3 SEA TURTLES ON LAND

Most sea turtles nest at night because exposure to the hot sun during the day would lead to lethal heat gain. Large sea turtles in tropical water are relatively warm and crawl onto the beach with T_b of 29 to 32°C. They are already close to their upper limit for thermal tolerance (which we assume is near 40°C, although it has not been measured). A rise of a few degrees in T_b would place them in danger of overheating. Green turtles walking on the beach at Tortuguero, Costa Rica during midmorning experienced a rapid rise in temperatures of the plastron and carapace, while T_b (near liver and pectoral muscles) rose at a slower rate.[15] Using multichannel telemetry we found that, in full sun, plastron temperature of a 117-kg turtle rose from 36.5 to 42.9°C, carapace temperature rose from 34.5 to 53.8°C, and deep body temperature rose from 32.1 to 35.1°C in 20 min. The gradient across the thickness of the carapace was 17.1°C and across the thickness of the plastron was 5.5°C. The T_e measured for a model green turtle on the beach was 44°C. At this point we allowed the turtle to enter the surf (28.5°C), and external temperatures dropped. After 17 min the carapace surface dropped to 40.6°C while the inner surface rose from 36.7 to 36.9°C. External plastron temperature dropped to 38.8°C while inner surface temperature rose from 37.4 to 37.6°C. Body temperature continued to rise (0.7°C) and reached 35.8°C. Heat continued to move into the turtle despite the fact that its shell was cooling in the water. This was due to internal heat lag similar to the phenomenon encountered by Colbert et al.[11] with the alligator discussed above.

Under overcast sky, T_b of two green turtles walking on the beach rose 2.6 and 2.8°C h^{-1}. Heating occurred primarily through the carapace, while the plastron remained cooler than the deep body and acted as a heat sink. Under clear sky at night, T_b of green turtles walking on the beach dropped slowly (0.3°C h^{-1}) over 2 h. This was due to thermal inertia, which was also indicated in the thermal time constants for green turtles. A time constant is the time it takes for the temperature of an object or animal to change about 67% of the way to equilibrium when the object or animal is transferred from one constant T_e to another.[12,20,23] Time constants of three turtles ranged from 420 min for a 54-kg turtle to 690 min for a 104-kg turtle (Table 11.1).

These thermal characteristics of green turtles combine to prevent them from nesting during the day. Spotila and Standora[1] computed that a green turtle nesting in the full sun (air temperature, T_a = 28°C, radiation absorbed of 864 W m^{-2} on the upper surface and 432 W m^{-2} averaged over the entire surface, heat gain from sand at 40°C of 272 W m^{-2} averaged over the entire surface) would warm up 3 to 6°C due to solar heating and 2 to 4°C due to elevated metabolism during nesting. Thus, it would reach 36 to 41°C, suffer heat stress, and probably have to return to the water before completing nesting. In addition, its superficial tissues would be much hotter and would suffer heat damage. Only small sea turtles like *L. olivacea* can regularly nest during the day. Intuitively, we might think that such a turtle would heat up faster than a green turtle because of their smaller surface-to-volume ratio. However, they do not do so because of the effect of convection. Olive ridleys nest primarily on windy and cloudy days when there is less heating due to solar radiation. In addition, their smaller adult body size results in more effective convective cooling.

TABLE 11.1
Time Constants for Cooling Experiments in Green Turtles in an Environmental Chamber Aboard the *Alpha Helix* at Cayos Miskito, Nicaragua in August, 1978

	Temperatures (°C)				
Turtle mass (kg)	T_a	T_e	T_b	ΔT	τ (min)
54	16.4	16.4	17.2	0.8	420
61	16.4	16.4	17.1	0.7	460
104	16.4	16.4	17.9	1.5	690

Note: T_a is mean air temperature; T_e is mean operative environmental temperature as measured with a hollow copper turtle model painted to have the same absorptivity as a green turtle; T_b is final equilibrium body temperature of turtle; ΔT is $T_b \cdot T_a$, and τ is the time constant computed as the time required for 63.2% of the temperature change between the initial body temperature and final body temperature at equilibrium. (Data from Standora, E. A., Spotila, J. R., and Foley, R. E., *J. Therm. Biol.*, 7, 159, 1982. With permission.)

The differential effects of body size and wind speed on environmental heat load are apparent in the T_e for different sized turtles. A 50-kg turtle with little wind would have a T_e of 58.3°C, while an increase of wind to 5 m s^{-1} would lower T_e to 30.0°C. At the same wind speeds a 200-kg turtle would be exposed to T_e of 58.7 and 36.0°C. For an explanation of the relationship between body size, wind speed, and convection coefficient in sea turtles see Spotila and Standora.[1]

11.4 BASKING

Sea turtles bask on land and in the water. Terrestrial basking by green turtles occurs in the northwestern Hawaiian Islands,[24-26] in Australia,[27] and historically in the Galapagos Islands and Mexico.[28] Whittow and Balazs[16] completed the most comprehensive study of this phenomenon at French Frigate Shoals in the northwestern Hawaiian Islands. Here turtles come ashore and bask on the side of islands facing the outer reef and the prevailing northeast trade winds. Sand temperatures and black globe temperatures (an approximation of T_e)[12] were lower on beaches used for basking than on beaches on the opposite side of the island that were not used by basking turtles (Figure 11.4). If we use black globe temperature as a measure of T_e, then it is apparent that beaches used for basking are cooler than nonbasking beaches. Perhaps turtles would overheat if forced to stay out on the hotter beaches.

Our calculations of heat stress in green turtles (above) suggest that T_e of 40°C or higher would result in heat stress for this turtle. Carapace temperatures were as high as 40.0 to 42.8°C in basking turtles. By flipping sand onto their flippers and carapace, turtles lowered surface temperatures by as much as 10°C. This would reduce heat load on the peripheral tissues and allow the turtle to warm up deep T_b without overheating the peripheral tissues. Basking on land was most prevalent among female turtles and appeared to be fostered by cool ocean temperatures (26.3°C) and a combination of white sand beaches with steady wind and moderate solar intensity. It is possible that females may be able to accelerate development of eggs by being at a higher T_b. Some authors have also suggested that these turtles are not thermoregulating because they do not use the hottest beach. Instead they may be avoiding predators such as sharks and avoiding mating encounters with male turtles. Data available to date are consistent with a thermoregulatory interpretation of this basking behavior. Additional studies are needed to clarify the driving force behind this behavior. These should include detailed studies of basking behavior of individual turtles and accurate measurements of the T_e to which these turtles are being exposed.

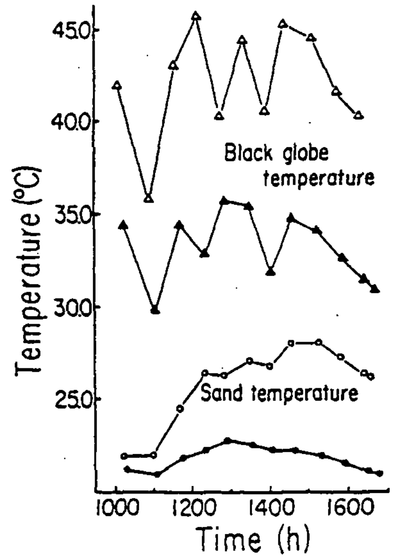

FIGURE 11.4 Environmental conditions experienced by green turtles basking on French Frigate Shoals in the Pacific Ocean.[16] Upper lines (triangles) indicate temperatures measured with a black globe thermometer and lower lines (circles) indicate temperatures of the sand. Temperatures on the basking beach (solid symbols) are lower than temperatures of the nonbasking beach (open symbols). The black globe temperature, which approximates T_e, is much higher than sand temperature on both beaches. (From Spotila, J. R. and Standora, E. A., *Copeia*, 1985, 694, 1985. With permission.)

11.5 SEA TURTLES IN WATER

Water places much tighter constraints on the thermal biology of sea turtles than does the environment on land. Water supports convection coefficients that are 100 times greater than in air[8] because it has a high heat capacity and high thermal conductivity. This allows water to act as a temperature stabilizer. It tends to keep animals at the same temperature as their environment. Liquid water is highly transparent to visible radiation, but absorbs in the ultraviolet and infrared. Thus, a turtle under water can absorb some solar radiation, but cannot reradiate heat to its surroundings. Heat transfer is very rapid via conduction and convection. The rapid heat transfer between the turtle and its environment strongly limits the warming effect of metabolism. In general, T_b of inactive loggerhead (*Caretta caretta*), green, and olive ridley turtles are within 1 to 2°C of water temperature (T_w) (reviewed in Reference 1). Heat transfer occurs through the soft skin of the neck and proximal area of the flippers, followed by the plastron, carapace, and scaled epidermis of the rest of the flippers. Leatherbacks are typically 30.5 to 32.0°C when they come ashore to nest.[19,29] Thus, in tropical waters, they have T_b similar to those of green turtles. In subarctic waters, they are much warmer than T_w due to their large body size and thermoregulatory capabilities (see below).

Both green turtles and loggerhead turtles maintain T_b slightly higher than T_w while swimming and resting in the water. Standora et al.[15] used multichannel sonic telemetry to determine that two green turtles had elevated body temperatures while swimming off Tortuguero, Costa Rica. One turtle (110 kg) had a T_b of 0.7 to 1.6°C above T_w when alternately resting and swimming slowly a few hundred meters from shore (Figure 11.5). The other (121 kg) had a T_b of 32.8 to 37.1°C while swimming rapidly in water of 29.1°C (Figure 11.6). They concluded that the green turtle was endothermic and could raise T_b through its swimming activity. This was supported by the results of Prange and Jackson,[30–32] who demonstrated that green turtles have a highly aerobic metabolism and raise their metabolism 10 times above standard metabolism when active. Warm pectoral muscles probably increase the swimming ability of this turtle and may facilitate long-distance migrations.

In a remarkable series of studies, Naito et al.[33] and Sakamoto et al.[34–36] used satellite telemetry and microminiature data recorders to track the movements of a loggerhead turtle during its internesting period and to measure its dive depths, T_b, and T_w. They found that stomach temperatures of the turtle were up to 2 to 3°C above T_w during a 20-d period while she swam and dove to a maximum depth of 233 m during her internesting movements.[33,34] In one instance, during a period of 127 min of active swimming the turtle raised its stomach temperature from 24.5 to 25.0°C. Since the accuracy of the thermistor was +/– 0.15°C,[36] this rise was just high enough to indicate that the turtle actually did warm up from metabolic activity.

In a more extensive study, Sato et al.[37] used time-temperature recorders, time-depth recorders, and time-light intensity recorders to determine the relationship between T_b and T_w and to determine if elevated T_b were caused by basking. Sapsford and van der Riet[38] had reported that a 42-kg loggerhead raised its T_b 3.8°C above T_w by basking in sunlight while keeping a substantial portion of its carapace exposed above the water surface. Sato et al.[37] found that 8 loggerheads had a mean T_b of 0.9°C above T_w and that this difference increased with increasing body mass to a maximum of 1.7°C (Figure 11.7). These turtles did not so much regulate at a constant T_b as maintain a relatively constant temperature difference between T_b and T_w. They spent most of their time within 30 m of the surface, and the light intensity data suggested that they were not basking. Body temperatures were higher than T_w both on cloudy days and at night. It appeared that the relative constancy of T_b in these turtles was due in part to thermal inertia as would be expected from biophysical considerations. A 70-kg loggerhead would have a time constant of perhaps an hour in water (see above and References 1, 20, 22, and 23) and a resultant overall thermal lag of a few hours. Thus, variation in T_b would be dampened out and it would remain somewhat above T_w with less variability as the turtle swam from a water mass at one temperature into a water mass at another temperature. Thus, as cautioned by Neill and Stevens,[39] while these data indicate that loggerheads enjoy considerable thermal inertia and have some endothermic capabilities, they do not conclusively demonstrate that these turtles regulate T_b by physiological means.

Despite the thermoregulatory adaptations of green turtles and loggerheads, neither species functions well at lower T_w. This makes them susceptible to cold stunning, a winter phenomenon in temperate and subtropical waters in which the T_w drops

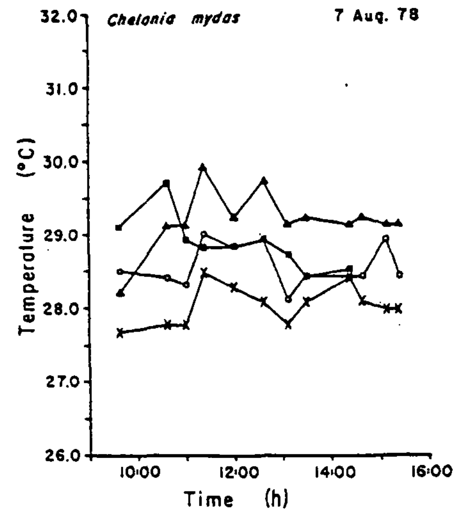

FIGURE 11.5 Temperatures of a 110-kg adult female green turtle swimming in the Caribbean Sea at Tortuguero, Costa Rica. A multichannel sonic transmitter with remotely positioned thermistors transmitted temperatures from the deep body (triangles), inside the plastron (squares), carapace surface (open circles), and water (crosses). This female was released from land at 1100 h, remained a few hundred meters off shore and was relatively inactive.[15] (From Spotila, J. R. and Standora, E. A., *Copeia*, 1985, 694, 1985. With permission.)

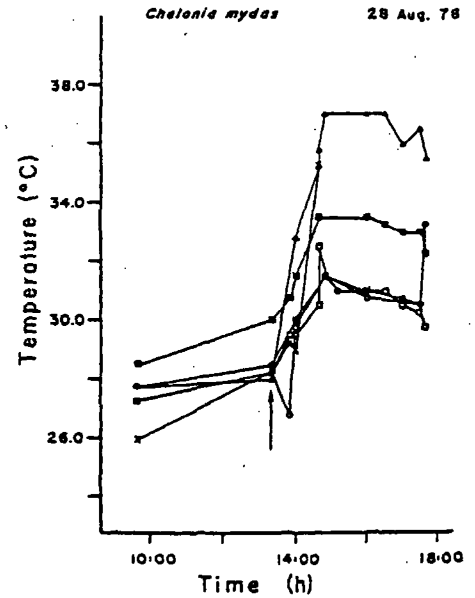

FIGURE 11.6 Temperatures of a 121-kg adult female green turtle swimming in the Caribbean Sea near Tortuguero, Costa Rica. A multichannel sonic transmitter with remotely positioned thermistors transmitted temperatures from the deep body (triangles), inside the plastron (solid squares), plastron surface (open squares), inside the carapace (solid circles), carapace surface (open circles), and water (crosses). Arrow indicates when turtle entered the water (29°C). This turtle was continuously active and pulled a large polyurethane float and long length (30 m) of manilla rope (diameter 1 cm).[15] (From Spotila, J. R. and Standora, E. A., *Copeia*, 1985, 694, 1985. With permission.)

quickly (in a few days) and turtles become incapacitated.[40,41] Kemp's ridley, *L. kempi*, turtles are similarly affected. Cold stunning occurs when T_w drops below 8°C before sea turtles can swim away from an area during the sudden onset of a cold front. The turtles lose their ability to swim and dive, lose control of buoyancy, and float to the surface. If not rescued and resuscitated by humans, most of these turtles die. The physiological basis for this response is unknown, but probably involves disruption of metabolic pathways and disruption of ion gradients across membranes.[42]

There remains a need for studies to determine the low-temperature tolerance of sea turtles, their high-temperature tolerance, and their preferred temperature. These studies can be most easily done on hatchlings, but are also needed for juveniles, subadults, and adults. It may be impractical to study large individuals and difficult to obtain permits to study the thermal tolerances of a sea turtle like the Kemp's ridley, which is highly endangered. However, carefully designed and nonlethal

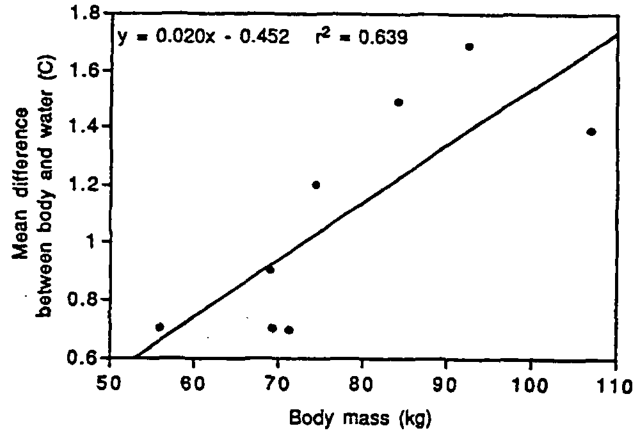

FIGURE 11.7 The relationship of mean difference between body temperature and water temperature to body mass of loggerhead turtles swimming in the Pacific Ocean off Japan during their internesting periods. Mean values are presented for each turtle. The linear regression is significant at $p = 0.05$. (Redrawn from Sato, K., Sakamato, W., Matsuzawa, Y., Tanaka, H., Minamikawa, S., and Naito, Y., *Mar. Biol.*, 123, 197, 1995. With permission.)

studies of critical thermal maximum and critical thermal minimum (CTM_{ax} and CTM_{in})[43] will elucidate thermal limits, and preferred-temperature studies will clarify the role of temperature in behavior and physiology of these species. These studies can be done without harming individual turtles and should be done so that we can understand the thermal biology of these species and avoid loss of sea turtles to thermal events such as cold stunning in the future.

11.6 METABOLISM, BODY SIZE, AND THERMOREGULATION

Are any sea turtles warm blooded? That is, do they have a high mammalian-like metabolic rate? We discussed that question in our previous review[1] and concluded that leatherbacks should be capable of maintaining large temperature differences between their body core and the surrounding water even with a low metabolic rate. Studies since 1985 have supported that hypothesis. Leatherbacks routinely occur in northern waters off Newfoundland where they occupy water with temperatures from 0 to 15°C (mean = 12.6°C).[44] Frair et al. [45] recorded a T_b of 25.5°C for a captive leatherback in 7.5°C seawater. This suggests that leatherbacks can thermoregulate in cold water, although the effect of thermal inertia in this particular turtle is unknown.

We measured the metabolic rates of six adult female leatherbacks while they were resting, walking, and covering their nests by analyzing expired air with gas

analyzers (Figure 11.8).[19] Metabolic rates for leatherbacks at rest were above those predicted by allometric relationships for green turtles and other reptiles scaled to leatherback size (0.387 W kg^{-1}, 1.15 ml O_2 kg^{-1} min^{-1}), but half the values predicted for mammals of this size. Lutcavage et al.[46] reported similar metabolic rates (1.1 ml O_2 kg^{-1} min^{-1}) for leatherbacks using another method (difference in gas concentration during rebreathing). It is interesting to note that hatchling leatherbacks also have a metabolic rate (0.286 l kg^{-1} h^{-1} = 4.77 ml kg^{-1} min^{-1}) three times that of green turtle and loggerhead hatchlings.[47] Leatherback hatchlings swam continuously in the respirometer and maintained a high level of activity for hours. They may have a higher routine (normal) metabolic rate than the other species, as do the adults.

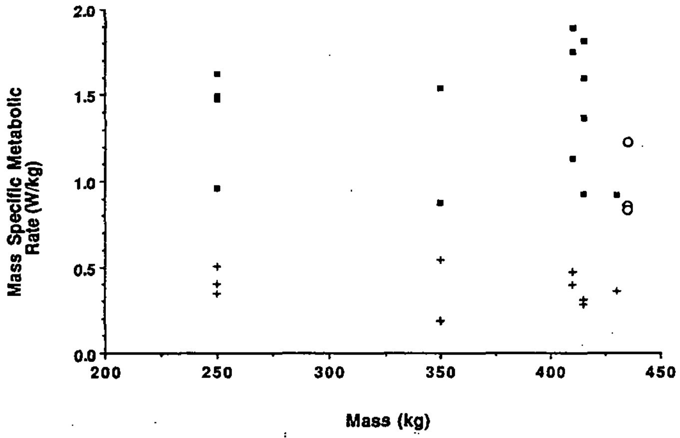

FIGURE 11.8 Mass specific metabolic rates for nesting leatherback turtles at Tortuguero, Costa Rica. We measured metabolic rate for turtles at rest (crosses), while they were covering their nests (solid squares), and while they were walking on the beach (open circles). We collected expired air in large Douglas bags and measured the O_2 and CO_2 content of that air with a Beckman C-2 gas analyzer and Scholander 0.5-ml gas analyzer. The lowest values of active metabolism were for turtles when they were covering their nests with their hind flippers after laying their eggs. The highest values were for turtles vigorously throwing sand with hind and foreflippers, crawling, and rotating the body from side to side while covering the nest with sand. (From Paladino, F. V., O'Connor, M. P., and Spotila, J. R., *Nature*, 344, 858, 1990. With permission.)

We[19] assessed the thermoregulatory capabilities of leatherbacks by mathematically analyzing heat exchange within the turtle, and between the turtle and the environment. As body size increases, resting metabolism can maintain increasingly larger core-skin temperature differences. Given their large adipose tissue layer (6 to 7 cm)[44] and their large body size, leatherbacks can use changes in blood flow to the skin and periphery to regulate body temperature such that they maintain warm

temperatures in the North Atlantic and avoid overheating in warm tropical waters. When leatherbacks are nesting it is typical to observe changes in color of their soft skin. When they crawl out on the beach their skin is pale. After nesting their skin is bright pink. We measured blood flow in the skin (unpublished data) and found that blood flow when the skin appears pink is more than 10 times higher than when the skin is pale. This increased blood flow helps to cool the turtles by bypassing the insulation and bringing heat to the surface where it can be transferred to the cool night air. This strategy would be ineffective during the day when T_e is much higher (see above). Thus, while the leatherback has a large enough body size to dampen the effects of solar heating if it nested during the day, the high T_e at its surface would make thermoregulatory strategy of the leatherback of changing blood flow to the surface to regulate T_b ineffective. Thus, while it could avoid overheating from external heat load due to its thermal inertia, it could not get rid of the excess heat generated within its body during the nesting process. Here again, biophysical constraints would combine with characteristics of the anatomy and physiology of the sea turtle to determine its behavior.

11.7 CONCLUSIONS

The thermal biology of sea turtles is determined by the interaction of the biophysical constraints imposed by the environment with the anatomical, physiological, and behavioral characteristics of the animals. We can obtain an understanding of the thermal constraints on these turtles by considering the limitations imposed by heat energy exchange with the environment. Judicious use of biophysical models can help to pose useful questions and to answer them. On land, sea turtles are affected by rapid heat gain during the day, and leatherbacks are also affected by the inability to dump metabolic heat during nesting activity. Heat gain and the inability to lose heat prevent large species of sea turtles from nesting during the heat of the day. In water, heat gain and loss are very rapid and T_b tend to remain close to T_w. Larger sea turtles such as loggerheads and green turtles can maintain a small (1 to 2°C) temperature difference between the body core and the water. Green turtles when swimming vigorously can be as much as 7°C above T_w. This endothermic capacity is even greater in leatherback turtles that can be active in cold northern waters that have temperatures between 0 and 15°C. They use a combination of large body size, thick insulation, an elevated metabolism, and changes in blood flow to remain warmer than the water in cold oceans and to avoid overheating in tropical waters and on the nesting beach at night. Their strategy of changing blood flow to dump heat on the nesting beach is ineffective during the heat of the day, because the T_e of their skin is too high to allow heat loss by convection. As we stated in 1985, additional experiments are still needed to elucidate the thermal biology of sea turtles. These include such simple measurements as determination of the preferred T_b and CTMs of these animals, as well as more sophisticated measurements of the thermal biology of sea turtles free ranging in the ocean. With the increased availability of sophisticated sensors, recorders, and telemetry, such measurements can now be a reality.

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12 Hormones in the Life History of Sea Turtles

David W. Owens

CONTENTS

12.1 INTRODUCTION

The presence of a chapter on hormones in a sea turtle book may surprise some readers. As it turns out, the initiation of sea turtle farming on Grand Cayman Island around 1969 was the initial stimulus for a long series of endocrine studies on sea

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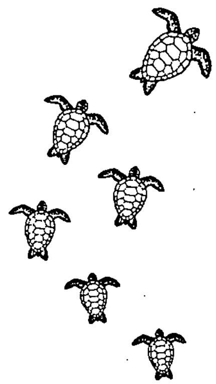

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6 Physiological and Genetic Responses to Environmental Stress

Sarah L. Milton and Peter L. Lutz

CONTENTS

6.1 WHAT IS STRESS?

Many people are uncomfortable with the term *stress* in animal biology. The root of the difficulty lies in the common usage of the word and its richness of meanings

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that bedevil an exact scientific definition. In biology, the term embraces psychology to biomechanics, and it is only in the latter that it is used in the precise and quantitative terms of Hooke's law, where stress (the deforming force) is proportional to strain (the deformation). For the rest there is no agreement about whether stress refers to external or internal factors, what it consists of, or how it can be measured. Nevertheless, the fact that the concept is still widely used in biology, from the molecular to ecosystem level, indicates its utility and its necessity (Bonga, 1997). Perhaps the term should be used only in combination with the causal factor (i.e., crowding stress, temperature stress), with the concept that there is an (identified) tolerance range for the external factor within which the individual or community copes by means of adaptive responses, but that outside this range there is a quantitative or qualitative break in the (described) response.

The adaptive function of the stress response is to accommodate changes in the environment (stressors) by adjustments in behavior and/or changes in physiology. However, an excessive exposure to the stressor, in either intensity or duration, will result in dysfunctional debilitating responses. Environmental conditions to which an animal cannot adapt lead to both transient and relatively long-term physiological changes. Such changes often contribute to the development of disease, especially if the organism is exposed at the same time to potentially pathogenic stimuli. Various stressors, however, do not all produce the same outcomes; effects will depend on the quality, quantity, and duration of the stressor; the temporal relationship between the exposure to a stressor and the introduction of pathogenic stimuli; environmental conditions; and a variety of host factors (age, species, gender, etc.) (Ader and Cohen, 1993).

This chapter presents an overview of the relationship between sea turtles and some of the more important stressful aspects of their environment. Because stress is such a broad topic, many aspects of stress have been treated in previous chapters and elsewhere in this volume (see Lutcavage et al., 1997; George, 1997; Epperly, Chapter 13; and Herbst and Jacobson, Chapter 15, this volume). This chapter reviews a few environmental stressors of particular significance to sea turtles: temperature, chemical pollutants (organic and inorganic) and habitat degradation, and the sea turtle's physiological and potential genetic responses are discussed. Distinct environmental stressors affect the terrestrial nest and hatchlings, and are discussed separately from the other (oceanic) life stages.

6.2 WHY SEA TURTLES ARE AT SPECIAL RISK

Sea turtles naturally encounter a wide variety of stressors, both natural and anthropogenic, including environmental factors (salinity, pollution, temperature), physiological factors (hypoxia, acid–base imbalance, nutritional status), physical factors (trauma), and biological factors (toxic blooms, parasite burden, disease). Although they are physically robust and able to accommodate severe physical damage, sea turtles appear to be surprisingly susceptible to biological and chemical insults (Lutcavage and Lutz, 1997). For example, in the green sea turtle even a short exposure to crude oil shuts down the salt gland, produces dysplasia of the epidermal epithelium, and destroys the cellular organization of the skin layers, thus opening routes for infection (Lutcavage et al., 1995). The effects of many stressors, however, are likely to be less obvious, as in the (unknown) long-term effects of toxin exposure and bioaccumulation.

Because sea turtles are long-lived animals, the cumulative effect of various stressors is likely to be great. Because sea turtles spend discrete portions of their life in a variety of marine habitats, they are vulnerable at multiple life stages: as eggs on the beach, in the open ocean gyres, as juveniles in nearshore waters, and as adults migrating between feeding and nesting grounds. Thus, turtles may be exposed to a greater variety of environmental stressors than less migratory animals, with presumably different vulnerabilities at each stage. However, their exposure to a particular stressor may be limited by the length of that life history stage. For example, fibropapilloma disease appears to affect primarily juvenile green turtles of 40–90 cm carapace length (Ehrhart, 1991), but is rare in nesting adults. Exposure to weathered oil has significant health effects on swimming turtles (Lutcavage et al., 1995), but in one study demonstrated little impact on egg survival. Fresh oil, on the other hand, significantly affected egg survival (Fritts and McGehee, 1981). Vulnerability to certain stressors will also vary by ecological niche, i.e., polychlorobiphenyl (PCB) and dichlorodiphenyldichloroethylene (DDE) accumulations are consistently higher in loggerhead turtle tissues and eggs than in those of green turtles (George, 1997; Clark and Krynitsky, 1980), presumably because of dietary differences. Clark and Krynitsky (1980) also reported that DDE and PCB loads in both loggerhead and green turtle eggs were significantly lower than in bird eggs taken from the same location (Merritt Island, FL) and lower than contaminant levels in eggs from Everglades (FL) crocodiles. They speculated that adult turtles nesting on Merritt Island lived and fed in areas less contaminated than did the residential bird and Everglades crocodile populations.

Natural stressors include thermal stress (heat stress, cold stunning), seasonal or temperature-related changes in immune function, and the presence of disease, parasites, or epiphytes. Even these natural physiological stressors may, of course, be impacted or exaggerated by anthropogenic factors. For example, physiological responses to natural diving are significantly different from those produced by the forced submergence of trawl entanglement (Lutcavage et al., 1997), and animals with a depressed immune system related to pollutant levels would be more vulnerable to parasites and disease.

Anthropogenic stressors may have either direct or indirect impacts on sea turtle health. Direct impacts include such problems as oil spills, latex or plastic ingestion, fishing line entanglement, and the presence of persistent pesticides, hormone disrupting pollutants, and heavy metals. Indirect effects occur primarily through habitat degradation: eutrophication, the contribution of pollutants to toxic algal blooms, and collapse of the food web.

Inappropriate sea turtle behavior can put them at particular risk. For example, it appears that unlike marine mammals, adult sea turtles show no avoidance behavior when they encounter an oil slick (Odell and MacMurray, 1986); they also indiscriminately ingest tar balls and plastics (Lutz, 1990), and hatchlings congregate in ocean rift zones where floating debris concentrate. Their breathing pattern of large tidal volumes and rapid inhalation before diving will result in the most direct and effective exposure to petroleum vapors (the most toxic part of oil spills), as well as biotoxin aerosols resulting from dinoflagellate blooms.

Sea turtles are at particular risk from the stresses presented by degraded tropical coastal marine environments. Indeed, the high public awareness of sea turtles is such that they can serve as effective sentinels of tropical coastal marine ecosystem health (Aguirre and Lutz, in press).

6.3 STRESSORS

This review selects some of the most critical identified natural and anthropogenic stressors of sea turtle physiology, while omitting some (oil, nesting, capture stress) that have been previously reviewed (see Lutz and Musick, 1997).

6.3.1 TEMPERATURE

Both high and low temperatures are known to negatively impact sea turtle physiology, affecting feeding behavior, acid–base and ion balance, and stress hormone levels.

6.3.1.1 Hypothermia

Temperature has a marked effect on the feeding rates of sea turtles. At 20°C Kemp's ridley turtles decreased food consumption to 50% of control levels (at 26°C), and a similar reduction in food intake was found in green turtles at 15°C (Moon et al., 1997). Below 15°C both species ceased feeding. Interestingly, Moon et al. (1997) found that green and Kemp's ridley turtles' swimming behavior differed as temperatures decreased. When temperatures dropped below 20°C green turtles reduced swimming activity, but at these temperatures the ridleys became very agitated. Below 15°C both species became semidormant, hardly moving and only coming to the surface at intervals of up to 3 h to breathe. Field evidence supports these findings. During cold temperatures in winter, loggerhead turtles in Tunisian waters reduce overall activity even though they continue to forage (Laurent and Lescure, 1994).

Temperature also profoundly influences the physiology of sea turtles. In ridleys and greens, both venous blood partial pressure of oxygen (pO_2) and partial pressure of carbon dioxide (pCO_2) decreased with temperature (Moon et al., 1997), whereas venous blood pH increased. Similar temperature-dependent changes in blood pH, pCO_2, and pO_2 have been widely found in other reptiles, including loggerhead sea turtles (Lutz et al., 1989). Temperature-related adjustments of blood pH in the loggerhead appeared to be managed at both the lung and tissue (ion exchange) levels (Lutz et al., 1989). In both wild (Lutz and Dunbar-Cooper, 1987) and captive (Lutz et al., 1989) loggerheads, plasma potassium increased with temperature, which may be related to cellular-mediated adjustments in blood pH. Excessively low temperatures can also interfere with physiological functioning. For example, there was an abrupt failure in pH homeostasis and a sharp increase in blood lactate at temperatures below 15°C in the loggerhead (Lutz et al., 1989). At 10°C the loggerheads were lethargic and "floated" (Lutz, personal observation). Such positive buoyancy is probably due to cessation of intestinal mobility and the collection of ferment gases and is commonly observed in cold stunning.

Unlike certain freshwater turtles, which overwinter in frozen ponds and thus withstand months submerged in near-freezing water (Jackson, 2000), sea turtles (with the exception of leatherbacks) trapped in cold waters (below 8–10°C) may become lethargic and buoyant, floating at the surface. This condition is defined as *cold stunning* (Schwartz, 1978). Salt gland function may be impaired in cold-stunned animals, as evidenced by increased blood concentrations of sodium, potassium, chlorine, calcium, magnesium, and phosphorus (George, 1997; Carminati et al., 1994). Affected animals may not eat for days or even weeks prior to cold stunning, increasing overall physiological stress (Morreale et al., 1992). However, it is likely that it is the rate of cooling below 15°C that evokes cold stunning rather than the temperature per se. Satellite tracking studies of ocean migrating Kemp's ridley and loggerhead turtles indicate that they remain active in water temperatures as low as 6°C (Keinath, 1993). Sea turtles that overwinter in inshore waters are most susceptible to cold-stunning because temperature changes are most rapid in shallow water, especially in semienclosed areas such as lagoons (Witherington and Ehrhart, 1989). As temperatures drop below 5–6°C, death rates become significant, because the animals can no longer swim or dive, become vulnerable to predators, and may wash up onshore, where they are exposed to even colder temperatures.

As with other physiological stressors, cold stunning can affect *specific populations* of sea turtles more than others. For example, although cold-stunning events occur in Florida as well as in northern waters, the extended exposure to frigid waters experienced by turtles off New England or New York results in much higher mortality rates. Morreale et al. (1992) reported overall mortality rates as high as 94% over three winters in New York, whereas Witherington and Ehrhart (1989) reported only 10% mortality for cold-stunned turtles in a Florida estuary.

Habitat utilization is also a significant factor in differential mortality during cold-stun events. The waters off New York and New England appear to be an important habitat for juvenile Kemp's ridley turtles, with the result that a large percentage of identified cold-stunned animals are of this species (Figure 6.1). Of the 277 total sea turtles found on Cape Cod, MA, during the 1999–2000 winter season, 79% were Kemp's ridley turtles, 19% loggerheads, and 2% greens (Still et al., in press). During the 1985–1986 winter, 79% of the turtles retrieved on Long Island (NY) were Kemp's ridleys (Meylan and Sadove, 1986). Indeed, Kemp's ridleys have consistently made up more than 50% of the cold-stunned turtles found along Cape Cod for the past 20 winters, and 67–80% of cold-stunned turtles found off Long Island over a 3-year period were Kemp's ridleys (Morreale et al., 1992). By contrast, in five significant stunning events over a 9-year period in the Indian River Lagoon (FL), 73% of 467 recovered turtles were greens (Figure 6.1), 26% were loggerheads, but less than 1% (2 animals) were Kemp's ridleys (Witherington and Ehrhart, 1989).

Size is also an important factor in susceptibility to cold-stun events, because juveniles are the primary life history stage affected. The majority of Kemp's ridleys retrieved off Cape Cod in the 1999–2000 season were in the 25.0–29.9 cm curved carapace length (CCL) size class, as were many greens. Similarly, Morreale et al. (1992) reported a mean straight carapace length (SCL) of 29.4 cm for *Lepidochelys kempii* and 32.7 cm for *Chelonia mydas* for cold-stunned turtles collected off Long

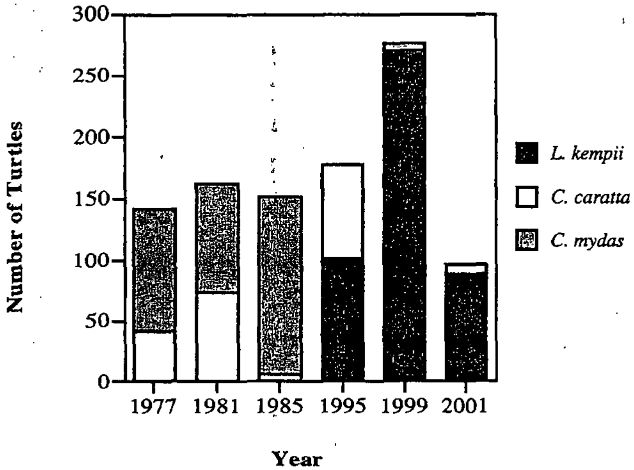

FIGURE 6.1 Species–habitat-specific susceptibility to cold-stun events at two different U.S. locations: the Indian River Lagoon, FL (south), and Cape Cod Bay, MA (north). Only large cold-stun events are shown: 1977–1985 data are from Florida (adapted from Witherington, B.E. and Ehrhart, L.M., Hypothermic stunning and mortality of marine turtles in the Indian River Lagoon system, Florida, *Copeia*, 1989, 696–703, 1989); 1995–2001 data are from Massachusetts (adapted from Still et al., 2000 and Still, B., Griffin, C., and Prescott, R., Factors affecting cold-stunning of juvenile sea turtles in Massachusetts, in: *Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation*, J. Seminoff (compiler), U.S. Dept. Commerce NOAA Tech. Memo. NMFS-SEFSC, Miami, FL (in press). (With permission.)

Island between 1985 and 1987. It appears that larger Kemp's ridley turtles either do not make much use of this habitat (Morreale et al., 1992) or are more successful in emigrating from northern waters prior to the onset of lethal winter temperatures (Standora et al., 1992).

Smaller turtles also succumb more quickly than larger animals (Witherington and Ehrhart, 1989). In their study on cold-stunning events in the Indian River Lagoon, Witherington and Ehrhart (1989) noted that the smallest turtles were found on the first day of the cold snap, and largest turtles on the last day; over the 9 years of the study, nearly half of the green turtles recovered were in the 0–10 kg size class (SCL ranged from 24.6 to 75.4 cm).

It is also likely that there are *species differences* in susceptibility to hypothermia. Witherington and Ehrhart (1989) reported that the loggerhead cold-stunning death rate was less than that for green turtles, and suggested that this was because loggerheads are a more temperate zone species, whereas the Indian River Lagoon appears to be the northernmost limit of the green turtles' winter range. Leatherback turtles nest on tropical beaches, but are seen as far north as the waters off Newfoundland, in temperatures ranging from 0 to 15°C (Goff and Lien, 1988). Frair et al. (1972) reported a body temperature of 25.5°C for a leatherback held in 7.5°C water, which makes the idea of a cold-stunned adult leatherback unlikely!

In addition to migrating toward warmer waters at the onset of the cold season, larger turtles may physiologically avoid cold stunning by entering a hibernation-like state. There is evidence that both green (*Chelonia agassizi*) and loggerhead turtles bury themselves in bottom sediments for extended periods of time during winter (Felger et al., 1976; Carr et al., 1980–81).

The recommended treatment for cold stunning is fairly straightforward: hold the animals in warm water until their core temperature recovers (George, 1997). The success rate is high — of the turtles treated at the New England Aquarium during the 1999–2000 cold-stunning season, survival ranged from 66% (*C. mydas*) to 100% (*Caretta caretta*) (Still et al., in press). Holding the victims in fresh or brackish water until salt gland function recovers has also been recommended (George, 1997).

6.3.1.2 Hyperthermia

Excessive heat exposure is also a stress to poikilotherms, though for sea turtles hyperthermia would be a rare phenomenon when they are in the ocean. However, increased water temperatures may indirectly increase stress on sea turtles, in that increased surface temperatures increase the growth rates of both pathogens and toxic phytoplankton.

High temperatures can, however, be experienced while they are on land, basking or nesting.

In turtles basking at French Frigate Shoals (HI) carapace temperatures as high as 42.8°C have been recorded (Whittow and Balazs, 1982). Behavioral adaptations are used to moderate the ambient heat load. Surface temperatures can be reduced as much as 10°C by flipping sand onto flippers and the carapace, and basking turtles appear to choose cooler beaches (Whittow and Balazs, 1982).

Heat stress can be fatal for nesting females. Environmental temperatures above 40°C can result in stress for green sea turtles (see Spotila et al., 1997), whereas excessive heat exposure routinely results in a high mortality (tens of turtles per day) of postnesting females at the Raine Island (Australia) green turtle rookery (Jessop et al., 2000). In the Raine Island study, an increase in body temperature of females stranded on the beach from 28.2 to 40.7°C over 6 h resulted in a 16-fold mean increase in plasma corticosterone (a hormonal marker of stress), to levels comparable to those seen in animals subjected to 8 hr capture stress (Jessop et al., 2000). In the soft-shelled turtle, *Lissemys punctata punctata*, increases in adrenomedullary function were detected as temperatures increased from 30 to 35 and 38°C, resulting in increased levels of circulating epinephrine, norepinephrine, and glucose (Ray and Maiti, 2001).

6.3.2 Chemical Pollutants

Age, gender, and diet are all important factors in the potential for animals to be affected by or bioaccumulate persistent pollutants, as is the identity and effects of

the specific contaminant. Manufactured chemicals released into the environment may act as endocrine-disrupting contaminants, affect tumor growth, depress immune function, or be acutely or chronically toxic. Two of the most significant groups of chemical stressors are the heavy metals and organopesticides.

6.3.2.1 Bioaccumulation

6.3.2.1.1 Heavy Metals

Despite the high toxicity of some compounds such as methylmercury, there is a relative paucity of data either for contaminated animals or for normal ranges (of trace elements) in tissues (for a review, see Pugh and Becker, 2001). In general, concentrations of heavy metals and trace elements appear to be lower in sea turtle tissues (by as much as one to two orders of magnitude) than values reported for marine birds and mammals, which may be a function of differences in their metabolic rates. Studies on liver concentrations of mercury indicate a correlation between diet and mercury accumulation, such as occurs in piscivorous marine mammals and seabirds, with mercury levels higher in the omnivorous loggerhead (Sakai, 1995; Storelli et al., 1998a; 1998b; Godley et al., 1999) than in herbivorous green and jellyfish-eating leatherback turtles (Godley et al., 1999; Davenport et al., 1990). Day et al. (2002) reported higher levels of mercury in loggerhead turtles residing near river mouths than those from farther away. One must be wary, however, of making assumptions based solely on trophic levels: Saeki et al. (2000) reported the surprising finding that arsenic levels were higher in hawksbill turtles (which consume primarily sponges) than in algae- and mollusk-eating green and loggerhead turtles. Changes in heavy metal accumulation with age (size) within a species have also been reported. For example, Sakai et al. (2000) found higher levels of copper in the livers of small green turtles than in larger ones; liver cadmium was also negatively correlated with size. They hypothesized a difference based on diet (i.e., life history stage), because cadmium levels are higher in the zooplankton diet of juvenile greens than in seagrasses. No data on heavy metal burdens are available for Kemp's or olive ridley turtles.

6.3.2.1.2 Pesticides

Reported levels of PCBs and other organic contaminants in sea turtle tissues are also generally an order of magnitude lower than those found in marine mammals (Becker et al., 1997). In particular, total dichlorodiphenyltrichloroethane (DDT) tissue concentrations in sea turtles are at the lowest end of the range reported for marine mammals and seabirds (Pugh and Becker, 2001). However, PCB contamination in sea turtles is widespread. One frequently detected congener, PCB 153, has been reported in the tissues of loggerheads and Kemp's ridleys along the East Coast of the U.S., in loggerheads and green turtles from the Mediterranean Sea, and in leatherbacks from the United Kingdom (Lake, 1994; Rybitski et al., 1995; Mckenzie et al., 1999). PCBs 153 and 138 were the dominant congeners detected in Hawaiian green turtle liver and adipose tissues, with detectable amounts of the more toxic congeners PCB 77, PCB 126, and PCB 169 (Miao et al., 2001). In these studies, levels were higher in loggerhead and Kemp's ridley turtles than in greens, most likely because these turtles are at a higher trophic level and thus more subject to bioaccumulation. Species-, gender-, or age-specific physiological differences clearly will play a role in the effects and accumulation of various chemicals; the "offloading" of pollutants to eggs, for example, is clearly not an option for male sea turtles as it is for the females. Unfortunately, most of such differences even in basic physiology are unknown (Milton et al., in press).

6.3.2.2 Effects

6.3.2.2.1 Toxicity

The toxicity of heavy metals and organopesticides is well established in other vertebrate groups (mammals and fish), with wide-ranging effects on the neurological, immunological, and reproductive systems. Although no long-term investigations in sea turtles have been reported, one might expect similar deleterious consequences.

For many compounds with potentially toxic effects, there are little or no data for sea turtles. Hexachlorobenzene (HCB), for example, is one of the most toxic and most persistent of the chlorobenzene compounds, which as a highly volatile compound is able to travel long distances in the atmosphere. No data on HCB, dioxin, or furan levels have been reported for sea turtle tissues or eggs. There is only one report of hexachlorocyclohexane and few for dieldrin, even though dieldrin is one of the most commonly detected and easily analyzed pesticides reported in marine biota (Pugh and Becker, 2001).

Although acutely toxic levels of xenochemicals have not been reported in sea turtles, even trace amounts may be of concern because of potential sublethal effects on health and normal physiology. Because of the difficulty of working with endangered animals, however, data are lacking on the normal physiology, immunology, and population biology of sea turtles, and it is difficult to determine chronic effects of pollutants. Such difficulties are compounded by the nature of the pollutants as well. For example, comparisons between studies on the harmful effects of organochlorines such as PCBs are difficult because of between-study variations in identification and quantification of congeners. Not all PCB congeners are metabolized at the same rate, and some are more toxic than others (Kannan et al., 1989). Despite these limitations, studies on other species indicate cause for concern. High organochlorines (such as PCBs and DDE) have been associated with uterine deformities and decreased pup production in seals (Baker, 1989; Reijnders, 1980); embryotoxicity and effects on the hypothalamus–pituitary–adrenal axis in herring gulls (*Larus argentatus*) (Fox et al., 1991; Lorenzen et al., 1999); decreased levels of circulating thyroid hormone and lesions of the thyroid gland in seals and rats (Byrne et al., 1987; Collins et al., 1977; Schumacher et al., 1993); decreased activity levels, feeding rates, and whole body corticosterone levels in tadpoles of the northern leopard frog (*Rana pipiens*) (Glennemeler and Denver, 2001); and decreased immune responsiveness in chicks (Andersson et al., 1991), rats (Smialowicz et al., 1989), primates (Tryphonas et al., 1989), mice (Thomas and Hinsdill, 1978), and beluga whales (De Guise et al., 1998). Beluga whales living in the highly contaminated St. Lawrence Seaway also have increased incidence of neoplasias (De Guise et al., 1995); PCBs apparently act as a tumor promoter as well as an

immunosuppressant. PCB immunosuppression results in higher sensitivities of experimental animals to a wide variety of infectious agents, including bacteria (endotoxin), protozoa, and viruses (De Guise et al., 1998). Lahvis et al. (1995) found a direct correlation between suppressed immunological function *in vitro* and PCB load in bottlenose dolphins, whereas the PCB-linked impairment of immune function likely contributed to the recent mass mortalities in European harbor seals resulting from morbillivirus infections (Ross, 2000).

Similar patterns of accumulation, if not actual concentrations, are possible in some sea turtle species when compared to marine mammals because similar diets can lead to similar tissue lipid compositions (Guitart et al., 1999). In sea turtles, fibropapilloma is more prevalent in green turtles captured near densely populated, industrial regions than in animals from sparsely populated areas (Adnyana et al., 1997), although no correlation was detected between organochlorine, PCB, or organophosphate levels and green turtle fibropapilloma disease (GTFP) (Aguirre et al., 1994). However, the potential for chronic pollutants to decrease immune function either directly or indirectly (by increasing overall stress) could have significant impacts on sea turtle populations, because how they deal with physical stress (infection or trauma) is affected by environmental stress, and stress in general most likely depresses the turtle immune system (George, 1997).

In general, chronic illnesses, mass mortalities, and epidemics are being reported across a wide spectrum of taxonomic groups in increasing numbers, with novel occurrences of pathogens, invasive species, and illnesses affecting wildlife globally. Such disturbances impact multiple components of marine ecosystems, disrupt both functional and structural relationships between species, and affect the ability of ecosystems to recover from natural or anthropogenic perturbations (Sherman, 2000).

6.3.2.2.2 Endocrine Disruption

Hormone disrupters are insidious but high-impact disturbers of population fitness. It is now well established that some organopesticides released into the environment act as endocrine-disrupting contaminants, functioning as hormone agonists or antagonists to disrupt hormone synthesis, action, and/or metabolism. Laboratory studies provide strong evidence of organopesticides' causing endocrine disruption at environmentally realistic exposure levels (Vos et al., 2000). In the aquatic environment, effects have been observed in mammals, birds, reptiles, fish, and mollusks. Alligators living in environments contaminated with endocrine disrupters, for example, have suffered population declines because of the developmental and endocrine abnormalities effected by these contaminants on eggs, juveniles, and adults (Guillette, 2000). Endocrine-disrupting contaminants have also adversely affected a variety of fish species in freshwater systems, estuaries, and coastal areas, whereas marine invertebrates (snails and whelks) have suffered population declines in some areas because of the masculinization of females (Vos et al., 2000).

PCBs, which are widespread, low-level environmental contaminants, are strongly implicated as endocrine disrupters. There is evidence that PCBs are capable of disrupting reproductive and endocrine function in a variety of taxonomic groups, in addition to producing other adverse health effects such as immune suppression and teratogenicity. Bergeron et al. (1994) demonstrated that the estrogenic effect of

some PCBs could cause a reversal of gonadal sex in freshwater turtles (*Trachemys scripta*), which, like sea turtles, have temperature-dependent sex determination. In some areas, sex-reversal in turtles is so prevalent that it can be utilized as a marker of environmental contamination.

The exposure of sea turtle eggs to such pollutants could be significant, because there is evidence that females offload contaminants to their eggs (Mckenzie et al., 1999). In one study, eggs sampled from 20 nests in northwest Florida had detectable amounts of polycyclic aromatic hydrocarbons (PAHs), dichlorodiphenyldichloroethane (DDD, a DDT metabolite), and PCBs (Alam and Brim, 2000). However, the effects of these compounds on sea turtles are not known. A direct application of DDE, another estrogen-like compound, to green turtle eggs did not alter normal sex ratios, incubation times, hatchling success or size, or number of deformities (Podreka et al., 1998).

6.3.3 Eutrophication and Algal Blooms

Eutrophication caused by excess nutrient pollution in coastal waters, particularly of nitrogen derived from sewage and agricultural fertilizers, affects sea turtles both directly and indirectly (Magnien et al., 1992; Burkholder, 1998). In particular, there is a growing link between harmful algal blooms (HABs) and eutrophication. Cyanobacteria blooms in Moreton Bay, Australia, for example, have been increasing in recent years in both size and severity, resulting in loss of seagrass beds, decreased fish catches, and increased levels of ammonia and toxins, including tumor promoters and immunosuppressants (Osborne et al., 2001). HABs thus may have many direct (toxic) and indirect harmful impacts on sea turtles and other marine fauna; in Moreton Bay, the cyanobacteria blooms affect green turtles by decreasing feeding directly (as well as indirectly through the loss of seagrasses) and through the ingestion of toxins (Arthur et al., 2002). A strong association has also been noted between the prevalence of a variety of diseases and coastal pollution in multiple taxonomic groups, such that the occurrence of the diseases derived from pathogens or algal-derived biotoxins often serve as indicators of declining ecological integrity in coastal areas (Epstein et al., 1998). Groups adversely affected by eutrophication-related diseases include humans, birds, marine mammals and turtles, fish, invertebrates, and seagrass beds (Epstein et al., 1998).

The most prevalent tropical–semitropical algal blooms are the so-called red tides (which may be any color or even be invisible), which are due primarily to dinoflagellate blooms and can lead to morbidity and mortality in many species. Immediate effects occur through aerosolized transport, and the sea turtle's mode of respiration (rapid inhalation to fill the lungs before a dive) puts the sea turtle at special risk here. Long-term effects may occur through the consumption of prey and toxin bioaccumulation.

Long-term exposure to biotoxins may exert more subtle, sublethal effects such as impaired feeding, physiological dysfunction, impaired immune function, and reduced growth and reproduction. Long-term effects often emerge as an increased susceptibility to disease (immunosuppression) and in the development of neoplasia (Epstein et al., 1998). Deaths are often attributed to viral factors as the immediate cause of mortality, whereas viral expression and host immunity have been affected

by chronic biotoxin exposure. Such may be the case in GTFP, where oncogenic viruses and tumor-promoting toxins may be acting in concert (Landsberg, 1996), with particular effects on immunosuppressed animals (Bossart et al., 2002). Eutrophication may directly increase viral and bacterial loads as well, in addition to the increased severity and frequency of algal blooms (Herbst and Klein, 1995).

In sea turtles, there appears to be an association between the distribution of toxic dinoflagellates (*Prorocentrum* spp.) and the occurrence of fibropapilloma disease among Hawaiian green sea turtles (Landsberg et al., 1999). These benthic dinoflagellates are epiphytic on seagrasses and macroalgae, and would thus be consumed by foraging green turtles. *Prorocentrum* are of particular interest because this group produces the tumor-promoting toxin okadaic acid, also detected in the tissues of Hawaiian green turtles (*C. mydas*) with GTFP (Landsberg et al., 1999).

More direct, toxic effects of red tide blooms of *Gymnodinium* have been suggested, although a direct link has yet to be demonstrated between brevetoxin and large die-offs of turtles such as have recently occurred in Florida. Chronic brevetoxicosis has been suggested as the likely primary etiology for manatee deaths that occurred in the same time frame (Bossart et al., 1998); simultaneous epizootics for manatees, fish, and cormorants associated with *Gymnodinium* blooms have occurred in the past (O'Shea et al., 1991). Sea turtle strandings in Florida increased significantly during four recent red tide blooms of the dinoflagellate *Karenia brevis*, with live turtles displaying symptoms of neurological disorders (Redlow et al., 2002). In nonsurviving animals associated with these blooms, liver brevetoxins were often as high as or higher than those in manatees determined to have died of brevetoxin poisoning. Patterns of bioaccumulation or species-specific susceptibility were also detected: brevetoxins were highest in Kemp's ridley turtles, intermediate in loggerhead tissue (only 1 animal), and lowest in greens (Redlow et al., 2002). Such die-offs appear to primarily affect juvenile and subadult turtles that are residents of nearshore waters; however, effects on breeding populations could be significant should springtime HABs continue into the start of the nesting season.

A secondary but important effect of eutrophication is the general degradation of the marine environment, which can seriously devalue its use as turtle habitat. Even nontoxic algal blooms (brown tides) can result in the loss of seagrass beds at nutrient-rich locations (Havens et al., 2001), as can increased levels of turbidity or changes in salinity (Figure 6.2). Prolonged blooms can also add large amounts of decaying matter to the water, causing hypoxic or anoxic conditions and furthering the devastation (Epstein et al., 1998). Havens et al. (2001) reported that a dense lawn of macroalgae on the bottom of one Virginia estuary reduced sediment–water nitrogen exchange when the algae were actively growing, but resulted in high nitrogen release during algal senescence. Such significant impacts on invertebrates and seagrasses would be magnified up the food chain, potentially resulting in large areas of ocean "desert," which appear to be occurring with increasing frequency. In Hervey Bay, Australia, for example, more than 1000 km^2 of seagrass beds have been lost, resulting in significant mortality and migration of the dugong population and the reduction of commercial prawn and fish catches (Brodie, 1999). The effects of such large-scale eutrophication on resident sea turtle populations are completely unknown because in-water population studies are lacking in affected areas.

FIGURE 6.2 *Thalassia testudinum* in Florida Bay. Algal blooms and turbidity contribute to seagrass die-offs in turtle feeding grounds worldwide. (Photo courtesy of Dr. Michael Durako, University of North Carolina.)

6.3.4 Disease

Disease can be both a cause and a symptom of stress. Large numbers of leeches, for example, can lead to anemia and damage the dermis, thus opening routes for secondary infections, whereas barnacle loads increase stress by increasing drag (George, 1997). Models of swimming and drag suggest that a heavy barnacle load may increase drag up to tenfold and energetic requirements in swimming sea turtles by more than threefold (Gascoigne and Mansfield, 2002).

In general, bacterial infections are relatively rare in free-roaming sea turtles (although they occur more frequently in the crowded conditions of captivity); traumatic injury to the dermis and aspiration of seawater are the two primary routes by which bacteria enter (George, 1997; see also Chapter 15). Even infections that are less acutely toxic may have significant effects on sea turtle health that will increase overall stress on the animal. This is seen, for instance, in the buoyancy abnormalities associated with pneumonia reported by Jacobson et al. (1979). Health problems and diseases of sea turtles are reviewed extensively in the first volume of this series (George, 1997).

6.3.4.1 Trematodes

Among loggerhead turtles, the most damaging parasites are the spirorchid trematodes, which reside in the vascular system and affect up to 30% of the Atlantic loggerhead population (Wolke et al., 1982). Green turtles are also vulnerable. A histopathological examination of four dead green turtles by Raidal et al. (1998) revealed severe granulomatous vasculitis, with aggregations of spirorchid eggs and microabcesses in the intestines, kidney, liver, lung, and brain. This damage in turn

permitted a variety of bacterial infections, including *Salmonella*, *Escherichia coli*, *Citrobacter*, and *Moraxella* spp. They concluded that Gram-negative bacterial infections caused systemic illness and death following the severe infestation by spirorchid cardiovascular flukes. Glazebrook and Campbell (1990) found cardiovascular flukes in green, loggerhead, and hawksbill turtles in the U.S., India, Pakistan, and Australia, as well as a variety of gastrointestinal (GI) flukes, barnacles, and mites. In that study, heart fluke infestations resulted in cases of bronchopneumonia and septicemia–toxemia, whereas all heavy infestations of cardiovascular flukes were associated with severe debilitation, generalized muscle wastage, and thickening and hardening of the walls of the major cardiac blood vessels.

6.3.4.2 GTFP

The epidemic of GTFP that has arisen over the last 15–20 years is of great concern. First recorded in the 1930s in the Florida Keys in a few green turtles, it appeared to increase in the 1960s and is now pandemic, with infection rates in some habitats of more than 70% (Aguirre and Lutz, in press). GTFP has been reported in every major ocean basin that is home to green sea turtles (Herbst, 1994). The rapid spread of this disease is exemplified by the record of its occurrence in the Indian River Lagoon on Florida's east coast. The first case in the Indian River was reported in 1982, and by late 1985 more than 50% of *C. mydas* captured in the lagoon had fibropapillomas (Herbst, 1994); current infection rates are approximately 67% (Hirama and Ehrhart, 2002). Although many turtles with GTFP will not die of the disease per se, the tumors, which may range up to more than 30 cm in diameter, interfere with normal functioning, cause physical weakening, and expose the carrier to other threats (Figure 6.3). Cutaneous tumors increase drag and may interfere with vision; large tumors could thus severely hamper the victim's ability to swim and dive; escape predation; and locate, capture, and swallow food. Internal tumors may affect organ function, digestion, buoyancy, cardiac function, and respiration (Herbst, 1994; Work and Balazs, 1999). Turtles with fibropapillomas are also more likely to become entangled in monofilament line or other debris (Witherington and Ehrhart, 1989). Turtles with advanced GTFP are chronically stressed. Those with large numbers of tumors are hypoferremic, anemic, and hypoproteinemic, and are in advanced stages of acidosis and calcium–phosphorus imbalance (Aguirre and Balazs, 2000). These symptoms, of course, may have additional effects on turtles: animals already in ion imbalance may be less able to handle additional osmotic stresses induced by cold stunning, for example, whereas anemic animals will have a lower oxygen-carrying capacity for diving, and would be more severely incapacitated if caught in a net or trawl. There is also likely to be a debilitating synergism between GTFP and spirorchidiasis; many animals suffer from both infections simultaneously, and many pathological outcomes are similar (Aguirre et al., 1998).

Although it initially appeared that GTFP was confined to green sea turtles, in which it is most prevalent, recent studies have found GTFP in loggerhead (Herbst, 1994), olive ridley (Aguirre et al., 1999), Kemp's ridley (Harshbarger, 1991), flatback (Limpus and Miller, 1994), and possibly leatherback turtles (Huerta et al., 2000).

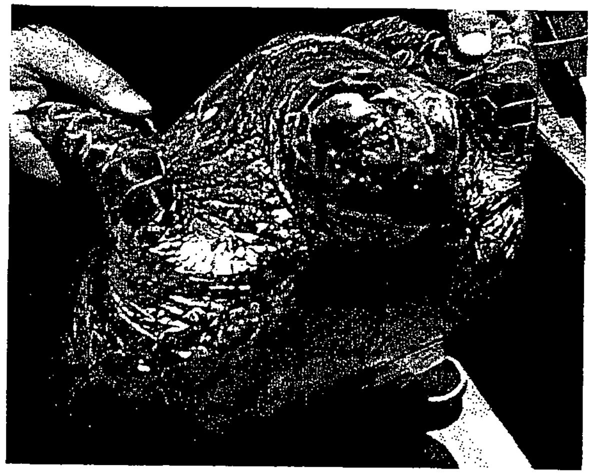

FIGURE 6.3 *Chelonia mydas* with fibropapillomatosis. (Photo courtesy of W. Teas.)

Although the precise etiology of GTFP is still under investigation, the disease has been linked to environmentally challenged habitats, and immunosuppression is strongly correlated with fibropapillomas in green turtles (Cray et al., 2001; Aguirre et al., 1994; Aguirre and Lutz, in press). Chronic stress, whether caused by environmental pollutants, parasites, or biotoxins, affects the immunological response of reptiles; thus, stressed sea turtles are likely to be less able to withstand the primary etiological factor for GTFP. There is convincing evidence of a virus as the transmissible causal factor for GTFP. Early work focused on papillomavirus (Jacobson et al., 1989), but recent work by Brown et al. (1999) failed to detect papillomavirus in freshly isolated tumor samples. More recently, a strong correlation has been detected between the presence of chelonian herpesvirus and papilloma (Lackovich et al., 1999), which has been supported by molecular (polymerase chain reaction) investigations (Lu et al., 2000; Quackenbush et al., 2001); papillomavirus was also detected.

6.3.5 Effects of Environmental Stressors on Hatchlings

Hatchlings must endure unique physiological stresses in emerging from the nest and swimming in the frenzy period away from shore to the open ocean gyres. Until hatching, the nest environment is controlled primarily by physical factors: the temperature, hydric environment, and gas exchange processes of the beach material (for a review, see Ackerman, 1997). As the embryos grow, they both consume more oxygen and produce more carbon dioxide, resulting in a hypoxic, hypercapnic nest environment. In addition, as the metabolic rate of the clutch increases with development, metabolic heat output increases as well (Figure 6.4), enough to raise nest

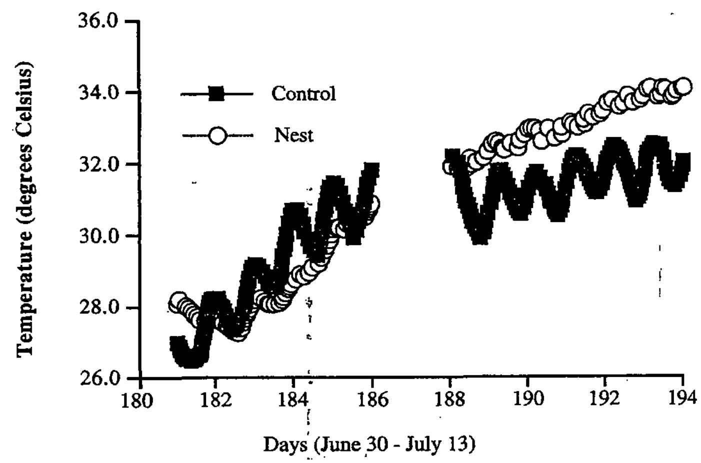

FIGURE 6.4 Mean temperature at 30 cm depth in a loggerhead turtle nest and in a control (sand, 4 m from nest) on a renourished Miami, FL, beach. During the final 2 weeks of incubation, metabolic heat raises nest temperatures above control. $N = 5$ nests. (Data adapted from Milton, S.L., Schulman, A.A., and Lutz, P.L., The effect of beach renourishment with aragonite versus silicate sand on beach temperature and loggerhead sea turtle nesting success. *J. Coast. Res.*, 13(3), 904–915, 1997. With permission.)

temperatures significantly over control (sand) temperatures by approximately 1–2°C (Milton et al., 1997). It is into this warm, low-oxygen environment that sea turtles hatch to dig their way to the surface, an energy-intensive effort that often exceeds the gas diffusion capacity of the environment as well as the aerobic capacity of the hatchlings such that anaerobic metabolism becomes necessary for successful nest emergence (Ackerman, 1977; Dial, 1987).

6.3.5.1 Emergence Stress and Lactate

Blood lactate levels in emerging green and loggerhead hatchlings increase significantly, with blood lactate concentrations in green turtle hatchlings approximately twice those of loggerhead hatchlings (Baldwin et al., 1989). Baldwin et al. (1989) suggested that emerging green turtles had higher lactate levels than loggerheads because they were digging from deeper nests, and were thus digging longer under possibly lower oxygen conditions. Recent work, however, indicates that the degree of lactate buildup, like many other stressors, is most significantly affected by interspecific differences. In a study by Giles et al. (in review), blood lactate concentrations in three species of hatchling sea turtles (*Dermochelys coriacea, C. caretta,* and *C. mydas*) were not significantly related to nest depth, oxygen levels, or temperature, but instead differed by species (Figure 6.5). Although lactate levels were highest in actively digging hatchlings of all three species (compared to those resting at the bottom of the nest or at the sand surface), leatherback hatchlings, which emerge from the deepest nests, had the lowest blood lactate levels, whereas green turtle hatchlings emerging from shallower nests had the highest lactate levels (an average of 42% higher than in *D. coriacea* and 33% higher than *C. caretta*).

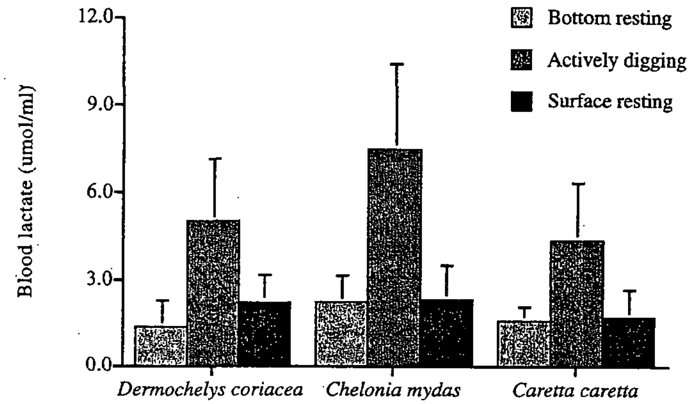

FIGURE 6.5 Mean blood lactate levels (1 ± SD) of hatchlings during emergence activities on a Florida beach. Lactate levels in actively digging hatchlings of all three species are significantly greater than for hatchlings of the same species resting at the surface or bottom of the nest. Mean nest depths were 60.5 ± 1.96 cm (*C. caretta*), 83.0 ± 8.06 cm (*C. mydas*), and 89.7 ± 873 cm (*D. coriacea*). There was no significant difference between lactate levels in hatchlings digging from the shallowest nests (*C. caretta*) and the deepest nests (*D. coriacea*). (Data are from Redfearn, 2000.)

Low levels of lactate accumulation after exercise have also been reported in adult leatherback turtles (Paladino et al., 1996), a factor indicating that overall lactate production may reflect species-specific differences. Once emerged, hatchlings rest at or near the sand surface, which provides time for blood lactate levels to decline before the hatchlings begin their swimming frenzy, another energetically costly activity. It is not known, however, if the rest period is an adaptation to allow lactate levels to decrease or if this is a side effect of other inhibitory factors, such as sand temperature. High lactate levels are correlated with diminished behavioral capacities and lethargy in reptiles (Bennett, 1982), and would thus be an additional physiological (pH) and behavioral stress on swimming hatchlings, increasing the likelihood of predation (Stancyk, 1982; Witherington and Salmon, 1992). (Of course, resting at the sand surface also increases the likelihood of predation.) Crawling from the nest to the water also increases body lactate levels (Dial, 1987), and studies on loggerhead and green turtle hatchlings have shown that the hatchling frenzy is supported in part by anaerobic metabolism (Baldwin et al., 1989). Once hatchlings have successfully emerged, it may take as long as an hour for lactate levels to return to basal, resting levels (Baldwin et al., 1989; Giles, in review), after which hatchlings make their way down the beach and into the surf.

6.3.5.2 Temperature

High sand temperatures are an additional stress affecting hatchling behavior as well as nest success. Although thermal inhibition of movement most likely prevents daytime emergence, preventing additional thermal and dehydration stress and exposure to daytime predators (Mrosovsky, 1968; Gyuris, 1993), when temperatures are particularly high in nests, embryonic and hatchling deaths may result either as a direct result of crossing into the upper lethal temperature range or possibly as a result of behavioral (movement) inhibition to the point of nonemergence. Miller (1985) found that sea turtle eggs held at temperatures greater than 33°C for extended periods of time did not hatch, consistent with the thermal tolerance range for developing sea turtles proposed by Ackerman (1997) of between 25–27°C and 33–35°C; it was noted by both Cheeks (1997) and Fortuna and Hillis (1998) that higher than normal nest temperatures in the field decrease sea turtle nest success. In an *in situ* comparison between naturally or artificially shaded hawksbill turtle nests in St. Croix and those exposed to direct sunlight (after Hurricane Hugo removed shoreline vegetation), Fortuna and Hillis (1998) found that unshaded nests averaged 2.1°C warmer than shaded nests in the same location. Unshaded nests also had significantly lower mean hatch success and nearly three times as many full-term dead embryos, with an apparent exponential relationship between maximum nest temperature and the percentage of embryos that died late in development.

A similar correlation was noted between extreme temperatures (greater than 33°C, with some temperatures as high as 37.6°C) in loggerhead nests relocated to a Miami Beach, FL, hatchery and low emergence (but not hatching) success. Especially significant were high temperatures during the last 3 days of incubation and number of pipped dead hatchlings in the nest (Blair, 2001). A significant increase in the number of pipped dead occurred in nests experiencing maximum temperatures between 32 and 34°C. Although high temperatures may be directly lethal to developing embryos, it cannot be determined if hatchlings from nests with high hatching but low emergence success are affected directly by temperature or indirectly through temperature effects on behavior. Experiments on newly emerged individuals and small-group behavior at various temperatures have shown that crawling by newly emerged loggerhead hatchlings from the Miami Beach hatchery, even in a group, is significantly inhibited by temperatures above 33°C (Blair 2001), which may result in nonemergence of a nest despite high hatch success. Physiological and behavioral responses to increased temperatures include the well-described thermal inhibition that prevents hatchling emergence when sand temperatures are high (Witherington et al., 1990; Moran et al., 1999) as well as reduced swimming speeds at temperatures above 30°C and loss of coordinated muscle movement in loggerheads swimming at temperatures above 33°C (O'Hara, 1980).

6.3.5.3 Frenzy Swimming

Crawling and frenzy swimming are also metabolically costly; as in emergence, the hatchlings (*D. coriacea*, *C. caretta*, and *C. mydas*) again exceed their aerobic scope and blood lactate increases, though to a lesser extent than in digging hatchlings

(Wyneken and Milton, unpublished observations). Lactate levels are lower in swimming (nonfrenzy) hatchlings than in crawling, emerging, or frenzy-swimming animals, though species-specific differences exist. Only in leatherback hatchlings were there no significant differences in lactate levels induced by activity (crawling, resting, or frenzy or postfrenzy swimming). By contrast, green and loggerhead hatchlings appear to rely more heavily on anaerobic metabolism for burst activities: lactate levels were significantly higher in crawling and frenzy-swimming green and loggerhead hatchlings than in resting or swimming animals (Wyneken and Milton, unpublished observations). Swimming appears to be particularly efficient in leatherback hatchlings; recent work by Jones et al. (2002) shows that swimming 1- to 5-week-old leatherbacks have oxygen consumption rates comparable to resting metabolism; mass-specific oxygen consumption (VO_2) increases to only 96% over resting (in 5-week-old turtles), even when swimming at maximal rates, with positive correlations between breath rates and VO_2, and flipper stroke rates and VO_2.

Interspecific differences in the cost of locomotion are apparent when comparing olive ridley hatchlings to the leatherbacks (Figure 6.6). In olive ridley turtles, aerobic scope (oxygen consumption during exercise) was 370–400% of resting metabolism in 1- to 4-week-old hatchlings, whereas swimming in 4-week-old leatherback hatchlings is no more costly than resting. In the 4-week-old olive ridley hatchlings, VO_2 was also lower in maximally swimming animals than in freely swimming

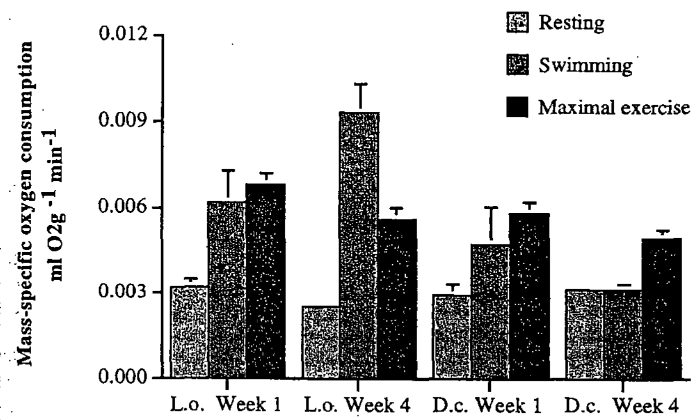

FIGURE 6.6 Mass-specific oxygen consumption (+SEM) in *Lepidochelys olivacea* and *D. coriacea* at 1 and 4 weeks of age during resting, swimming, and maximal (stimulated) swimming. (Data are adapted from Jones, T.T., Reina, R., and Lutz, P.L., A comparison of the ontogeny of oxygen consumption in leatherback sea turtle *Dermochelys coriacea* and olive ridley hatchlings, *Lepidochelys olivacea*. Different strokes for different life styles, in: *Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation*, J. Seminoff (compiler), U.S. Dept. Commerce NOAA Tech. Memo. NMFS-SEFSC, Miami, FL (in press), 2002. With permission.)

hatchlings, indicating an increase in the anaerobic component (although VO_2 in both conditions was higher than in resting animals). Similarly, Wyneken (1992) reported that the cost of locomotion in leatherback hatchlings is as much as 20% lower during frenzy swimming than in green and loggerhead hatchlings, with leatherbacks having the slowest swimming speeds, stroke rates, and lowest metabolic rates. Because leatherback turtles of less than 110 cm CCL are not found in waters above 34° latitude (26°C) (Eckert, 2000), it has been suggested that leatherback hatchlings may become active, distance swimmers early in development, allowing them to forage in upwelling and convergence zones rather than being swept as passive feeders into the ocean gyres. Thus, although the physical requirements of emergence, crawling, and frenzy and postfrenzy swimming are common to all sea turtle species, the physiological stresses that these activities place on hatchlings again vary with interspecific metabolic differences.

6.4 RESPONSES TO STRESS

Stress responses may be expressed at multiple levels, from the immediate effects of acute stress on catecholamine levels to long-term effects such as immune suppression, changes in gene expression, and population effects, i.e., decreased reproductive rates. Harmful effects from both anthropogenic and natural insults include compromised physiology, impaired immune function, and an increase in the incidence of disease (Lutz, 1998). Immunosuppression is strongly correlated with GTFP in green turtles in Florida (Cray et al., in press; Sposato et al., 2002) and Hawaii (Aguirre et al., 1995), and it is likely that immunosuppressed turtles will suffer from other disease or parasite stressors as well.

6.4.1 NEUROENDOCRINE RESPONSES (STRESS HORMONES)

Selye (1936) proposed that different stresses produced a similar set of responses, which he called the general adaptation syndrome (GAS), i.e., alarm–resistance–exhaustion. In this widely adopted scheme, the primary response is at the neuroendocrine level, involving the hypothalamus–pituitary–adrenocorticoid axis. It is often identified as an increase in blood cortisol levels and has been taken as the stress-defining response (Nelson and Demas, 1996). Stress-related changes in corticosteroids are well documented in both freshwater and sea turtles.

Capture stress produces changes in corticosterone levels, but there are seasonal and size differences (Gregory et al., 1996; Gregory and Schmid, 2001). In examining acute captivity stress responses, Gregory et al. (1996) found that smaller turtles had higher levels of corticosterone in summer than did larger animals, whereas corticosterone levels were suppressed in both size classes in winter. It was suggested that the lower responses exhibited by large turtles in summer were related to reproductive condition, a finding supported by reduced adrenocortical function in heat-stressed breeding green turtles and in arribada olive ridleys exposed to turning stress (Jessop et al., 2000; Valverde et al., 1999). Similarly, male olive ridleys captured by hand and held in crowded conditions exhibited significantly higher corticosterone levels than females held under the same conditions (Schwantes, 1986). The stress of handling or capture in nets and trawls results in increased corticosterone in hatchling (Morris, 1982), juvenile (Morris, 1982; Wibbels et al., 1987), and adult sea turtles (Schwantes, 1986). Notably, forced submergence results in decreased corticosterone in freshwater turtles (Keiver et al., 1992).

In addition, corticosterone release is sensitive to temperature. Jessop et al. (2000) found that heat stress caused a 16-fold increase in circulating corticosterone in green sea turtles. In soft-shelled turtles adrenomedullary activity is stimulated by high temperatures and inhibited by low temperatures (Ray and Maita, 2001; Mahapatra et al., 1989).

Stress also results in increased blood levels of the catecholamine hormones epinephrine (EP), norepinephrine (NE), and dopamine, which, on an emergency basis, facilitate the fight or fight response by enhancing oxygen uptake and transfer, and the mobilization of energy substrates (Bonga, 1997). For example, forced submergence and acidosis greatly increases NE and EP levels in freshwater turtles (Wasser and Jackson, 1991). Hyperosmotic conditions deplete NE in soft-shells, whereas dehydration stress depletes EP but increases NE levels (Mahapatra et al., 1991). On the other hand, aldosterone and corticosterone levels were not affected by 4 days of freshwater exposure in Kemp's ridley turtles (Ortiz et al., 2000).

Although excessive or extended elevation of the stress hormones is immediately useful, it can have harmful effects by, for example, reallocating energy away from growth and reproduction, and suppressing immune functions (see Section 6.4.2) (Bonga, 1997). The experimental evidence for these effects is from species other than sea turtles, but it is undoubtedly a vertebrate-wide phenomenon. In the male common carp, prolonged elevation of cortisol levels inhibits testicular development and impairs the synthesis of the 11 oxygenated androgens (Consten et al., 2001); disease can also result in higher cortisol levels in fish (Mustafa et al., 2000; Sures et al., 2001).

There is some indirect evidence of such effects in sea turtles. Valverde et al. (1994) reported that olive ridley females restrained in the shade after nesting did not show the expected next-day progesterone peak indicative of ovulation, whereas unrestrained females captured in the water had ovulated (Valverde et al., 1992). Other work however, indicates that this response may be species-specific; postnesting loggerhead (Wibbels et al., 1992) and green turtles (Licht et al., 1980) subjected to severe handling stresses ovulated normally.

Increased levels of stress hormones have a variety of other harmful effects on turtles, including disturbed blood glucose levels (Keiver et al., 1992), impaired salt gland function (Reina and Cooper, 2000), and a compromised immune function (George, 1997).

Reina and Cooper (2000) found that both adrenaline and the cholinergic agonist methacholine inhibited salt gland activity in hatchling green sea turtles. Because the majority of salt excretion in sea turtles occurs through salt gland activity (Lutz, 1997), suppression of such activity could have significant effects on osmotic homeostasis in sea turtles, especially for hatchlings, which have an apparent requirement for seawater intake and concomitant high secretion rates (Bennett et al., 1986; Marshall and Cooper, 1988). Other potentially lethal ion imbalances may occur, for example, when salt gland function is inhibited during cold stunning.

Animals already subjected to physiological stresses (high or low temperatures, capture trauma, starvation) are likely to experience increased circulating glucocorticoid levels, which in turn depress immune function and accelerate catabolic processes. Recurrent environmental stressors may reduce survival if they result in persistent glucocorticoid secretion (Nelson and Demas, 1996); however, the potential links between environmental stressors, stress hormones, and immune function in sea turtles have not been investigated.

6.4.2 Immunological Responses

It is now commonly accepted that manipulation of neural and endocrine functions alters vertebrate immune responses, and the antigenic stimulation that generates an immune response results in changes in neural and endocrine functions; thus the immune status of an individual also has consequences for behavior (Ader and Cohen, 1993).

The suppression of the immune response by adrenocortical hormones, especially the glucocorticoids, is a well-described vertebrate response. Although most work describing the link between immunosuppression and elevated adrenocortical hormones has been done on mammals (Munck and Naray-Fejes-Toth, 1994), a few reptile studies have been performed. Saad and el Ridi (1988) observed significant lymphocytic destruction and the impairment of immune reactivity in the lizard *Chalcides ocellatus*, which they associated with sustained high levels of endogenous corticosteroid levels in the autumn and winter. By contrast, fully developed splenic lymphoid tissue and immune responses were coincident with low summer corticosteroid levels. The administration of exogenous corticosteroids to "summer" lizards depleted lymphoid elements and suppressed immune responses, whereas the pharmacological inhibition of corticosteroid synthesis in autumn ameliorated the natural winter-dependent immune depression (Saad and el Ridi, 1988).

The immune response of reptiles is of course affected by numerous factors. Steroid sex hormones, for example, also have significant effects on immunological activity in reptiles and other vertebrates, although again most studies in this area involve mammals. The reptile immune system is strongly affected by seasonal changes caused by both temperature changes and changes associated with the breeding cycle. Seasonal changes in thymic mass in turtles were first reported in 1912; Aime (1912) reported decreased thymic mass during winter estivation, and thymic regeneration in the spring. Androgens, like the glucocorticoids, appear to have immunocompromising properties. In poikilotherms, lymphoid mass and immunological activity is greatest in spring and summer, after breeding activities have been completed and testosterone levels decline. In the turtle *Mauremys caspica*, lymphocyte proliferation induced by mitogens showed high values in the spring and winter and decreased responses in summer and fall (Munoz et al., 2000; Munoz and De la Fuente, 2001), whereas a single injection of testosterone (200 μg/g body weight) produced thymic involution and intense lymphopenia in the spleen and peripheral blood compartment (Saad et al., 1991). Female mammals generally have higher immune activities by several indices than male conspecifics, whereas gonadectomized mice and rats treated with physiological or greater estrogen levels exhibited

increased antibody responses to a variety of antigens (Nelson and Demas, 1996). It has been suggested that seasonal changes in immune responsiveness reflect seasonal changes in the neuroendocrine system, with a regular relationship between neuroendocrine and lymphoid systems (Zapata et al., 1992).

Two studies have also found seasonal patterns of immune responsiveness in sea turtles. McKinney and Bentley (1985) reported that lymphocyte blastogenic responses in *Chelonia mydas* to the mitogens phytohemagglutinin (PHA) and concanavalin A (ConA) varied between individuals but did not correlate with size–age, season, or temperature; however, responses to the mitogens pokeweed and lipopolysaccharide (LPS) were measurable only in spring. More recently, Keller et al. (2002) reported increases in both mitogen-induced lymphocyte proliferation and overall white blood cell counts during the summer months in loggerhead turtles. Differences in the seasonal patterns of immunological activity between other turtles and sea turtles may be due to differences in peak hormone levels, because some turtles breed immediately upon emerging from winter hibernation (Lee et al., 2002).

Although seasonal changes of the immune system have not been well described in sea turtles, seasonal cycles in testosterone levels have been well documented (Owens, 1997). The pattern is similar to other poikilotherms, with testosterone levels highest in the winter and early spring and decreasing as the mating season progresses (Wibbels et al., 1990). Because most species have seasonal fluctuations in reproductive activity, seasonal changes in immune function may be mediated by photoperiod effects on reproductive function and steroidal activity. Reptiles differ from other groups (mammals) in which laboratory studies show that decreasing photoperiods enhance immune function, whereas field studies report an increase in lymphatic tissue size and immune in winter (for a review, see Nelson and Demas, 1996). One example is the saltwater crocodile hatchling (*Crocodylus porosus*), in which suboptimal temperatures induced stress and immunosuppression with significant decreases in total white cell and lymphocyte counts (Turton et al., 1997).

The stress of coping with energetically demanding conditions can also indirectly cause illness and death by compromising immune function (Nelson and Demas, 1996). Although it has been assumed that low environmental temperatures and other stressors decrease immunoglobulin production and immune response in sea turtles, as they do in other reptiles (Zapata et al., 1992), these assumptions have not been examined. There has been no systematic examination of the relationships between acute and long-term stress on the immune function in sea turtles.

6.4.3 Gene Response, Molecular Biomarkers, and the Measurement of Stress: Potential Tools for the Future

In addition to short-term stress markers such as corticosterone levels, all organisms respond to environmental and physiological stress by altering gene expression (at the transcriptional and/or translational level) for a variety of compounds, including increasing synthesis of an evolutionarily conserved family of proteins known as the heat shock or stress proteins (HSPs). The HSP family is elicited by stressors as diverse as xenobiotics, heavy metals, heat, hypoxia, and osmotic stress.

These molecular stress responses have been studied mostly in organisms maintained under constant laboratory conditions; there is much less information on the regulation of stress responses in animals that are exposed to and tolerate large fluctuations in internal or external conditions (Rabergh et al., 2000). However, genetic changes such as increased HSP expression are becoming an important and powerful tool through which the direct effects of different stressors on organismal health and fitness can be measured by their effects on cellular and molecular processes. Most attempts to monitor the environmental status of an ecosystem rely on determining the abiotic components, such as contaminant analysis–loads, or assessing ecological responses to stressors (e.g., species richness, sex ratios, and indicator species fitness) (O'Connor, 1996). Such studies do not reveal the links between the stressor and its effects, and therefore we cannot predict how a species or ecosystem will respond to even one contaminant (Downs et al., 2001a), much less the more likely problem of a suite of stressors.

A number of different compensatory mechanisms may operate at multiple levels (cells, tissues, organ systems, and individual animal) to ameliorate stress before the fitness of an individual or its functional role in the community is altered (Allen and Starr, 1982), and thus stress affects higher levels of the biological hierarchy only when it overwhelms the homeostatic mechanisms of individual organisms. Rather than simply measuring stress responses, data regarding individual and population responses (especially for endangered species) would be far more useful if they could be used to forecast population changes. Forecasting stress responses in time to intervene and prevent population declines, however, requires linking changes at lower levels of biological organization with the fitness of individuals (and then accurately modeling the long-term demographic consequences).

The use of molecular biomarkers to assess organismal and ecosystem health is thus becoming a popular concept (Downs et al., 2001a). Although numerous studies, including many on sea turtles, examine a single or small set of physiological parameters to assess the overall physiological response to a stressor (Adams et al., 1992), and other studies support the validity of biomarker use as indicators of contaminant or stressor exposure (de Zwart et al., 1999; Adams and Ryon, 1994), very few attempt to integrate physiological status with multiple, specific biomarkers (Adams et al., 1992; Stegmann et al., 1992). A system to simultaneously assess multiple biomarkers to quantify known physiological responses to stressors would tell us: (1) whether an animal is physiologically stressed, (2) whether the animal is evolutionarily or physiologically adapted to a chronic stress, and (3) the physiological impact of the stress (Downs et al., 2001a). Such an integrated system using molecular biomarkers will allow for a diagnosis of an animal's physiological condition at the cellular level when challenged with a real or suspected stress.

With the development of molecular markers for specific individual or suites of stressors, such a system would become a powerful tool to identify environmental insults that are physiologically affecting an organism, providing a more accurate quantification of the health status of a population in response to a natural or anthropogenic stressor. Such a system, for example, has been developed for the intertidal eastern mud snail (*Ilyanassa obsoleta*), where biomarkers can differentiate between snails exposed to different stressors, including heat, cadmium, an herbicide and a pesticide, and a petroleum compound (Downs et al., 2001a). Other biomarker systems have been developed for species as diverse as cordgrass, estuarine fish, tadpoles, heat-stressed corals (Downs et al., 2000), and grass shrimp (Downs et al., 2001b). Representative stressors already used include elevated temperature, pesticides, heavy metals, and a pathogenic bacterium. Such a system could be extremely useful to measure the health status of marine turtle populations. Because turtles have nucleated red blood cells, a molecular biomarker system could theoretically be developed for diagnosis using blood samples relatively quickly, easily, and inexpensively.

A system for molecular diagnosis of stress might include biomarkers of general cellular integrity and oxidative stress (i.e., ubiquitin or malondialdehyde), HSPs such as hsp60 and hsp70, antioxidant enzymes (superoxide dismutases), enzymes that respond to pH stress (acid and alkaline phosphatases and dehydrogenases), and members of the P450 family (markers of xenochemical exposure). The synthesis of HSPs at normal physiological and at elevated temperatures, for example, has been correlated with the natural adaptation of nine lizard species to heat, in that animals adapted to desert conditions showed higher constitutive levels of hsp70 than lizards that inhabited cooler climates (Ulmasov et al., 1992). Lizards adapted to cooler climates also have a lower thermal threshold for HSP expression when exposed to heat shock than desert-adapted animals (Zatsepina et al., 2000). It has been suggested that increases in hsp70 mRNA levels in blood may serve as an early indicator of temperature stress in fish (Currie et al., 2000). The genetic response to stress in sea turtles is (naturally!) unknown, although changes in hsp70 and hsp60 have been detected in anoxic freshwater turtles (H. Prentice, personal communication).

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Preface

The success of the first volume of *The Biology of Sea Turtles* revealed a need for broad but comprehensive reviews of recent major advances in sea turtle biology. At that time, book size constraints as well as the fast-paced changes in some fields dictated that this need could be only partially addressed in a single volume. Many important topics were not covered and were left for future volumes. Volume II emphasizes practical aspects of biology that relate to sea turtle management and changes in marine and coastal ecosystems. These topics include the interactions of humans and sea turtles, an introduction to sea turtle anatomy, sensory and reproductive biology, sea turtle habitat use and ecology, stress and health, and the maintenance of captive animals. This volume provides both historical and up-to-press-time information. The field is growing dramatically as established scientists expand their views and fine new scientists bring their novel ideas, techniques, and perspectives to the understanding and application of the biology of marine turtles.

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NOTES

ANALYSIS OF SEA TURTLE CAPTURES AND MORTALITIES DURING COMMERCIAL SHRIMP TRAWLING

Five species of sea turtles occur in coastal United States waters of the southern North Atlantic and the Gulf of Mexico and are listed and protected under the Endangered Species Act (1973). These are the Kemp's ridley turtle, *Lepidochelys kempi*; hawksbill turtle, *Eretmochelys imbricata*; leatherback turtle, *Dermochelys coriacea*; green turtle, *Chelonia mydas*; and loggerhead turtle, *Caretta caretta*. Each of these species are captured by commercial shrimp trawlers, and these incidental captures have been identified as a source of sea turtle mortalities (Hopkins and Richardson 1984).

Several prior studies have attempted to quantify turtle catch rates and mortalities by trawlers through interviews with vessel captains (Anonymous 1976,[1] 1977[2]; Cox and Mauerman 1976; Rabalais and Rabalais 1980) and through direct observations by observers during commercial shrimp trawling (Hillestad et al. 1978; Ulrich 1978[3]; Roithmayr and Henwood 1982[4]). While these studies provide estimates of capture and mortality rates, more specific information is required to effectively protect the stocks. In particular, managers need to know when and where turtle captures occur, which species are impacted, at what depths the majority of captures occur, and how many turtles are captured and killed.

This report provides a preliminary analysis of existing data collected by fisheries observers during commercial U.S. shrimp trawling. Data from three National Marine Fisheries Service (NMFS) observer projects were used for analysis of turtle catch per unit effort (CPUE) and mortality rates. A brief description of the projects follow:

1) The sea turtle incidental catch and mortality project was instituted to provide information on the incidental capture and associated mortality of sea turtles off the southeastern United States. Trained fishery observers were placed aboard commercial shrimp vessels operating on the major grounds in the Gulf of Mexico and southern North Atlantic from 1979 through 1981.
2) The goal of the excluder trawl project was to design an apparatus for use with existing shrimping gear which would effectively prevent the incidental capture of sea turtles. Initial design and testing of prototype models were conducted during 1977, and field trials were continued through 1984. Fishery observers aboard cooperative and chartered shrimp trawlers began data collection in 1978. Data collection procedures were similar to those of the incidental catch project except that data records were maintained for each net. In this manner, the performance of excluder nets could be compared with that of standard trawls.
3) The objectives of the shrimp fleet discards project were to estimate the magnitude and species composition of incidental fish captures by the Gulf shrimp fleet. Data were collected through contractual arrangements with state agencies from 1973 through 1978. These agencies placed observers on commercial vessels to obtain at-sea sampling off their respective coasts. Data records similar to those of the other two projects were completed for each tow.

In estimating turtle CPUE and mortalities by species, we restricted our analyses to loggerhead, Kemp's ridley, and green turtles. Leatherback and hawksbill turtles were also captured in shrimp trawls, but the infrequency of captures made predictions of CPUE for these species imprecise. In predictions of CPUE for all species combined, these capture records were included.

Data Analyses

For estimations of turtle CPUE and mortalities, the three observer projects were merged. For each data set, effort (E) was standardized to re-

[1]Anonymous. 1976. Incidental capture of sea turtles by shrimp fishermen in Florida. Preliminary report of the Florida West Coast Survey, University of Florida Marine Advisory Program, 3 p.

[2]Anonymous. 1977. Alabama shrimp fishermen interviews for 1977-1978. Marine Resources Office, Alabama Cooperative Extension Service, 1 p.

[3]Ulrich, G. F. 1978. Incidental catch of loggerhead turtles by South Carolina commercial fisheries. Report of the National Marine Fisheries Service, Contract No. 03-7-042-35151, 33 p.

[4]Roithmayr, C., and T. Henwood. 1982. Incidental catch and mortality report. Final report to Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149, 20 p.

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Gulf of Mexico (Table 1). This indicates that per unit effort, 16 turtles were captured in the Atlantic for every one turtle captured in the Gulf.

An attempt was made to compare mean depth and duration of tow for turtle captures with the mean depth and duration of tow for all effort by area with and without turtle captures. The mean depth of fishing and mean length of tow were computed from effort data for each statistical zone and for tows in which loggerhead, Kemp's ridley, or green turtles were captured. In most cases (particularly the Gulf of Mexico) sample sizes were small, and no patterns or consistency were evident. We suggest that despite some apparent statistical differences which we attribute to small sample sizes, average depth and tow duration of turtle captures were probably not different from that of the effort.

Summary information on observer effort, CPUE, shrimping effort, estimated captures, and estimated mortality in the Gulf of Mexico and southern North Atlantic are presented for loggerhead, Kemp's ridley, and green turtles (Table 1). Estimated CPUE for all turtles in the Gulf of Mexico (zones 1-21) was 0.0031 ± 0.0008 turtles/net hour, and CPUE for the southern North Atlantic (zones 24-33) was 0.0487 ± 0.0041 turtles/net hour.

The calculation of estimated mortality used minutes fished as a means of estimating the percent of the turtles captured that are killed. Based on mean tow times from our effort data, the overall mortality rate for the Gulf of Mexico is 29%. The eastern Gulf mortality rate is 34%, the central Gulf rate is 22%, and the western Gulf rate is 38%. For the Atlantic coast, the rate is 21% reflecting the shorter average duration of trawl tows on this coast.

The mortality rates based on minutes fished do not distinguish among species. This is because of the small numbers of captures for species other than loggerhead turtles. If there are differences in the ability of the other turtle species to survive long periods of immersion and the stress involved in being captured in a trawl, the differences are not measurable from these data.

In using minutes fished to estimate mortality, the data did not conform to expected models over the range of our observations. In tows of <60-min duration, mortality rates were <1% suggesting that the logistic model might be most appropriate to describe the relationship. However, of logistic, 2d and 3d order polynomial and linear models, the best fit over the range of tow times observed in these studies was provided by the linear model. In tows of <60-min duration and in tows longer than 360 minutes, the linear model is probably inappropriate; mortality is negligible in very

TABLE 1.—Observer effort, turtle captures, CPUE, shrimping effort, estimated captures and estimated mortality of loggerhead, Kemp's ridley, and green turtles in the Gulf of Mexico and the southern North Atlantic.

Area	NMFS observer effort (net hours)	Number of turtles	CPUE + 95% C.I. on CPUE (turtles/net hour)	Annual shrimping effort (net hours)[1]	Estimated captures (turtles/yr)	Estimated mortality (turtles/yr)
Loggerhead turtles, *Caretta caretta*						
Atlantic	9,943	453	0.0456 ± 0.0039	704,376	32,120 ± 2,747	6,745 ± 577
Gulf of Mexico						
eastern	2,589	12	0.0046 ± 0.0026	611,530	2,813 ± 1,590	956 ± 541
central	6,353	14	0.0022 ± 0.0012	2,391,498	5,261 ± 2,870	1,157 ± 631
western	7,829	16	0.0020 ± 0.0010	1,312,670	2,625 ± 1,313	998 ± 499
overall	16,771	42	0.0025 ± 0.0008	4,315,698	10,789 ± 3,453	3,129 ± 1,001
Kemp's ridley turtles, *Lepidochelys kempi*						
Atlantic	9,943	18	0.0018 ± 0.0008	704,376	1,268 ± 564	266 ± 119
Gulf of Mexico						
eastern	2,589	0	0	611,530	[2]245 ± 245	83 ± 83
central	6,353	2	0.0003 ± 0.0004	2,391,498	717 ± 957	158 ± 210
western	7,829	4	0.0005 ± 0.0005	1,312,670	656 ± 656	249 ± 249
overall	16,771	6	0.0004 ± 0.0004	4,315,698	1,726 ± 1,726	501 ± 501
Green turtle, *Chelonia mydas*						
Atlantic	9,943	7	0.0007 ± 0.0003	704,376	493 ± 211	104 ± 44
Gulf of Mexico						
eastern	2,589	0	0	611,530	[2]61 ± 122	21 ± 41
central	6,353	2	0.0003 ± 0.0003	2,391,498	717 ± 717	158 ± 158
western	7,829	0	0	1,312,670	[2]131 ± 262	50 ± 100
overall	16,771	2	0.0001 ± 0.0002	4,315,698	432 ± 863	125 ± 250

[1]Gulf of Mexcio effort estimates provided by NMFS, Galveston Laboratories (E. Klima text footnote 5) and southern North Atlantic effort based on estimates from Anonymous 1983.

[2]Based on CPUE for the overall Gulf of Mexico.

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TYRRELL A. HENWOOD
WARREN E. STUNTZ

National Marine Fisheries Service, NOAA
Southeast Fisheries Center
Mississippi Laboratories
Pascagoula Facility
Pascagoula, MS 39568-1207

THE RELATIONSHIP BETWEEN LUNAR PHASE AND GULF BUTTERFISH, *PEPRILUS BURTI*, CATCH RATE

Through the joint efforts of Japan and the United States, a research program was conducted in fall 1984 and spring 1985 to identify squid resources in the northern Gulf of Mexico (Grace 1984, 1985). Although large concentrations of squid were not located, commercial quantities of gulf butterfish, *Peprilus burti*, were encountered. Maximum sustainable yield (MSY) estimates from the spring data indicated annual potential catches of 50,000 t with a projected ex-vessel value of $19 million (Gledhill[1]). Although gulf butterfish are sufficiently abundant to support a fishery, critical gaps of information on gulf butterfish distribution and location exist which are needed in order to harvest this resource efficiently. Preliminary data from the U.S.-Japan joint surveys indicated that gulf butterfish catch rates were greatest at bottom temperatures of 15°-19°C. Subsequent scientific and commercial efforts at targeting gulf butterfish based upon bottom temperature have produced catches ranging from few individuals to many tons. In a recent study, we found that fishing success for gulf butterfish was often high for several days followed by periods of low success (Allen et al. 1986). This phenomena parallels catch patterns encountered by east coast gulf butterfish fishermen (Amos[2]), who suggest that lunar phase affects catch rates. We analyzed the effect of lunar phase on catch rates. The purpose of this paper is to present evidence that bottom trawling success for gulf butterfish is related to lunar phase.

Methods

Gulf butterfish catches from the two U.S.-Japanese joint surveys and from an additional gulf butterfish survey conducted by SEAMAP (August 1985) were examined. Initially, catch rates per hour of individual trawls were calculated per calendar day. A lunar day value (1-29) was assigned to each calendar day of trawling during the three cruises. Lunar day 1 was assigned to the third calendar day proceeding the new moon on through day 29 falling on the third calendar day following the last quarter moon phase. Mean catch (kg/hour per lunar day) was then calculated and plotted. Catches from trawled stations outside of the depth range in which gulf butterfish were caught during each trip (i.e., < minimum depth or > maximum depth) were not included when calculating mean catch/hour per lunar day.

The effects of moon phase and trip on natural log catch rates ($\ln(x + 1)$, where x = kg/hour per individual trawl) of gulf butterfish were investigated, using the general linear model (GLM) procedures (SAS) Institute (1982). Type III sums of squares were used for the analysis due to unequal number of observations in each subclass. Each observation from each trip was assigned into a lunar phase period (1-4). Mean catch ($\ln(x + 1)$/hour) and number of trawls sampled during each trip and lunar phase are presented in Table 1. An

[1]Gledhill, C. T. 1985. A preliminary estimate of gulf butterfish (*Peprilus burti*) MSY and economic yield. Unpubl. manuscr., 66 p. Southeast Fisheries Center, Mississippi Laboratories, National Marine Fisheries Service, NOAA, Pascagoula, MS 39568-1207.

[2]Duncan Amos, Georgia Marine Extension Program, P.O. Box Z, Brunswick, GA 31523, pers. commun. July 1986.

containing 365 and 730 mgCl−/kg successfully hatched (although pecentage hatch decreased with increasing chlorinity) indicating that chlorinity in the natural nest was not a limiting factor.

Introduction

The physical requirements of parchment-shelled reptile eggs are very poorly understood and the present investigation aims at providing additional information on a group for which knowledge is at present quite inadequate. It is one aspect of a long-term study of the ecology and population dynamics of the green turtle centered on Heron Island, Queensland, on the Great Barrier Reef of Australia.

Green turtles nest above the spring high tide mark, usually close to vegetation. The eggs, which average about 120 per clutch, are deposited in a chamber 18–24 inches deep which the female digs by means of her rear flippers. Accounts of the nesting process have been given by Moorhouse (1933, who also made his observations on Heron Island), Hendrickson (1958) and Carr and Ogren (1960).

At the commencement of this study it was suggested that accumulation of salt spray combined with leaching effects of rainstorms might result in a high level of chloride in the sand at the depth where the egg chamber is formed, but opinion was divided on the probable concentration.

Preliminary observations were made on the temperature relations in the natural nest. Recording probes were located within an egg mass and at a similar depth at a distance of one meter. There was no 24 hour temperature variation at either location but a gradual increase in temperature occurred in the egg mass during the latter stages of incubation. This temperature increase did not occur in the adjacent sand and was presumably due to metabolic heating. The approximate range (25°–31°C, depending, in part, on the stage of incubation) should be compared with the figures given by Hendrickson (1958) and Carr & Hirth (1961). Hendrickson in Malaysia gives the range 28°C to 30.4°C but recorded approximately 6°C rise in temperature during incubation. Carr and Hirth on Ascension Island recorded temperatures of the nest initially at 27.8°–28°C with an average gain of 2.3° during incubation.

The high degree of calcification of the juvenile turtle at hatching requires five times the calcium present in the egg yolk (Simkiss 1962). In part because of the high magnesium content observed in the hatchling (Ca:Mg 16:1 as against 40:1 in average vertebrate) Simkiss postulated that these cations might be obtained by the developing egg from sea water. Micro-environment studies of the natural nest may perhaps indicate if this is possible.

Methods

(a) Field Studies.

Sand samples were collected from the bottom of successful and unsuccessful egg chambers (the latter collapsed towards the end of construction). At the same time the presence or absence of tree rootlets in the egg chambers was noted. If present, the density of rootlets was recorded according to an arbitrary density scale.

Sand samples were also collected from the bottom of 24 inch deep holes dug inland at 10 foot intervals from the spring high tide mark (as a datum point) on one traverse of each of the north, east, south west and western beaches on the island (Fig. 1). Tree rootlet density was noted as for natural nests. All sand samples were sealed in polyethylene bags and weighed within 30 min of collection.

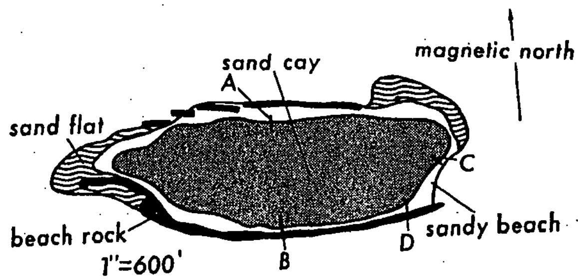

Fig. 1. Heron Island showing location of transects.

Two marked turtle nests were dug up the day following laying and their eggs placed in sealed plastic bags for flight to Canberra. On arrival, approximately 48 hr after being laid, the eggs were incubated as described below.

(b) Laboratory work.

Sand samples were dried for 5 hr at 115°C and reweighed. To obtain Cl^- concentration, 10 gm of dried sand were placed in 25 ml distilled water and titrated against 0.005 N $AgNO_3$ with K_2SO_4 indicator. They are tabulated as mg Cl^-/kg of dried sand.

Eggs were incubated in groups of 5 or 10 in 15 cm diameter culture dishes containing 1300 gm of dry, heat-sterilized coral sand and 100 ml of distilled water or other solution of known chlorinity. This produced an experimental moisture content of 7.8% by weight. Each group of 15 eggs used in the experiments comprised 5 eggs

from one clutch and 10 from the other. The eggs, marked with Indian ink, were placed in the culture dishes and covered with sand. Weights of the culture dishes containing sand and water were recorded and their moisture content maintained by weekly additions of distilled water if necessary. At weekly intervals eggs were individually weighed to the nearest 0.5 gm (because of adhering sand), and dead eggs (as indicated by loss of turgidity and growth of a blackish mold) removed. Dates of hatching were recorded.

Results

Properties of natural nests.

1. Factors affecting egg laying.

The vast majority of green turtle nests on Heron Island are dug adjacent to vegetation above a sand bank of variable height which encircles most of the island. A small number are dug in the beach below the bank and in such cases the high chlorine concentration resulting from contamination by spring high tides will rapidly prove lethal to the developing eggs (see Table 3). A paper on the nesting behavior of this population of green turtles is in preparation and the behavior associated with nest site selection will be fully discussed therein.

Not all egg chambers dug are successful, failures being caused by 1) obstruction of the digging action of the turtle by large or thickly matted tree roots; 2) collapse of the chamber sides due to insufficient support of the sand.

On encountering either of these situations the turtle will move to a new site and commence digging another egg chamber. Three factors are involved in situation 2). They are

(a) Very low moisture content
(b) Insufficient numbers of tree rootlets and root hairs
(c) Poor sand compaction.

The last component was not evaluated quantitatively but it was apparent that hard compacted sand was rare on the island. Tree rootlets and root hairs are generally present in the sand above bank level. Data from natural nests are summarized in Table 1.

The comparatively high moisture contents in successful nests and the very low chlorine level of the sand in all egg chambers should be noted. The moisture content of sand from successful and unsuccessful natural egg chambers containing few and no rootlets was significantly different at the 1% level. Chloride values do not differ significantly between successful and unsuccessful egg chambers.

TABLE 1. Natural egg chamber successes and failures classified according to the density of tree rootlets arbitrarily divided into many, moderate, few and none. Percent moisture content and chlorinity of sand samples are shown

Successful			Failure		
Tree Rootlets	mgCl⁻/kg	% moisture	Tree Rootlets	mgCl⁻/kg	% moisture
No rootlets	32	7.37	No rootlets	60	2.74
" "	69	7.02	" "	53	3.24
" "	16	7.04	" "	436	1.97
" "	28	6.91	" "	27	5.66
" "	23	4.67			
" "	16	7.14			
" "	71	4.47			
		Avge 6.37			Avge 3.40
Few rootlets	66	8.37	Few rootlets	80	5.24
" "	87	9.51	" "	57	4.87
" "	19	8.38	" "	90	3.81
" "	16	7.32	" "	74	4.61
" "	71	8.18	" "	54	3.51
" "	39	7.18	" "	30	5.26
" "	71	7.97	" "	71	5.70
" "	73	6.92			
" "	44	7.51			
" "	39	5.45[a]			
		Avge 7.92			Avge 4.71
Moderate rootlets	42	4.25	Moderate rootlets	44	3.33
" "	83	4.65			
" "	186	5.21			
		Avge 4.70			Avge 3.33
Many rootlets	46	11.00	Many rootlets	80	3.47
" "	58	4.90			
" "	94	3.85			
" "	58	6.80			
		Avge 6.64			Avge 3.37

[a]Compacted sand. Not included in average.

2. Properties of sand in "potential" nest sites.

Distance from datum (after an initial 5 to 10 ft) and height above sea level did not significantly alter moisture values which may be an expression of the efficiency of capillary action between sand grains in retaining moisture (Table 2).

The obvious features of chloride values are that below and at datum they approximate sea water. However, about 5 to 6 feet inland from datum and 1 foot above it, the values have dropped by approximately 95% with the exception of north beach. Here, where the slope is lowest, and spring high tides encroach on the bank, 10 feet inland from datum and 2 feet above it the chlorinity approximates 25% sea water which laboratory studies have shown not to be lethal to incubating eggs.

Statistical analysis of presence of tree rootlets

TABLE 2. Data from transects on Heron Island beaches. Holes 1 to 10 on north beach; 11 to 19 on south beach; 20 to 30 on west beach; 31 to 34 on south-east beach

Hole. number	Distance from datum	Approximate height above datum	Roots Present	Chlorinity mgCl⁻/kg	% moisture
1	-10′	-1′	none	1,413	part sample lost
2	0′	0′	none	1,394	10.17
3	10′	2′	few	372	7.03
4	20′	3′	many	108	3.09
5*	30′	5′	none	80	4.66
6*	40′	7′	few	80	3.16
7	50′	6′	moderate	12	5.77
8	60′	5′	many	53	4.04
9	70′	4′	few	32	5.87
10+	80′	5′	many	11	6.14
11	-4′	-1′	none	1,365	10.71
12	6′	2′	few	43	6.86
13	10′	4′	moderate	55	3.77
14	20′	7′	many	65	3.58
15	30′	9′	many	70	4.54
16*	40′	12′	moderate	samples con-	3.97
17+	50′	12′	many	taminated	5.39
18+	60′	11′	many	25	4.75
19+	70′	10′	few	41	5.41
20	-5′	-0.5′	none	1,000	9.11
21	5′	1′	few	36	5.82
22+	15′	2′	moderate	27	5.33
23+	25′	3′	hole obstructed by 2″ thick tree root		
24	35′	5′	moderate	71	5.56
25	45′	5′	few	66	6.48
26	55′	4′	none	20	6.65
27	65′	5′	few	57	5.48
28	75′	7′	few	69	7.04
29	85′	9′	few	42	8.29
30+	95′	8′	many	71	3.37
31	-5′	-1′	none	1,170	9.65
32+	5′	2′	many	66	8.85
33+	15′	5′	many	18	5.59
34+	25′	7′	many	18	4.51

*Hole a failure. +Hole would in practice be a failure due to superficial sand containing *Pandanus* roots too thick for turtles' flippers to penetrate.

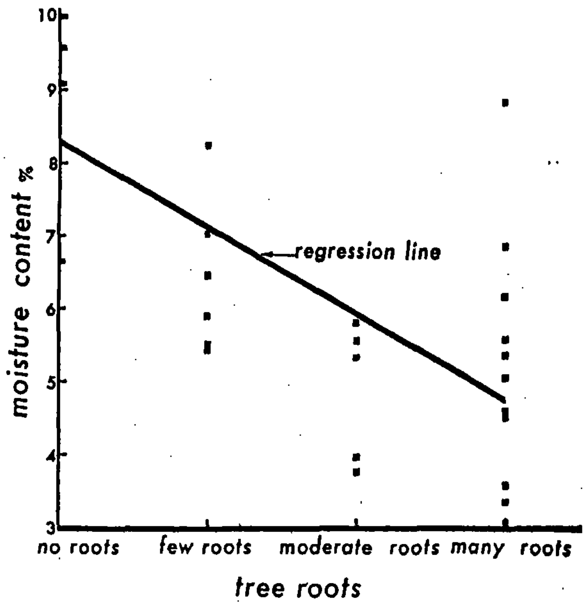

FIG. 2. Transect successes, A, B, C, and D.

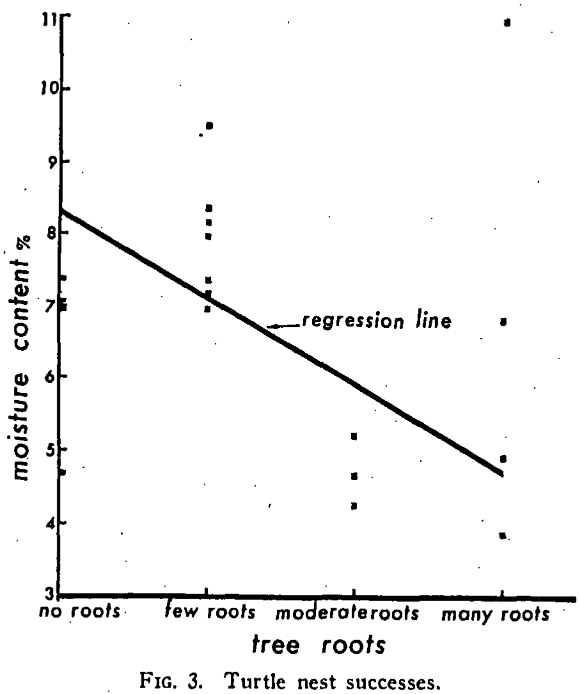

FIG. 3. Turtle nest successes.

and moisture content for successful holes from all transects indicates a high inverse correlation (at better than 1% significance level). Thus for a successful hole to be formed, in the absence of moisture more rootlets must be present, or conversely in the absence of rootlets, moisture content must be higher.

Figure 2 illustrates the regression line calculated from transect successes. This line represents the most probable value for moisture content corresponding to a given quantity of rootlets present in a successful hole. On this line are superimposed the values used in its calculation. Figure 3 illustrates the same line but on which are now superimposed moisture contents from successful egg chambers dug by turtles. These values fit the line quite well, i.e. the inverse correlation between moisture content and rootlets holds true for successful egg chambers dug by turtles. The "fit" of points about the regression line would be much improved if all sand samples (transects and egg chambers) had come from holes or chambers in which there was a critical balance for success between rootlets present and moisture content. What is found on Heron Island, however, is a spectrum of combinations of the two variables which together determine either success or failure of the chamber. These combinations may be sum-

marized using the arbitrary parameters of moist, dryish and dry sand, and many, few and no rootlets. Each of these combinations can be assigned a purely hierarchical values of success, thus:

Successes	Success Index	*Failures*	Success Index
moist sand + many rootlets	7	dryish sand + few rootlets	2
moist sand + moderate rootlets	6	dry sand + many rootlets	1
moist sand + few rootlets	5	dry sand + moderate rootlets	0
dryish sand + many rootlets	4	dry sand + few rootlets	0
dryish sand + moderate rootlets	3		

It should be emphasized that for example moist sand and many rootlets is not seven times more likely to be a success than dry sand and many rootlets. These hypothetical values have been chosen simply for convenience. When this table is represented on a 3 dimensional graph (Fig. 4) using the same ordinates, the various combinations plot as a curved slightly concave surface. All points on this surface above the arbitrary index point denoting the boundary between success and failure (here, 3) will be a success (light stippling)

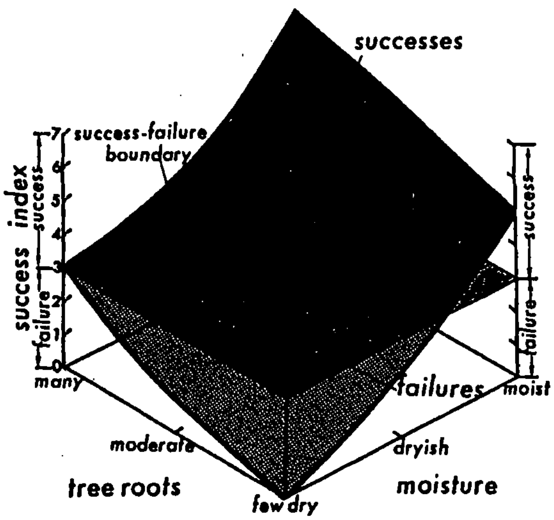

FIG. 4. Hypothetical scheme of probability of success for egg chambers dug in sand with varying degrees of moisture and number of tree roots.

and all points below it are a failure (heavy stippling).

Superimposed on the two variables of moisture and rootlets is the effect of compaction. If present, it may influence a failure combination in the direction of success, i.e. alter the concave surface to a convex surface at that particular point and elevate it above the success-failure boundary.

3. Natural incubation success.

In order to obtain large numbers of hatching turtles for a tagging program thirty thousand eggs of the Heron Island green turtle population were re-buried in a hatchery closely approximating natural conditions. Sixty-seven percent of these eggs hatched. Preliminary observations indicate that the temperature of a natural nest is initially about 25–26°C and there is a rise in temperature to 31°C during the latter part of incubation due to metabolic heating.

Laboratory incubation.

1. Salinity studies.

Seventy-five eggs in groups of 15 were incubated at 30°C in sand moistened with distilled water, sea water or a known dilution of sea water.

Effect of salinity.

(a) On incubation success.

Data on percentage hatch at different incubation salinities are given in Table 3. No hatchlings were produced in the groups moistened with 75% sea water or 100% sea water.

TABLE 3. Percentage hatch and weight changes in groups of 15 *Chelonia mydas* eggs in sand moistened with solutions of graded salinity. Temperature 30°C

% age sea water	Chlorinity mgCl-/kg	% age hatch	% age weight change: after 1 week	% age weight change: after 2 weeks
0	0	53	+3.5	+6.6
25	365	33	+2.0	+5.3
50	730	27	No change	+1.9
75	1095	0	−1.6	−0.7
100	1461	0	−1.1	−0.8

(b) On water uptake.

The effect of these salinities on water uptake by the eggs is given in Table 3 for two, weekly intervals. It should be noted that the only groups which showed a net gain in weight were those which produced hatchlings and were moistened with distilled water, 25% or 50% sea water. The other groups showed a loss in weight from the start which was not completed compensated for in the second week, indicating that egg metabolism was not proceeding normally. Weight gains during incubation of some eggs which produced hatchlings are given in Table 4. An egg in sand

TABLE 4. Weights (gm) of individual *Chelonia mydas* eggs during laboratory incubation

Temperature °C	Percent sea water	Incubation time (days)											
		2	6	13	20	27	34	41	48	58	63	69	78
27	0	42	43	47	48	48	49	50	51	52	52	52	[a]45.5 } Hatched at 80 days
27	0	44	44	47	48	50	50	51.5	52.5	53	53	52.5	51
27	0	50	49	52	54	55	55	56.5	57.5	58.5	59	59	57
30	0	49	49	52	55	58	59	64.5	67 } hatched at 55 days				
30	25	49	48	52	52.5	53	58	59.5	65				
30	50	46	46	48	50	50	48.5	50	51.5				
32	0	45	45	47	49	51	56.5	63 } Hatched at 47-49 days					
32	0	45	46	49	50	51	55	61					

[a]ruptured due to weak area in shell

moistened with 25% sea water gained 33% compared with the egg in sand moistened with 50% sea water which gained only 12% in weight during the incubation period. These should be contrasted with an egg at the same temperature in sand moistened with distilled water which gained 37%.

(c) On incubation period.

There is no indication that salinity affected the duration of the incubation period. The eggs appeared to be relatively more tolerant to variations in salinity than to variations in temperature (see below).

2. Temperature studies.

Seventy-five eggs in groups of 15 were incubated in sand moistened with distilled water.

Effect of temperature

(a) on incubation success.

Data on percentage hatch at different incubation temperatures are given in Table 5. Only the groups at 27°C and 32°C produced hatchlings.

(b) on water uptake.

The effect of these temperatures on water uptake by the eggs is given for two, weekly intervals in Table 5. It should be noted that the only groups to show a net gain in weight are those at 27°C and 32°C which alone produced hatchlings. The other groups showed a loss in weight from the start which continued in the second week indicating a disturbance in egg metabolism. Weight gains during incubation of some eggs producing hatchlings are given in Table 4. The greatest weight increase during incubation occurred in the 2 eggs at 32°C and the single egg at 30°C. These gained 40, 35 and 37% respectively. Weight gains of the eggs at 27°C were 14, 16 and 24%.

TABLE 5. Percentage hatch and weight changes in groups of 15 *Chelonia mydas* eggs in sand moistened with distilled water at different incubation temperatures (°C)

Temperature	% age hatch	% age weight change	
		after 1 week	after 2 weeks
15	0	−4.8	−5.4
20	0	−2.9	−3.9
27	60	−0.9	+1.9
32	60	+1.6	+3.2
38	0	−1.4	−2.5

(c) on incubation period.

Three eggs at 27°C hatched after 80 days, 3 at 30°C hatched after 55 days and 2 at 32°C hatched after 47 to 49 days.

The 27°C incubator (group of 3 eggs) was accidentally given a temperature of 16°C for 48 hours between days 62 and 64. This did not prevent hatching which occurred on the 80th day.

DISCUSSION

Success of egg laying depends upon the absence of thick roots in the upper layers of sand which would otherwise obstruct digging action of the turtle. In addition the sand must be sufficiently stable to withstand the formation of an egg chamber in it. Principal factors for sand stability are sufficient moisture and enough tree rootlets but superimposed on these (to a lesser extent) is compaction (Fig. 4).

The natural nest temperatures at Heron Island approximate the range 25°C–31°C (depending in part on the stage of incubation). On the basis of Hendrickson's (*ibid.*) results, viz. a 5.9°C rise during incubation, which are confirmed by our preliminary observations, the eggs must be adapted to withstand normal climatic variations of say 2°C plus the effect of metabolic heating—i.e. they must be able to be incubated over a temperature range of at least 8°C. The experimental studies showed that a high incubation success was achieved at 27°C–32°C. Licht and Moberley (1965) have provided data for the tropical lizard *Iguana iguana* suggesting that temperatures very close to 30°C are required for the development of the eggs. After 27 days of incubation they transferred 2 eggs from a batch kept at 30°C to 28°C and 2 others from 30°C to 32°C. These four eggs failed

to hatch. Four of five eggs kept at 30°C throughout the incubation period hatched. Too much reliance should not be placed on these results until they are repeated with larger numbers of eggs. The extremely narrow range of temperature tolerance recorded allows remarkably little leeway for climatic fluctuation combined with temperature increase due to metabolic heating. The extremely large clutch size and the high mean weight (about 45 gm at deposition) of green turtle eggs makes them ideal for experimental studies. A single clutch can provide groups of eggs for a number of experiments.

Licht and Moberly (*ibid.*) stated that the effects of temperature on embryonic development may comprise an important factor in the ecology and distribution of lizards. This factor may be important also in the distribution of sea turtle rookeries and the sand temperatures of 25°C which are recorded in some nesting areas of Heron Island may be close to the tolerable minimum. This factor could explain this island being near the southern distributional limits of the nesting of the species.

The laboratory chlorinity experiments demonstrated that the eggs are able to hatch in chloride concentrations very much greater than those occurring in the natural egg chamber. Chloride concentration is not, therefore, a limiting factor in incubation success except for those few nests which are laid below the spring high tide mark. These nests are destroyed by the high chloride concentration resulting from temporary inundation by the monthly spring high tides.

The transect results (Table 2) show that once above the bank the micro-environment of the egg chamber is relatively uniform throughout the area frequented by nesting turtles.

Many parchment-shelled reptile eggs imbibe large quantities of water during incubation if this is available, for instance the eggs of the Australian agamid lizard *Amphibolurus barbatus* can increase by 225–250% of their weight at laying (Bustard, 1966). Such an increase, however, is not necessary for normal hatching (Bustard, *ibid.* D'miel, pers. comm.). It may be a safeguard against subsequent water shortage during the incubation period and therefore would have survival value in arid areas (Bustard 1965) or in regions where the egg micro-environment is subjected to a daily cycle of rain and drying (Gordon 1960). Significantly, the turtle eggs reported on in the present study were laid in a micro-environment where water shortage is unlikely to occur and did not show such large scale weight increases. In situations where the female turtle successfully dug an egg chamber in the presence of an average amount of roots there was enough moisture for the eggs during incubation. (See the discrepancy between percentage moisture content in sand samples from successful and unsuccessful natural nests.)

Table 4 shows that a significant decrease in weight occurred in the week before hatching in eggs at 27°C which were the only ones reweighed at this time. Data for this period for other reptiles [fully summarized by Bustard (1966)] show considerable variability. Some parchment-shelled reptile eggs continue to increase in weight right up to hatching and may even show an increased rate of water uptake in the few days prior to hatching (e.g. agamid lizards, *Calotes, Agama, Amphibolurus,* the iguanid *Anolis* and the box turtle *Terrapene ornata*), whereas others show an actual decrease (e.g. the snake *Diadophis,* the iguanid *Sceloporus*).

Simkiss (1962) showed that the yolk of the leathery sea turtle *Dermochelys coriacea* only contains about 20% of the calcium and magnesium present in the hatchling and because of the richness of magnesium he was inclined to consider that it might be absorbed from the 1 to 2 ml of water that Hendrickson (1958) anticipated would be taken up. Table 4 shows that water uptake is much greater than this value but in spite of this the micro-environment of the egg mass indicates that as chloride levels are so low, the required amounts of calcium and magnesium probably cannot be obtained from the traces of sea water present.

If the calcium is not obtained from the egg shell, we postulate that it may be obtained externally by means of the metabolism of the egg mass. The coral sand is in excess of 99% calcium carbonate, which is relatively insoluble, but the carbon dioxide given off by the metabolism of the egg mass will form carbonic acid which will react on the calcium carbonate to form the much more soluble calcium bicarbonate.

Simkiss (pers. comm.) has informed us that there is not much magnesium present in the turtle egg shell. If calcium and magnesium are obtained from an external source other than the egg shell and are essential for normal hatching then some mechanism such as postulated above must operate, since we have successfully incubated many turtle eggs in coral sand moistened only with distilled water.

ACKNOWLEDGMENTS

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INFLUENCE OF WATER BALANCE AND MICROCLIMATE ON THE LOCAL DISTRIBUTION OF THE REDBACK VOLE AND WHITE-FOOTED MOUSE

LOWELL L. GETZ

Department of Zoology, University of Connecticut, Storrs, Connecticut

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Abstract. A comparison was made of the importance of water balance, as influenced by microclimate, upon the local distribution of the white-footed mouse, *Peromyscus leucopus*, and the redback vole, *Clethrionomys gapperi*. The characteristic habitats of the two species in southern New England are dry upland woods and low swamps, respectively. Temperature and relative humidity in the habitats of the two species differed only from 0800 to 1600 on clear days; at other times they were the same. Daytime relative humidities averaged 75 to 85 and 70 to 80% in swamp and upland sites, respectively. There was no consistent difference in the absolute humidities between the swamp and upland at any season. Air temperatures during the summer were 2 to 3°C lower in the swamp than in the upland; during the winter they were the same in both. Water turn-over rate of *C. gapperi* is approximately 2.2 times that of *P. leucopus* (10.46 and 4.82 g/day, respectively). The difference results primarily from a more dilute urine from *C. gapperi*; the urine of *P. leucopus* is 2.2 times as concentrated as that of *C. gapperi*. Restriction of *C. gapperi* to low, wet areas in southern New England is correlated with the availability of standing water or an accessible water table, not with microclimate. Evaporative water losses of *C. gapperi* are significantly greater than those of *P. leucopus* at absolute humidities of 6.0–12.8 mg/l; they were essentially the same at 16.3 mg/l. *C. gapperi* is only slightly diurnal; living in the drier uplands would increase its water requirements by only 0.02 g/day. The low water requirement for kidney function of *P. leucopus* permits it to live in drier upland wooded situations where free water is normally restricted to that available in food (fruits and insects). *P. leucopus* is strictly nocturnal; microclimates in swamps and uplands are similar at these times and would not be a factor in the water balance or local distribution of this species.

INTRODUCTION

The correlation between water balance and habitats of small mammals has received considerable attention in recent years. Most of these studies have dealt with adaptations for extreme environments such as deserts. Only a few studies have also concerned species living in mesic situations (Chew 1951, Chenoweth 1917, Pruitt, 1953, 1959, Lindeborg 1952, Dice 1922, Getz 1963, 1965, Church 1966). Most of the latter suggest positive correlations between water balance and the moisture regime of the habitats of the species studied. Some further indicated a significant influence of microclimate upon the water balance of certain species (Getz 1963, Chew 1951, Pruitt 1953, 1959, Chenoweth 1917). Others (Getz 1965, Dice 1922) suggested local microclimate conditions were not sufficiently different to place enough of a stress on the water balance of a species to be a factor in its local distributional pattern.

Most of the above studies, however, were essentially laboratory measurements of water balance of the small mammals with only limited field measurements of water availability and microclimate conditions.

The redback vole, *Clethrionomys gapperi*, and the white-footed mouse, *Peromyscus leucopus*, lend themselves to a study of influence of water balance and microclimate on local distributions of small mammals. In general, *C. gapperi* is limited to relatively moist situations such as low, wet swamps; in some regions it may be found in more

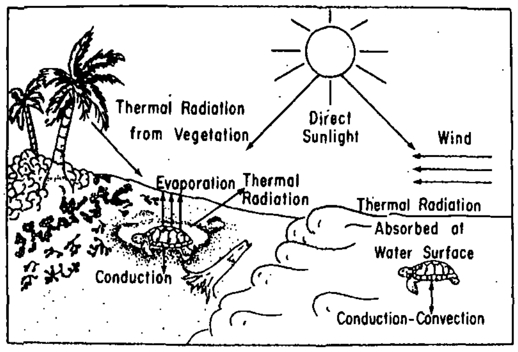

Fig. 1. Heat exchange between sea turtles and their environment. On land heat transfer occurs via radiation, convection (wind), evaporation and conduction. In water heat transfer occurs by conduction-convection.

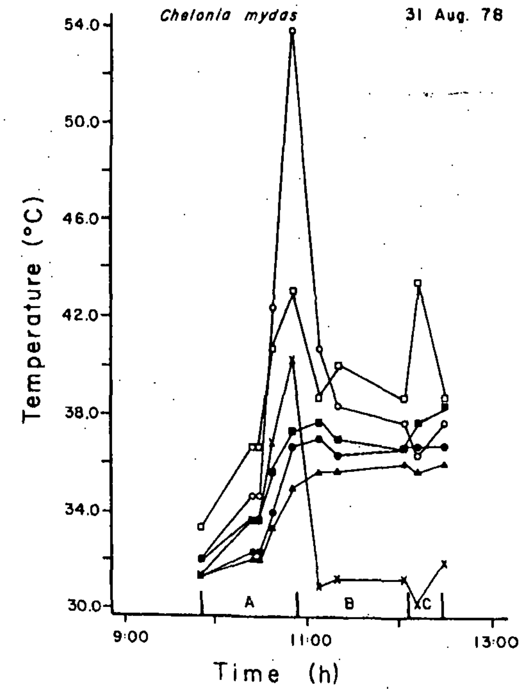

Fig. 2. Telemetered temperatures of a 117 kg adult, female green turtle exercising on land at Tortuguero, Costa Rica. Triangles represent deep body, solid squares are inside plastron, solid circles are inside carapace, open squares are plastron surface, open circles are carapace surface and crosses are unshaded air temperatures. At the beginning of the period indicated as A, the turtle was on its back in the shade. The second data points indicate when this female began to walk on the beach while exposed to full sunlight and a clear sky. When carapace surface temperature reached 53.8 C, the turtle entered the surf (period indicated by B). Deep body temperature continued to rise slowly due to the turtle's internal heat lag. The turtle was placed on its back on the beach (C) and the plastron surface heated. Its temperature dropped quickly when the turtle was placed in the shade (last data point) (Standora et al., 1982).

cause of its elevated metabolism (Mrosovsky, 1980; Standora et al., 1982), reaching 36–41 C when it finished nesting. Thus, it would probably have to return to the water due to heat stress before completing its nest. Eight reports of *Caretta caretta* and *Chelonia mydas* nesting during the day on Florida beaches (Fritts and Hoffman, 1982) include three turtles that emerged in the dark or just before dawn, one that emerged in the evening, and one in midmorning. Of the remaining three turtles, one had been injured by a shark, and two emerged between 1115 and 1450. There are few other instances of diurnal nesting reported for large sea turtles. This is not surprising given the danger of overheating, in addition to the obvious problem of predation.

In light of these data it is surprising that some sea turtles regularly nest during the day (*Lepidochelys kempi* and *L. olivacea*). These species emerge in mass nestings during which thousands of females come ashore in "arribadas." In *L. olivacea* an arribada extends over several days and turtles nest throughout the day and night. In *L. kempi* the arribada occurs during the day and is associated with a strong onshore or offshore wind. This raises an obvious question "Why do ridleys nest during the day when larger sea turtles do not?" The answer to this question is found in the heat exchange properties of these animals and those of their environment.

The primary heat source for a turtle on the beach during the day is solar radiation. Experiments with alligators (*Alligator mississippiensis*) indicate that the body temperatures of large reptiles are more coupled to the absorption of solar and thermal radiation than are the body temperatures of small reptiles because large individuals are less affected by the cooling effect of wind than smaller ones (Terpin et al., 1978). All animals on land are surrounded by a boundary layer of air that adheres to their surface and retards heat exchange with the air (Fig. 3). Moving air strips away the boundary layer and increases heat transfer by convection (Foley and Spotila, 1978). Large size results in a thicker boundary layer and reduces the effect of con-

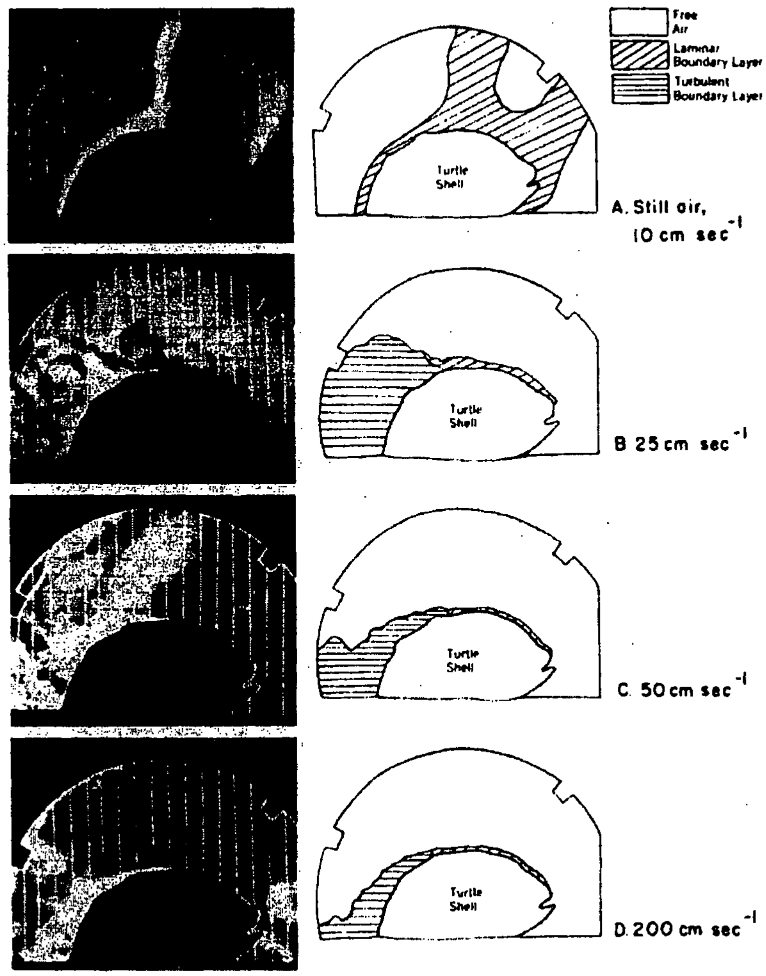

Fig. 3. Schlieren pictures of a heated box turtle shell, with regions of laminar and turbulent flow shown in the accompanying diagrams. Wind (flow from right to left) strips away the boundary layer and brings surface temperature closer to air temperature (Foley and Spotila, 1978).

vection (Spotila et al., 1981). Convection theory as related to animals is discussed at length by Gates (1980:268–305). Mitchell (1976) provides a general predictive relation for convection heat transfer from animal forms based on an equation for convection from a sphere. Using his equations we can evaluate the effect of wind on the heat exchange of sea turtles and explain why small species can nest during the day while large ones cannot.

Convective heat transfer for a turtle or any object immersed in a fluid (air, water, etc.) is a function of many different variables, including size, shape, and orientation of the object; density, viscosity, specific heat and thermal conductivity of the fluid; velocity of flow; and occurrence of laminar or turbulent flow (Gates, 1980). Many of these variables can be combined in dimensionless groups which allow us to compute the convective heat transfer coefficient and from it the amount of heat transfer between an object and the fluid in which it is immersed. Two important dimensionless variables are the Reynolds number (Re) which is an indication of whether flow over a surface is laminar or turbulent and the Nusselt number (Nu) which is

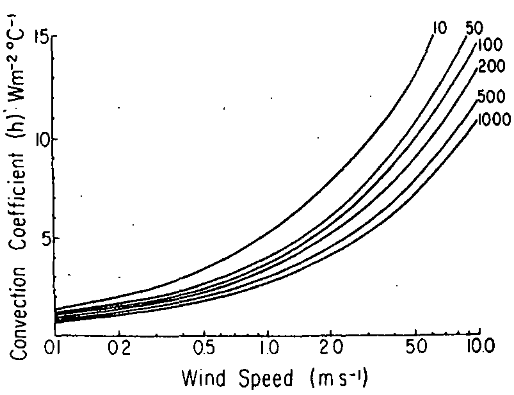

Fig. 4. Effect of body size and wind speed on the convection coefficients (h) of sea turtles in air. Numbers adjacent to curved lines indicate mass in kg. Calculations are based on equations from Mitchell (1976) as discussed in the text.

related to boundary layer thickness and can be used to compute the convective heat transfer coefficient (h). Mitchell (1976) computed h by first deriving equations to define Re and Nu and then computing h as a function of Nu.

In Mitchell's terminology, organism mass is replaced by volume

$$V = m/\rho \qquad (1)$$

where V is volume in m^3, m is mass in kg and ρ is bulk body density. The characteristic dimension (e.g., trunk diameter or length) is defined as

$$L = V^{1/3} \qquad (2)$$

where L is volume-related characteristic dimension in m. The Reynolds number is given as

$$Re_L = vL/\nu \qquad (3)$$

where v is velocity in ms^{-1}, and ν is fluid kinematic viscosity in m^2s^{-1} (relationship of dynamic viscosity to density of the fluid). From a graph of Re vs Nu numbers for a wide variety of organisms Mitchell determined

$$Nu_L = 0.34\ Re_L^{0.6} \qquad (4)$$

and computed h for spherical objects as

$$h = \frac{Nu_L k}{L} \qquad (5)$$

where k is thermal conductivity in $Wm^{-1}\ C^{-1}$. This relationship between body size, wind speed and convection coefficient is seen in Fig. 4. As wind speed increases for a given sized turtle the convection coefficient gets larger and as body size increases for a given wind speed h gets smaller. Thus, small turtles are more affected by wind speed than large ones.

By combining the data in Fig. 4 with microclimatological data for a sunny day on Tortuguero beach, we can analyze the heat load for different sized sea turtles and compute their operative environmental temperatures using standard energy budget equations (Porter and Gates, 1969; Spotila et al., 1972). On a sunny afternoon in Aug. heat radiation absorbed by a turtle (assuming an absorptivity to solar radiation of 0.7 and that one half the body surface is exposed to the sun) would be 864 Wm^{-2} on the upper surface or 432 Wm^{-2} when averaged over the entire surface. Heat gain from the sand at a temperature of 40 C would be 272 Wm^{-2} when averaged over the entire surface. Operative environmental temperatures for 50 and 200 kg sea turtles for these conditions depend upon wind speed (Table 1). In still air, small and large sea turtles would both suffer severe heat stress. At a wind speed of 2 m s^{-1} this stress would be reduced and at higher wind speeds (5 m s^{-1}) these turtles would experience T_e of 30 and 36 C. Thus, a 50 kg ridley turtle could come ashore when wind speed at ground level was at least 3.3 m s^{-1} while a large green turtle (200 kg) could not avoid overheating until wind speed was at least 4.5 m s^{-1}. If we take into account the addition of metabolic heat due to nesting, these values would increase to at least 4.5 m s^{-1} and 6.5 m s^{-1}. Thus, it is not surprising that ridley turtles only come ashore to nest on windy days. This may also explain reports of daylight nesting by *Chelonia depressa* in the Gulf of Carpentaria in Australia (Bustard, 1973) and *Eretmochelys imbricata* in the Camore Island Group in the Indian Ocean (Fritts and Hoffman, 1982).

TABLE 1. THEORETICAL OPERATIVE ENVIRONMENTAL TEMPERATURES (T_e) FOR TWO DIFFERENT SIZED SEA TURTLES RESTING ON THE BEACH AT TORTUGUERO, COSTA RICA ON A SUNNY DAY IN AUGUST.

Body mass (kg)	Wind speed (m s^{-1})	T_e (°C)
50	0.1	58.3
50	2	44.2
50	5	30.0
200	0.1	58.7
200	2	47.2
200	5	36.0

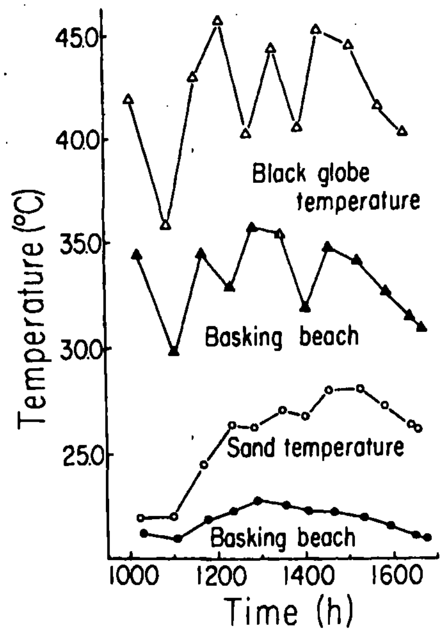

Fig. 5. Sand temperatures (lower two curves) and black globe temperatures (upper two curves) of a beach used for basking (closed circles and triangles) and one not used for basking (open circles and triangles) by green turtles at French Frigate Shoals in the Pacific Ocean (166°13'W, 23°52'N). Redrawn from Whittow and Balazs (1982).

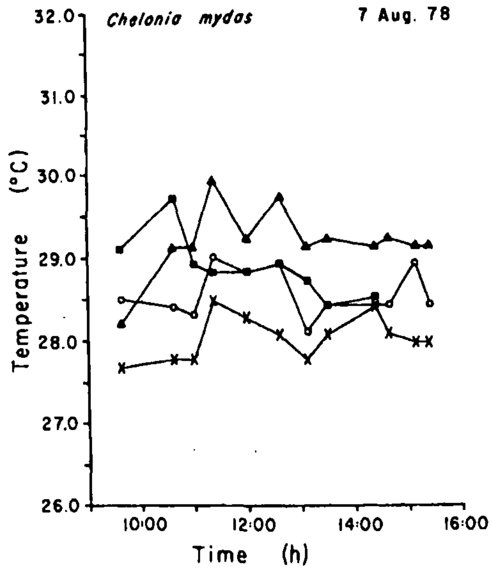

Fig. 6. Temperatures of a 110 kg free-swimming, adult female, green turtle obtained using sonic telemetry at Tortuguero, Costa Rica. Triangles represent deep body, solid squares are inside plastron, open circles are carapace surface, and crosses represent water temperatures. This female was released at 1100 h, remained a few hundred meters off shore and was relatively inactive (Standora et al., 1982).

Basking on Land

Terrestrial basking has been reported for green turtles in the northwestern Hawaiian Islands (Balazs and Ross, 1974; Balazs, 1976, 1980; Whittow and Balazs, 1982), in Australia (Bustard, 1973), and historically in the Galapagos Islands and Mexico (Fritts, 1981). The most complete study of this phenomenon is for *C. mydas* at French Frigate Shoals in the northwestern Hawaiian Islands (Whittow and Balazs, 1982).

Here turtles came ashore and basked on the side of islands facing the outer reef and the prevailing northeast trade winds. Sand temperatures and black globe temperatures (an approximation of T_e) were lower on the basking beach than on a beach on the opposite side of the island that was not used by basking turtles (Fig. 5). In light of the above discussion of convection and T_e for sea turtles, it is apparent that the T_e on the basking beach was moderate and would allow turtles to maintain a stable, elevated body temperature for an extended period of time without danger of overheating. The duration of basking was inversely related to black globe temperature suggesting that high heat loads placed these turtles under heat stress. Carapace temperatures were as high as 40.0–42.8 C. By flipping sand on their carapaces and rear flippers, turtles could reduce surface temperature by as much as 10 C, apparently reducing heat load on peripheral tissues as well as to the deep body. It is of interest to note that green turtles did not orient towards the sun or wind. The same was true for freshwater turtles, *Pseudemys scripta* (Spotila et al., 1984). In this latter species a change in orientation had no effect on T_e (Crawford et al., 1983). Terrestrial basking in Hawaiian green turtles appeared to be fostered by cool ocean temperatures (26.3 C) and a combination of white sand beaches with steady wind and moderate solar intensity that allowed these turtles to reach an elevated body temperature (31.3 C maximum) without being heat stressed. Most of these turtles were females and most of this activity took place during the nesting season. This thermoregulatory behav-

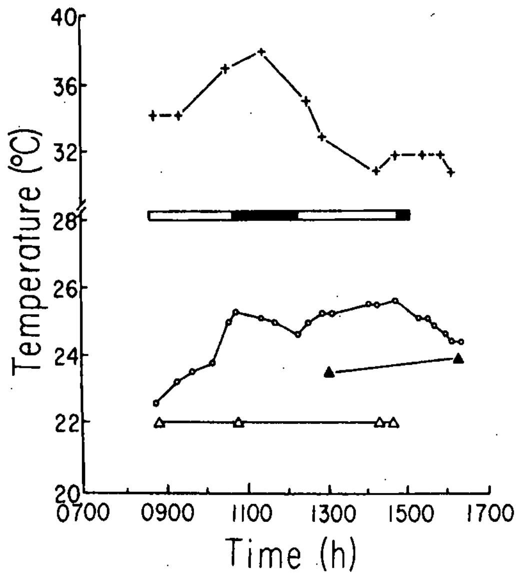

Fig. 7. Body temperature (open circles) of a 42 kg loggerhead during voluntary surface basking in sunlight. Open bar: basking in elevated posture. Closed bar: submerged. Closed triangles: air temperature. Open triangles: water temperature. Crosses: black bulb temperature (Sapsford and van der Riet, 1979).

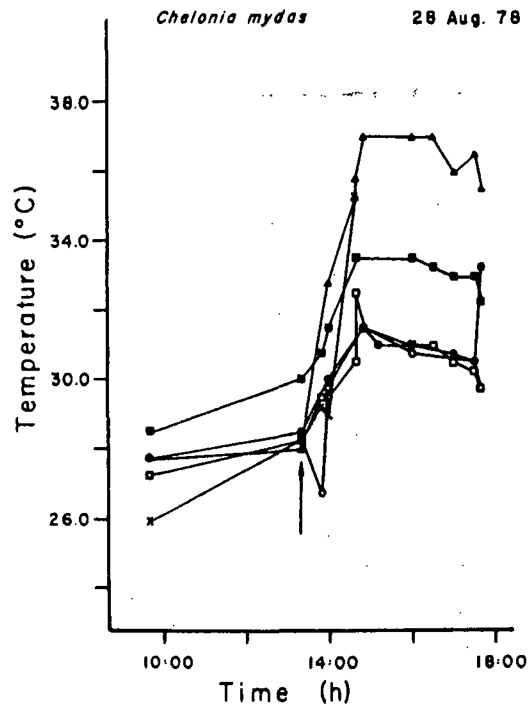

Fig. 8. Temperatures of a 121 kg adult, female green turtle free swimming vigorously in the Caribbean Sea near Tortuguero, Costa Rica. Symbols are as in Fig. 2 except that crosses represent water temperature. Arrow indicates when turtle entered the surf (29 C). This turtle was continuously active and pulled a large polyurethane float and long length (30 m) of manilla rope (diameter 1 cm).

ior, by keeping females warmer than water temperature, may cause an accelerated rate of development of eggs, with a corresponding reduction in inter-nesting interval.

Sea Turtles in the Water

Convection coefficients in water are approximately 100 times greater than in air (Gates, 1980). Therefore, heat transfer is very rapid between the surface of a turtle and the water and heat loss predominates over heat gain by metabolism. In general, the body temperatures of inactive adult green, loggerhead and ridley turtles are within 1–2 C of sea temperature (Mrosovsky and Pritchard, 1971; Hirth, 1962; McGinnis, 1968; Sapsford and van der Riet, 1979; Heath and McGinnis, 1980; Standora et al., 1982). In these animals most heat loss is across the soft skin of the neck and proximal area of the flippers, followed by the plastron, carapace and scaled epidermis on the distal areas of the flippers (Heath and McGinnis, 1980). Multichannel telemetry data (Fig. 6) demonstrates that the body temperature of a resting adult green turtle is above carapace and plastron temperatures which in turn are above water temperature. This suggests that this turtle has some endothermic capability when minimally active (Standora et al., 1982).

In addition to metabolic heat production, sea turtles can also raise their body temperatures above ambient by basking. Aquatic basking has been observed in captive *Caretta caretta, Chelonia mydas* and *L. olivacea* (Sapsford and van der Riet, 1979). A 42 kg *Caretta caretta* raised its body temperature 3.8 C above water temperature by basking in sunlight while keeping a substantial portion of its carapace exposed above the water surface (Fig. 7). Basking during overcast conditions did not cause a rise in body temperature.

In general, sea turtles have body temperatures of 25–33 C. Mean selected temperatures of hatchling loggerhead *C. caretta* are reported as 28–30 C (Owens and Ralph, 1978). Nesting females have temperatures which range from 25.8 C–30.5 C (Mrosovsky, 1980). The tem-

peratures of water occupied by loggerheads during the summer along the Atlantic Coast of the United States can be estimated from data from airborne radiation thermometer charts presented by Bell and Richardson (1978) and range from 25–30 C. These data, plus data on temperatures for maximum sustained swimming speeds of hatchlings (25.6–28.9 C) (O'-Hara, 1980) indicate that the mean selected temperature range for this species is 25–30.5 C. Data reported by Mrosovsky (1980, Fig. 5) indicate that the mean selected body temperature of leatherback turtles ranges from 25.5–33 C. Data are not available to estimate the mean selected body temperature of other sea turtle species.

Lethal temperatures are known for some sea turtle species (Mrosovsky, 1980). Upper lethal temperatures appear to range from 33–40 C (Bustard, 1970; Faulkner and Binger, 1927). Lower lethal temperatures for loggerhead, Kemp's ridley and green turtles range from 5.0–6.5 C (Schwartz, 1978). These temperatures are reflected in the lowest surface water temperatures (7 C) reported in association with sea turtles off the Atlantic coast of the United States by Bell and Richardson (1978) and in the temperatures at which cold stunning of loggerhead and green turtles occurs in Mosquito Lagoon, Florida (Erhart, 1983).

Warm Blooded Turtles?

Leatherback turtles occur often along the coast of Canada and New England (Bleakney, 1965; Shoop et al., 1981). They have been reported from as far north as Sedgwick Bay (52°36'N, 131°82'W) in British Columbia, swimming actively at a temperature of 11.6 C, and in the North Sea (61°18'N, 4°E) off western Norway (Willgohs, 1957). Mrosovsky and Pritchard (1971) reported that leatherback turtles nesting in Surinam and French Guiana had body temperatures of 30.5–31.3 C when sea temperature was 28.3 C. Frair et al. (1972) reported that a leatherback caught off Nova Scotia had a body temperature of 25.5 C when held in water at 7.5 C. This information, in addition to anatomical evidence for a counter current heat exchanger in the front and rear flippers of this turtle (Greer et al., 1973) suggests that the leatherback turtle has considerable endothermic capability and can maintain its body temperature well above the temperature of its environment. Neill and Stevens (1974) caution that while these data indicate that leatherbacks do enjoy great thermal inertia and have some endothermic capabilities, they do not conclusively demonstrate that these turtles can regulate body temperature by physiological means.

Two recent studies on green turtles and one on a leatherback lend support to the hypothesis that large turtles have considerable endothermic capability. Jackson and Prange (1979) found that oxygen consumption of exercising adult green turtles was 10 times the standard resting value. Standora et al. (1982) reported that an adult green turtle swimming vigorously had a body temperature of 37.1 C in water of 29.1 C (Fig. 8). They concluded that *C. mydas* was endothermic. It had a highly aerobic metabolism, (Prange, 1976; Prange and Jackson, 1976) increased its metabolism when active, displayed considerable thermal inertia because of its large size and the excellent insulatory properties of its shell, and exhibited both heterothermy and regional endothermy (Standora et al., 1982).

Standora et al. (1984) recently acquired new data using a multichannel temperature transmitter that clearly indicates that an adult leatherback turtle is endothermic. A 172 kg turtle heated internally from 29.6–30.1 C while inactive on land for 2½ h, with air temperature dropping from 26.2–21.8 C and carapace surface temperature dropping from 26.4–25.3 C.

Given the large size attained by adult leatherback turtles and their anatomical adaptations that conserve heat (counter current heat exchangers and insulating layer of subepidermal fat) we expect that these turtles should be capable of maintaining large temperature differentials between their body core and surrounding water. More data are needed to test this hypothesis for free swimming leatherbacks in cold water.

Conclusions

The thermal biology of sea turtles is a compromise between the constraints imposed by the physical environment and the physical, physiological and behavioral characteristics of the turtles. Heat energy exchange analysis helps us to clarify the thermal energetics of these animals. On land heat gain can rapidly lead to heat stress and this prevents large species from daytime terrestrial activity. In water, heat loss predominates over heat gain and the body temperatures of most sea turtles remain close to water temperatures. However, large sea turtles

can be endothermic. Recent experimental studies have quantified the role of heat exchange in the basking behavior of sea turtles and in their ability to employ endothermy to control body temperature in warm and cold oceans.

Finally, we believe that the studies reviewed in this paper indicate that more can be learned about the thermal biology of sea turtles from a few well planned quantitative experiments than from years of random temperature measurements and anecdotal observations. A quantitative approach will provide more insight into the ecology of sea turtles with less adverse impact on these species than will other less quantitative techniques.

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DEPARTMENT OF BIOLOGY, STATE UNIVERSITY COLLEGE, BUFFALO, NEW YORK 14222. Accepted 6 Nov. 1984.

The Physiological Effects of Multiple Forced Submergence in Loggerhead Sea Turtles (*Caretta caretta*) During Trawling

Final Report to National Marine Fisheries Service, Galveston Laboratory

Erich K. Stabenau and Kimberly R. Vietti

Department of Biology, Bradley University, Peoria, Illinois 61625

Correspondence and questions to: Dr. Erich K. Stabenau, Department of Biology
Bradley University, 1501 W. Bradley Ave.
Peoria, Illinois 61625
e-mail - eks@bumail.bradley.edu
Phone (309) 677-3012, FAX (309) 677-3558

Abstract

Sea turtles are subjected to involuntary submergence and potential mortality due to incidental capture by the commercial fishing industry. Despite implementation of turtle excluder devices (TEDs) to reduce at-sea mortality, dead stranded turtles continue to be found in near-record numbers along the coasts of the western Atlantic Ocean and northern Gulf of Mexico. One plausible explanation for this continued mortality is that sea turtles are repetitively submerged in legal TEDs of one vessel following another. A laboratory study conducted in 1997-1998 revealed that multiple submergence of loggerhead sea turtles (*Caretta caretta*) induced a significant acid-base disturbance (Stabenau and Vietti, 1998). Recovery of blood homeostasis in that study was dependent on the interval between the submergence episodes. However, turtles in that study were confined during the submersion episodes, a condition that does not occur during exposure in TED-equipped commercial fishing nets. The present study was designed, therefore, to examine the physiological effects of multiple enforced submergence in loggerheads following release into and escape from TED-equipped shrimp nets. Pre- and post-submergence blood samples were collected from turtles submerged three times at 7.5 min per episode with a rest interval of 10, 42 or 180 min between submergences. No turtles died during the course of this study. Analyses of the pre- and post-submergence blood samples revealed that the initial submergence produced a severe and pronounced metabolic and respiratory acidosis in all turtles. Successive submergences produced significant changes in blood pH, Pco_2, and lactate, although the magnitude of the acid-base imbalance was substantially reduced as the number of submergences increased. In addition, increasing the interval between successive submergences permitted greater recovery of blood

homeostasis. Taken together, these data suggest that repetitive submergence of sea turtles in TEDs would not significantly affect their survival potential provided the animal has an adequate rest interval at the surface between successive submergences.

Introduction

The five sea turtle species inhabiting the waters of the U.S. Gulf of Mexico and Atlantic Ocean are considered to be threatened or endanger of extinction. One contributing factor to sea turtle mortality is incidental capture in the nets of commercial shrimping vessels. The National Research Council's Committee on Sea Turtle Conservation (1990) suggested that as many as 5,500 to 55,000 loggerhead (*Caretta caretta*) and Kemp's ridley (*Lepidochelys kempi*) sea turtles were killed annually during shrimping-related activities. More recently, two independent studies statistically confirmed the relationship between shrimping activity and the appearance of stranded sea turtles in the U.S. Gulf of Mexico and the Atlantic Ocean (Caillouet *et al.*, 1991; Crowder *et al.*, 1995). Due to the impact of trawl-related mortality on sea turtle populations, the U.S. government passed legislation in 1987 requiring that commercial shrimping vessels pull nets equipped with certified turtle excluder devices (TEDs). TEDs are designed to exclude any turtle that may enter into shrimping nets, while not affecting catch of the target species. Crowder *et al.* (1995) reported that the sea turtle population off the coast of South Carolina continued to decline when TED regulations were implemented, although the rate of decline was significantly less since full-time TED use.

In spite of the TED regulations, near-record numbers of dead stranded sea turtles have been found on U.S. Gulf of Mexico and Atlantic Ocean beaches (W. Teas, pers. comm.). While there may be other man-related or natural causes for this continued sea turtle mortality, there are two plausible reasons for the mortality to be caused during shrimping activities. First, commercial shrimp fishermen are not carrying legally certified TEDs, which may occur with improper installation or by purposely sewing them shut.

Second, the shrimp fishermen are pulling legal TEDs; however, the turtles are repetitively involuntarily submerged as they are caught in the TEDs of vessels following each other. This successive submergence may compound the physiological effects experienced by sea turtles during an involuntary submersion, and thus, may limit their survival potential.

Sea turtles spend all but 1% of their time under the surface of the water. During the brief period at the surface, the turtle will exhale and inhale a solitary breath and then dive under the surface (Jackson, 1985). In fact, multiple breaths by sea turtles are seen only after prolonged dives. Scant information is available on the physiological effects of voluntary submergence of sea turtles. It has been suggested that voluntary dives by sea turtles are aerobic in nature (Wood *et al.*, 1984), whereby oxygen availability minimizes the metabolic production of lactic acid. The turtles may accumulate carbon dioxide, resulting in a respiratory acidosis that is ameliorated by hyperventilation at the surface. Obviously, voluntary diving does not limit sea turtle survival potential.

In contrast, involuntary submergence of Kemp's ridley and loggerhead sea turtles produces significant blood respiratory and metabolic derangements. Stabenau *et al.* (1991) reported that involuntary submergence of Kemp's ridley sea turtles for less than 7.5 min in shrimp nets equipped with TEDs resulted in significant increases in blood lactic acid and Pco_2, and decreases in blood pH. Moreover, several hours were required for turtles to fully recover blood homeostasis (E. Stabenau, pers. observ.). However, the study by Stabenau *et al.* (1991) did not address the physiological effects of multiple submergence of sea turtles. More recently, Stabenau and Vietti (1998) investigated the

effects of three successive submergence episodes of loggerhead sea turtles with an interval of 10, 42 or 180 min between each 7.5 min submergence period. The data revealed that the initial submergence produced a significant and severe acid-base disturbance. Successive submergence episodes caused decreases in blood pH, and increases in blood P_{CO_2} and lactate that were less in magnitude than that measured following the initial submergence. In addition, more than three hours was required to completely recover from the metabolic derangement. Overall, the data suggested that while repeated submergence induces significant blood acid-base disturbances, repetitive submergence should not limit sea turtle survival potential given adequate recovery time at the surface. One problem with the experimental design of the laboratory multiple submergence experiment was that it was conducted under controlled conditions, whereby the turtles were placed into a canvass bag to minimize struggling during submergence. This methodology minimized potential sea turtle mortality, but may have led to an underestimate of the acid-base imbalance caused by the multiple submergence. Therefore, the purpose of the present study was to examine the physiological effects of multiple forced submergence of loggerhead sea turtles during exposure in TED-equipped commercial fishing nets. These data may offer greater insight into potential sea turtle mortality caused by multiple capture in commercial shrimping nets carrying legal TEDs.

Materials and Methods

Thirty-six 2-year old loggerhead sea turtles from the NMFS Galveston Laboratory were used in this study. The turtles were transported from Galveston, TX to Panama City, FL where they were placed into pens in St. Andrews Bay. Each turtle was randomly placed into the experimental (submerged) or control (non-submerged) treatment. Table 1 lists the straight standard carapace length and weight of the 24 experimental turtles used in the submergence study, while Table 2 lists the morphometric data for the 12 control turtles. All turtles were of comparable size and weight, and therefore, any alterations in blood parameters between experimental and control turtles represented treatment effects rather than size effects. The submergence study was initiated after approximately 21 days of natural conditioning in the in-water pens.

The study was initiated by collecting pre-submergence blood samples from the experimental turtles immediately prior to their individual confinement in a weighted mesh bag. Each turtle was then submerged using the standard protocol for TED certification tests. Briefly, the mesh bag containing a turtle was placed onto a line connecting the trawl vessel to the headrope on the shrimp net. Divers then released the turtle (without handling the animal) into the mouth of the trawl. Although the shrimp net was equipped with a TED, divers held the escape door closed for 5 min. The turtle was then permitted to leave the trawl and surface. Thus, the total submergence time was approximately 7.5 min, including the time for the weighted mesh bag containing the turtle to reach the headrope for release into the trawl, the 5 min within the trawl, and the time for the turtle to surface. Turtles were immediately captured at the surface and returned to the trawl vessel for post-

submergence blood sampling. Typically, post-submergence blood samples were collected within 1 min of the turtle surfacing. Following a rest interval of 10 (treatment 1), 42 (treatment 2) or 180 (treatment 3) min in water-filled containers on the trawl vessel, a pre-submergence blood sample was collected and the turtle was submerged a second time. A post-submergence blood sample was then collected immediately upon surfacing. The turtle was then submerged a third time, following the same rest interval between the first and second submergence episodes, and pre- and post-submergence blood samples were collected as described above. A final blood sample was collected 180 min after the final submergence in all turtles. Blood samples were also collected from non-submerged control turtles over the same time intervals to ensure that repetitive handling and blood sampling did not alter blood homeostasis. All blood samples were collected into heparinized vacutainers from the dorsal cervical sinus as described by Owens and Ruiz (1980). No more than 4-6% of blood volume was collected during the serial sampling to minimize potential physiological affects associated with blood volume depletion.

Blood gases (Po_2 and Pco_2) and pH were analyzed immediately following collection using a blood gas analyzer thermostatted to turtle body temperature (27-28.5 °C). Packed red cell volume (hematocrit) was determined following centrifugation of heparinized micro-capillary tubes. Two hundred microliters of whole blood were then added to 10% trichloroacetic acid for lactate analysis. The deproteinized samples were centrifuged, and the supernatant removed and stored at -70°C. Lactate was determined spectrophotometrically using standard enzymatic techniques (Sigma, kit 826-B). The remaining whole blood was then centrifuged, the plasma removed and stored at -70°C.

Plasma Na^+ and K^+ were measured with flame photometry (Jenway, Model PFP7), while plasma Cl^- was determined with electrometric titration (Haake-Bucher, Model 4425000). Plasma osmolality was determined with a vapor pressure osmometer (Wescor, Model 5500). Plasma catecholamine (norepinephrine and epinephrine) samples have been processed and extracted. The samples will be analyzed with high-pressure liquid chromatography (BAS, Model 480). Catecholamine data will be provided to the NMFS Galveston Laboratory as soon as the analyses are completed. However, the preliminary data suggest that catecholamine concentrations recover more rapidly from acid-base imbalances than respiratory and metabolic components.

All data are expressed as means ± SE. Where appropriate, the data was analyzed with one-way ANOVA. Post-hoc comparisons between means were analyzed with Tukey's multiple comparison test. A fiduciary level of $P \leq 0.05$ was regarded as significant.

Results

Blood acid-base status. The initial submergence of loggerhead sea turtles produced a dramatic and severe acidosis in all experimental turtles with blood pH falling an average of 0.63 ± 0.06 (range 0.53 to 0.73 pH units) from pre-submergence values (Figure 1). The blood acidosis was derived from respiratory and metabolic components as evident from a positive proton-lactate deficit (Buffer capacity • ΔpH - Δ[lactate]), and from significant increases in blood Pco_2 (average increase 45 ± 3 mm Hg, Figure 2) and blood lactate (average increase 10.13 ± 0.6 mM, Figure 3) in all experimental turtles. Significant decreases in blood Po_2 also occurred following the initial submergence (Figure 4). In contrast, no significant changes in blood pH, Pco_2 and Po_2, and lactate were measured in non-submerged control turtles (Tables 3-5) following collection of the first two samples.

Recovery of the respiratory and metabolic imbalance in submerged turtles was dependent on the interval between successive submergences. A 10 min interval between the first and second submergence (treatment 1 turtles; blood collection 3 on the figures) permitted partial recovery of blood pH (Figure 1A), although these values remained significantly lower than the pre-submergence values. The blood Pco_2 and Po_2 were comparable to the initial pre-submergence values (Figures 2A and 4A). However, additional increases in the blood lactate concentration were measured during the first recovery interval in these turtles (Figure 3A). Turtles with a 42 min interval (treatment 2 turtles) between the first and second submergence had complete recovery of blood pH (Figure 1B), Pco_2 (Figure 2B), Po_2 (Figure 4B), and slight recovery of the blood lactate concentration (Figure 3B). The [lactate] in the third blood sample from treatment 2

turtles remained significantly elevated from the pre-submergence values. Turtles with a 180 min interval (treatment 3 turtles) between the first and second submergence had complete recovery of the blood pH, Pco_2, Po_2 and lactate (Figures 1C-4C). Non-submerged control turtles exhibited no significant changes in blood pH, Pco_2, and Po_2, whether the interval between collection of the second and third serial blood sample was 10, 42 or 180 min (Tables 3-5). The lactate concentration in control turtles was not affected by repetitive handling (Tables 3-5), although the [lactate] decreased significantly from the initial blood sample lactate values in one control group (Table 5).

The second 7.5 min submergence produced a significant decrement in blood pH and increment in Pco_2 (Figure 1-2) in all experimental treatments. However, the severity of the acid-base imbalance was not as drastic as the acidosis measured following the first submergence. The mean pH difference (Δ pH) between the second pre- and post-submergence blood samples ranged from 0.16 in treatment 1 turtles to 0.66 in treatment 3 turtles. The substantial drop in blood pH in treatment 3 turtles resulted from greater pre- to post-submergence increases in blood Pco_2 and lactate (Figures 2-3) than measured in treatment 1 and 2 turtles. Treatment 3 turtles had a comparable acid-base response to that measured following the initial submergence, whereas treatment 1 and 2 turtles had a reduced acid-base deficit as a result of retention of blood lactate during the recovery period. Collection of the fourth sample from non-submerged control turtles revealed no significant changes in the blood pH, Pco_2, Po_2 or lactate concentration (Tables 3-5).

The fifth serial blood sample collected from treatment 1 and 2 turtles revealed that the blood pH remained significantly lower than the initial pre-submergence value (Figure 1A), reflecting the brief 10 min or 42 min post-submergence recovery interval, respectively, following the second submergence. The acidosis in these animals was due to the continued presence of blood lactate during the post-submergence recovery period (Figures 3A and 3B). In contrast, the blood pH, Pco_2, Po_2 and [lactate] were completely recovered in treatment 3 turtles as a result of the 3 h post-submergence recovery interval (Figures 1C-4C). The acid-base status of non-submerged control turtles was unaffected by collection of the fifth serial blood sample (Tables 3-5).

The third and final submergence produced comparable acid-base changes in treatment 1-3 turtles to that measured following the second submergence. The Δ pH ranged from 0.11 in treatment 1 turtles to 0.65 in treatment 3 turtles (Figure 1). Blood Pco_2 increased in all experimental turtles following the third submergence, with increments ranging from 9.3 to 27.5 mm Hg in treatment 1 and 3 turtles, respectively (Figure 2). Lactate also increased in all experimental turtles following the third submergence, with the magnitude of the increases ranging from 0.9 mM in treatment 1 turtles to 9.3 mM in treatment 3 turtles (Figure 3). In all experimental turtles, the third submergence produced significant decreases in the blood Po_2 (Figure 4). No blood acid-base changes were measured in non-submerged control turtles following collection of the sixth serial sample (Tables 3-5).

Blood homeostasis was achieved in all experimental turtles 3 h after the final forced submergence (Figures 1-3). No significant changes in the blood pH, Pco_2, Po_2 and lactate concentration were detected when compared to the initial pre-submergence values in treatment 1-3 turtles. Similarly, few significant changes in the blood acid-base status were measured in non-submerged control turtles following collection of the final serial sample (Tables 3-5).

Plasma ion concentration and osmotic pressure. Brief forced submergence of loggerhead turtles had a profound effect on the plasma ionic status. Plasma [K^+] increased significantly immediately following submergence in all experimental turtles. Significant increases were also observed in the plasma [Na^+] and osmotic pressure, although these changes did not occur in turtles from all of the experimental treatments (Tables 6-8). Turtles recovered from the ionic imbalances in turtles with a 42 min or 3 h post-submergence interval between collection of the second and third blood sample. However, the plasma K^+ remained significantly higher in turtles with a 10 min post-submergence recovery interval. The second submergence also caused significant increases in plasma K^+ in all experimental turtles (Tables 6-8), whereas the plasma [Cl^-] and [Na^+] were unaffected. As before, the ionic disturbances were resolved during the post-submergence recovery interval, with the exception of the significantly elevated plasma K^+ in turtles with a 10 min post-submergence recovery interval (Tables 6-8). The plasma ionic concentrations and osmotic pressure were not significantly different in treatment 1 and 3 turtles following the third submergence (Tables 6 and 8). However, significant increases in the plasma Na^+ and K^- concentrations were measured in treatment 2 turtles following

the final submergence (Table 7). The ionic concentrations in all experimental turtles 3 h following the final submergence were comparable to the initial pre-submergence values (Tables 6-8). Finally, it should be noted that the plasma ion concentrations and osmotic pressure in non-submerged control turtles were unaffected by serial blood sampling (Tables 9-11). These data suggest that ionic changes in experimental turtles were due to the forced submergence and was not an artifact of handling and repetitive blood sampling.

Discussion

Acid-Base Status. Brief submergence (7.5 min) of 2-yr old loggerhead sea turtles in commercial fishing nets produced a severe and significant acid-base imbalance, whereby pH dropped an average of 0.63 ± 0.06 U after the initial forced submergence. For comparison, a pH drop ranging from 0.37 to 0.50 has been measured in Kemp's ridley (*Lepidochelys kempi*) and loggerhead sea turtles following trawling (Stabenau *et al.*, 1991; Stabenau and Vietti, 1999). Turtles in the latter studies were permitted to escape the TED, and thus, the total submergence duration averaged < 3 to 4 min. To our knowledge, Stabenau and Vietti (1998) have conducted the only study in the literature that offers a comparable experimental protocol to that reported herein. Those authors reported a pH decrease of 0.54 ± 0.03 U following 7.5 min of confined forced submergence of 2-yr old loggerhead turtles under laboratory conditions. The greater acidosis measured in trawled turtles in the study herein resulted from increased swimming activity during the forced submergence. This is confirmed by a post-submergence increase in blood lactate of 10.1 mM under trawling conditions versus 8.8 mM following laboratory submergence.

Recovery of blood homeostasis was dependent on the length of the interval between submersion episodes. Turtles with a 10 min interval following submersion had a lower pH, higher Pco_2 and increased lactate than turtles with a 42 or 180 min post-submergence recovery interval. These results were comparable to those reported for forcibly submerged loggerhead turtles by Stabenau and Vietti (1998). Turtles forcibly

submerged under lab or field conditions hyperventilate upon surfacing. Stabenau *et* al. (1991) reported a 9- to 10-fold increase in the breathing frequency of trawled Kemp's ridley turtles. Comparable breathing rates were observed in the present study (data not shown) after submersion. Thus, turtles with a brief period between the submergence episodes would have a limited ability to release the CO_2 retained during submersion or to breakdown lactic acid produced during the course of the forced dive. In fact, blood [lactate] continued to increase in treatment 1 turtles during collection of the first six serial samples. Substantial retention of CO_2 and lactate during the 10 min post-submergence recovery interval reduced blood pH when compared to the other two treatments. In contrast, turtles with a 42 or 180 min interval between the submersion episodes would have had more time to eliminate CO_2 and lactate during the recovery intervals. Treatment 2 turtles exhibited a 6% drop in the blood [lactate] during the first 42 min post-submergence recovery interval and a 17.5% decrease in the blood [lactate] during the second recovery interval. Thus, a 42 min post-submersion recovery interval permitted recovery of blood gases, but was inadequate to clear blood lactate. Lactate declined 80.4% and 83.8%, respectively, during the first two 180 min post-submergence recovery intervals in treatment 3 turtles. Therefore, the longer surface interval resulted in an increased ability to recover from the submersion episodes. In fact, lactate declined 82.7%, 82.8% and 87.9%, respectively, in treatment 1, 2 and 3 turtles 180 min after the final submersion episode.

Lutz and Dunbar-Cooper (1987) reported that loggerhead turtles captured during trawling at Cape Canaveral, Florida exhibited a 16.8% decline in lactate 3 hr following

submergence. Those authors proposed that the rate of lactate decline was dependent on the magnitude of the lactate concentration, so that 10 mM of lactate would decline at a rate of 1.25 mM lactate hr^{-1}. However, in the current study the rate of lactate decline was considerably higher than suggested by Lutz and Dunbar-Cooper (1987). The overall rate of lactate decline in the present study was 3.6 ± 0.2 mM hr^{-1}. For comparison, Stabenau and Vietti (1998) reported an overall rate of lactate decline of 2.6 ± 0.2 mM hr^{-1} in loggerheads forcibly submerged 7.5 min under laboratory conditions.

Ions, Osmolality and Hematocrit. There are three primary mechanisms for recovery of blood pH following an acid-base disturbance: cellular buffering, and respiratory and renal compensation. Cellular responses occur immediately following the disturbance, whereas respiratory and renal adjustments occur within minutes to hours, respectively. Previously, Stabenau *et al.* (1991) and Stabenau and Vietti (1998) have reported that Kemp's ridley and loggerhead sea turtles exhibited a significant increase in plasma $[K^+]$ following submergence. In the present study, a cellular response to the severe acid-base disturbance caused by multiple forced submergence was suggested by alterations of the plasma ion concentrations and osmolality during and after trawling. Correlation analyses confirmed that decreases in blood pH were associated with increases in the plasma ion concentrations and osmolality (data not shown). Stabenau and Vietti (1998) suggested that turtles might possess stress-mediated red blood cell ion transporters that are activated to restore cell volume and/or cellular pH. The presence of ion transporters would explain the changes to plasma ion concentrations and osmolality during acidosis and warrants further investigation.

Effects of Handling. The blood samples from control turtles did not exhibit significant changes in the blood pH, P_{CO_2}, P_{O_2}, [lactate], or ion concentrations. These data suggest that repetitive serial blood sampling did not cause alterations to acid-base and ionic status in loggerhead sea turtles. Stabenau and Vietti (1998) reached a comparable conclusion following serial sampling of control loggerhead turtles. Thus, the changes in the blood parameters measured in the experimental turtles in the present study were the result of the forced submergence and not an artifact of handling.

Conclusions. From the current study, the data suggest that forced submergence of 2-yr old loggerhead sea turtles produces a significant blood metabolic and respiratory acidosis. Repetitive submergence did not augment the acidosis rather subsequent submergence resulted in less severe acid-base disturbances. Under trawl conditions, the turtle must recover from any physiological acid-base disturbance when it is freed from a TED-equipped net. This is accomplished, in part, by the turtle immediately surfacing and hyperventilating (Jackson, 1985, Stabenau *et al.*, 1991). This behavior was observed during the current study following each submergence episode. Turtles would resume normal voluntary diving behavior, presumably after partial to complete recovery from the acid-base disturbance. These data suggest that repetitive submergence of sea turtles in TEDs would not significantly affect their survival potential, provided that the turtles have an adequate recovery surface interval between successive submergences. However, it should be noted that the latter statement is based on turtles that may be involuntarily submerged in shrimp nets equipped with legally certified and installed turtle excluder devices. Poor installation or lack of use of legal TEDs would result in augmenting the

acid-base imbalance in the turtles. Increasing the magnitude of the blood acid-base and ionic disturbance during each submersion would increase the length of time necessary to achieve partial or complete recovery.

Acknowledgments

Grateful appreciation is expressed to personnel from the National Marine Fisheries Service Galveston and Pascagoula Laboratories for their assistance in turtle husbandry and in conducting the submersion protocol under very difficult field conditions.

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Table 1. Straight standard carapace length, weight, and the interval between successive submergence episodes for experimental turtles.

Tag #	Submergence Interval	Length (cm)	Weight (kg)
sss-404	10 min	36.3	7.19
sss-408	10 min	36.3	6.69
sss-441	10 min	36.2	6.73
sss-456	10 min	34.5	6.19
sss-495	10 min	36.6	7.20
sss-503	10 min	35.0	6.30
sss-559	10 min	35.9	6.85
sss-564	10 min	35.0	6.01
	mean	35.7	6.64
	SE	0.3	0.16
sss-448	42 min	34.7	5.92
sss-479	42 min	35.4	5.99
sss-490	42 min	37.1	7.15
sss-505	42 min	37.0	7.53
sss-509	42 min	37.10	7.10
sss-553	42 min	35.0	6.42
sss-562	42 min	36.4	6.69
sss-588	42 min	36.0	6.82
	mean	36.1	6.70
	SE	0.3	0.20
sss-445	180 min	34.6	6.25
sss-453	180 min	36.5	7.19
sss-466	180 min	33.9	7.15
sss-523	180 min	34.4	6.82
sss-534	180 min	36.4	7.07
sss-541	180 min	36.6	6.89
sss-567	180 min	36.3	7.06
sss-576	180 min	37.4	7.36
	mean	35.8	6.97
	SE	0.4	0.12

Table 2. Straight standard carapace length and weight of individual control turtles.

Tag #	Length (cm)	Weight (kg)
sss-491	35.5	6.18
sss-528	34.4	5.99
sss-565	34.5	6.53
sss-574	35.2	6.11
sss-407	36.0	6.65
sss-422	34.5	6.11
sss-513	36.5	7.00
sss-514	37.0	7.15
sss-485	36.7	6.72
sss-536	36.5	6.90
sss-593	34.7	6.07
sss-598	33.9	6.11
Mean	35.4	6.46
SE	0.3	0.12

Table 3. Blood pH, P_{CO_2}, P_{O_2}, and lactate from control non-submerged turtles to examine the effects of repetitive sampling. Serial blood samples were collected with a 7.5 min interval between samples 1-2, 3-4, and 5-6. A 10 min interval separated collection of samples 2-3, and 4-5. Sample 7 was collected 3 h after sample 6. A significant difference between samples 1-2, 3-4, and 5-6 are indicated by an asterisk (*), whereas significant differences of samples from the initial pre-submergence sample (serial sample 1) are denoted by a pound sign (#).

Serial Sample	pH	P_{CO_2} (mm Hg)	P_{O_2} (mm Hg)	Lactate (mM)
1	7.54 ± 0.02	30.2 ± 1.5	58.9 ± 5.3	0.5 ± 0.1
2	7.55 ± 0.02	28.2 ± 2.3	73.2 ± 3.0	0.6 ± 0.0
3	7.56 ± 0.03	30.4 ± 2.4	73.3 ± 3.7	1.0 ± 0.2
4	7.58 ± 0.02	31.2 ± 1.9	70.6 ± 5.4	1.1 ± 0.1
5	7.55 ± 0.02	30.9 ± 2.4	61.8 ± 6.8	1.1 ± 0.2
6	7.53 ± 0.02	31.2 ± 2.0	68.2 ± 6.2	1.3 ± 0.2#
7	7.53 ± 0.03	33.8 ± 1.9	58.4 ± 1.6	0.7 ± 0.1

Table 4. Blood pH, P_{CO_2}, P_{CO_2}, and lactate from control non-submerged turtles to examine the effects of repetitive sampling. The rest of the legend is as in Table 3, with the exception that the interval between samples 2-3, and 4-5 was 42 min.

Serial Sample	pH	P_{CO_2} (mm Hg)	P_{O_2} (mm Hg)	Lactate (mM)
1	7.50 ± 0.01	37.2 ± 1.5	67.6 ± 6.5	0.9 ± 0.1
2	7.52 ± 0.02	34.9 ± 1.8	68.2 ± 5.3	1.1 ± 0.1
3	7.58 ± 0.02	32.8 ± 1.5	64.0 ± 3.5	0.8 ± 0.1
4	7.55 ± 0.03	36.5 ± 3.2	64.2 ± 3.7	1.6 ± 0.5
5	7.60 ± 0.01#	33.1 ± 0.7	61.4 ± 4.1	0.9 ± 0.2
6	7.60 ± 0.02#	32.9 ± 0.6	65.9 ± 1.6	1.1 ± 0.2
7	7.54 ± 0.02	30.7 ± 0.8	59.9 ± 3.0	0.7 ± 0.0

Table 5. Blood pH, P_{CO_2}, P_{O_2}, and lactate from control non-submerged turtles to examine the effects of repetitive sampling. The rest of the legend is as in Table 3, with the exception that the interval between samples 2-3, and 4-5 was 180 min.

Serial Sample	pH	P_{CO_2} (mm Hg)	P_{O_2} (mm Hg)	Lactate (mM)
1	7.47 ± 0.03	28.6 ± 0.8	68.9 ± 1.9	1.5 ± 0.2
2	7.47 ± 0.02	31.0 ± 1.7	68.5 ± 3.9	1.1 ± 0.2
3	7.52 ± 0.01	29.2 ± 1.6	60.1 ± 3.5	0.6 ± 0.1#
4	7.54 ± 0.02	29.2 ± 0.4	63.3 ± 4.4	0.9 ± 0.1
5	7.56 ± 0.01#	28.0 ± 1.8	64.9 ± 3.2	0.6 ± 0.2#
6	7.54 ± 0.03	32.6 ± 1.4	73.3 ± 2.6	0.9 ± 0.2
7	7.52 ± 0.01	34.4 ± 0.8	61.4 ± 2.1	0.7 ± 0.1#

Table 6. Mean (± SE) plasma Na^+, K^+, Cl^- concentration, hematocrit and plasma osmotic pressure prior to and following multiple forced submergence in loggerhead sea turtles. The interval between each submergence episode was 10 min. The rest of the legend as in Table 3.

Serial Sample	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Hematocrit (%)	Osmotic pressure (mosmoles•kg^{-1})
1	153 ± 2	3.3 ± 0.3	112 ± 5	31.9 ± 1.2	318 ± 4
2	171 ± 8	5.5 ± 0.3*#	120 ± 3	32.6 ± 0.7	345 ± 4*#
3	156 ± 6	4.3 ± 0.0#	113 ± 6	32.4 ± 0.6	332 ± 4
4	171 ± 8	5.3 ± 0.1*#	123 ± 3	32.9 ± 0.7	349 ± 1#
5	166 ± 4	4.3 ± 0.1#	114 ± 3	32.6 ± 0.9	334 ± 2
6	166 ± 12	5.1 ± 0.1#	116 ± 5	31.9 ± 1.1	335 ±11
7	157 ± 4	3.7 ± 0.1	111 ± 3	29.5 ± 1.1	325 ± 2

Table 7. Mean (± SE) plasma Na^+, K^+, Cl^- concentration, hematocrit, and plasma osmotic pressure prior to and following multiple forced submergence in loggerhead sea turtles. The interval between each submergence episode was 42 min. The rest of the caption is as described in Table 3.

Serial Sample	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Hematocrit (%)	Osmotic pressure (mosmoles•kg^{-1})
1	160 ± 4	3.1 ± 0.2	112 ± 3	29.6 ± 1.1	331 ± 12
2	186 ± 8*#	5.0 ± 0.4*#	120 ± 2	31.4 ± 1.1	368 ± 10
3	163 ± 3	2.8 ± 0.1	112 ± 4	29.6 ± 1.3	338 ± 11
4	181 ± 3	4.9 ± 0.3*#	120 ± 4	29.1 ± 1.1	361 ±13
5	160 ± 8	2.9 ± 0.2	115 ± 6	28.7 ± 1.0	332 ± 9
6	185 ± 4*#	4.5 ± 0.4*#	114 ± 1	28.7 ± 1.0	343 ±14
7	161 ± 6	2.6 ± 0.2	108 ± 3	29.5 ± 1.1	326 ± 9

Table 8. Mean (± SE) plasma Na^+, K^+, Cl^- concentration, hematocrit, and plasma osmotic pressure prior to and following multiple forced submergence in loggerhead sea turtles. The interval between each submergence episode was 180 min. The rest of the caption is as described in Table 3.

Serial Sample	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Hematocrit (%)	Osmotic pressure (mosmoles•kg^{-1})
1	164 ± 2	4.5 ± 0.7	114 ± 3	31.4 ± 1.9	325 ± 9
2	188 ± 4	7.0 ± 0.6*#	125 ± 5	31.2 ± 1.0	355 ± 3*#
3	163 ± 10	3.6 ± 0.3	116 ± 4	29.7 ± 0.4	314 ± 3
4	176 ± 10	6.2 ± 0.3*#	116 ± 7	29.0 ± 1.1	352 ± 9*
5	173 ± 10	4.0 ± 0.2	117 ± 5	27.2 ± 0.3	323 ± 3
6	175 ± 18	5.3 ± 0.0	112 ± 5	28.9 ± 0.6	333 ± 11
7	159 ± 11	3.6 ± 0.6	116 ± 7	25.3 ± 0.5	320 ± 4

Table 9. Mean (± SE) plasma Na^+, K^+, and Cl^- concentration, and plasma osmotic pressure in control non-submerged turtles. Samples were taken following the 10 min blood collection protocol. None of the pre- to post-submergence samples was significantly different.

Serial Sample	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Osmotic pressure (mosmoles•kg^{-1})
1	150 ± 3	3.0 ± 0.2	116 ± 2	313 ± 8
2	144 ± 6	3.2 ± 0.1	110 ± 2	309 ± 6
3	146 ± 2	3.1 ± 0.1	112 ± 2	314 ± 7
4	153 ± 1	3.2 ± 0.1	112 ± 3	314 ± 4
5	150 ± 3	3.2 ± 0.2	111 ± 4	324 ± 4
6	143 ± 4	3.2 ± 0.1	114 ± 5	313 ± 4
7	142 ± 4	3.1 ± 0.2	109 ± 2	315 ± 7

Table 10. Mean (± SE) plasma Na^+, K^+, and Cl^- concentration, and plasma osmotic pressure in control non-submerged turtles. Samples were taken following the 42 min blood collection protocol. None of the pre- to post-submergence samples was significantly different.

Serial Sampling	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Osmotic pressure (mosmoles•kg^{-1})
1	139 ± 6	3.4 ± 0.2	115 ± 2	321 ± 7
2	146 ± 5	3.2 ± 0.1	116 ± 2	314 ± 7
3	146 ± 4	3.4 ± 0.2	116 ± 2	316 ± 6
4	144 ± 4	3.4 ± 0.2	110 ± 2	319 ± 5
5	145 ± 3	3.3 ± 0.2	114 ± 3	315 ± 4
6	146 ± 6	3.3 ± 0.3	114 ± 3	317 ± 5
7	148 ± 3	3.2 ± 0.2	114 ± 2	319 ± 6

Table 11. Mean (± SE) plasma Na^+, K^+, and Cl^- concentration, and plasma osmotic pressure in control non-submerged turtles. Samples were taken following the 180 min blood collection protocol. None of the pre- to post-submergence samples was significantly different.

Serial Sample	Na^+ (mM)	K^+ (mM)	Cl^- (mM)	Osmotic pressure (mosmoles•kg^{-1})
1	151 ± 1	3.1 ± 0.1	113 ± 2	310 ± 5
2	152 ± 5	3.1 ± 0.1	115 ± 1	311 ± 6
3	156 ± 2	3.0 ± 0.1	117 ± 4	310 ± 6
4	148 ± 3	3.0 ± 0.1	116 ± 1	311 ± 5
5	151 ± 4	2.9 ± 0.1	117 ± 1	307 ± 5
6	146 ± 2	2.9 ± 0.1	118 ± 2	308 ± 5
7	154 ± 5	2.9 ± 0.2	119 ± 3	307 ± 8

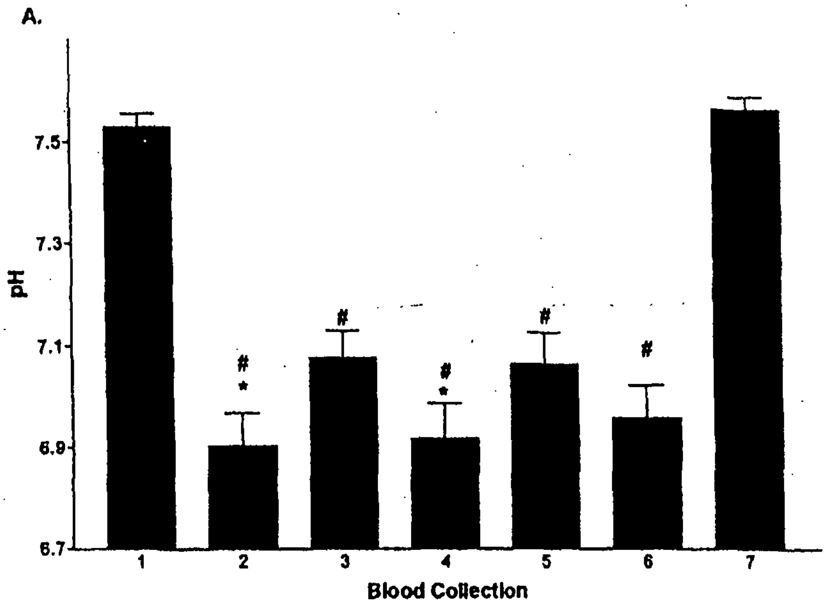
Figure Legends

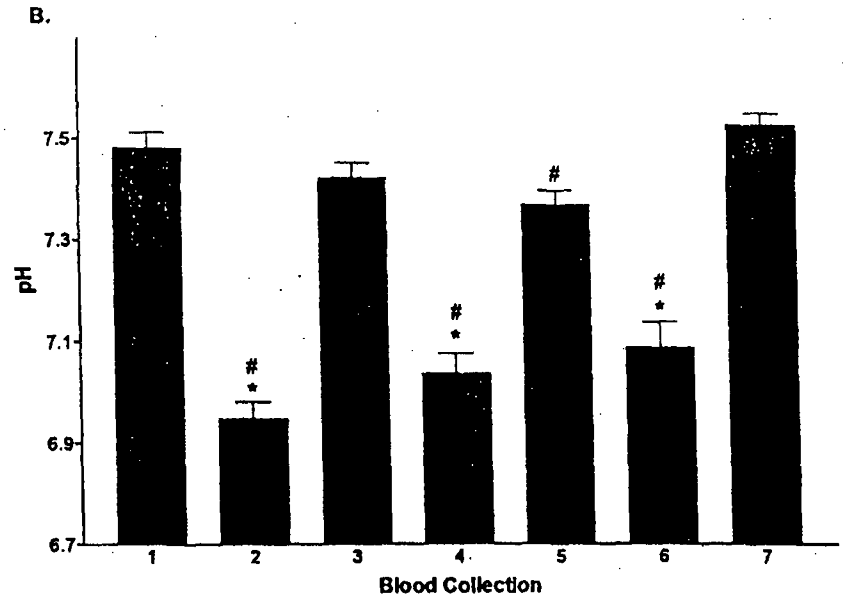
1. Blood pH measured prior to and after three successive forced submergence episodes in loggerhead sea turtles. Samples 1, 3 and 5 are pre-submergence, whereas samples 2, 4, and 6 are post-submergence. Sample 7 was collected three hours after the final submergence. The interval between the submergences was 10 min (A), 42 min (B) or 180 min (C).

2. Blood P_{CO_2} measured prior to and after three successive forced submergence episodes in loggerhead sea turtles. The interval between the submergences was 10 min (A), 42 min (B) or 180 min (C). Rest of the legend as in Figure 1.

3. Blood lactate concentration measured prior to and after three successive forced submergence episodes in loggerhead sea turtles. The interval between the submergences was 10 min (A), 42 min (B) or 180 min (C). Rest of the legend as in Figure 1.

4. Blood P_{O_2} measured prior to and after three successive forced submergence episodes in loggerhead sea turtles. The interval between the submergences was 10 min (A), 42 min (B) or 180 min (C). Rest of the legend as in Figure 1.


A.
7.5
7.3
7.1
6.9
6.7
pH
#
*
1
2
3
4
5
6
7
Blood Collection


B.
7.5
7.3
7.1
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6.7
pH
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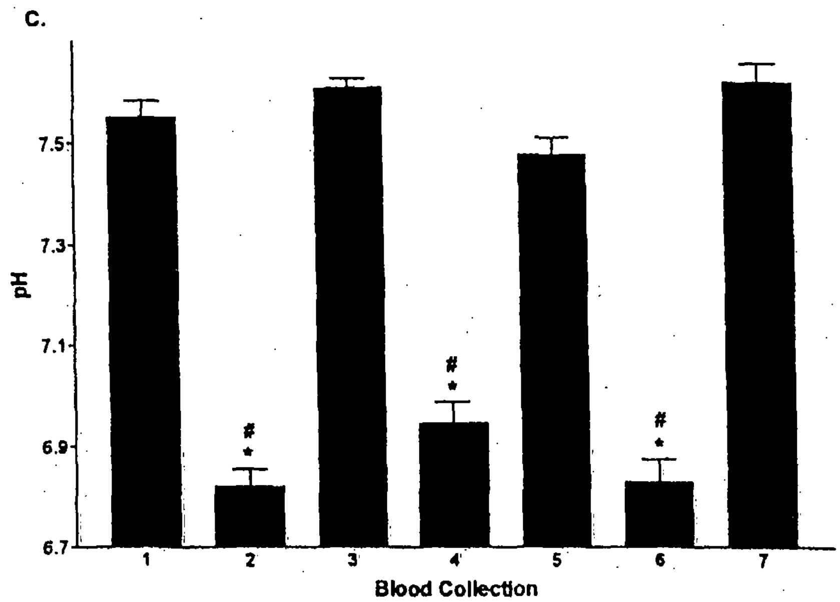
5
6
7
Blood Collection


C.
7.5
7.3
7.1
6.9
6.7
pH
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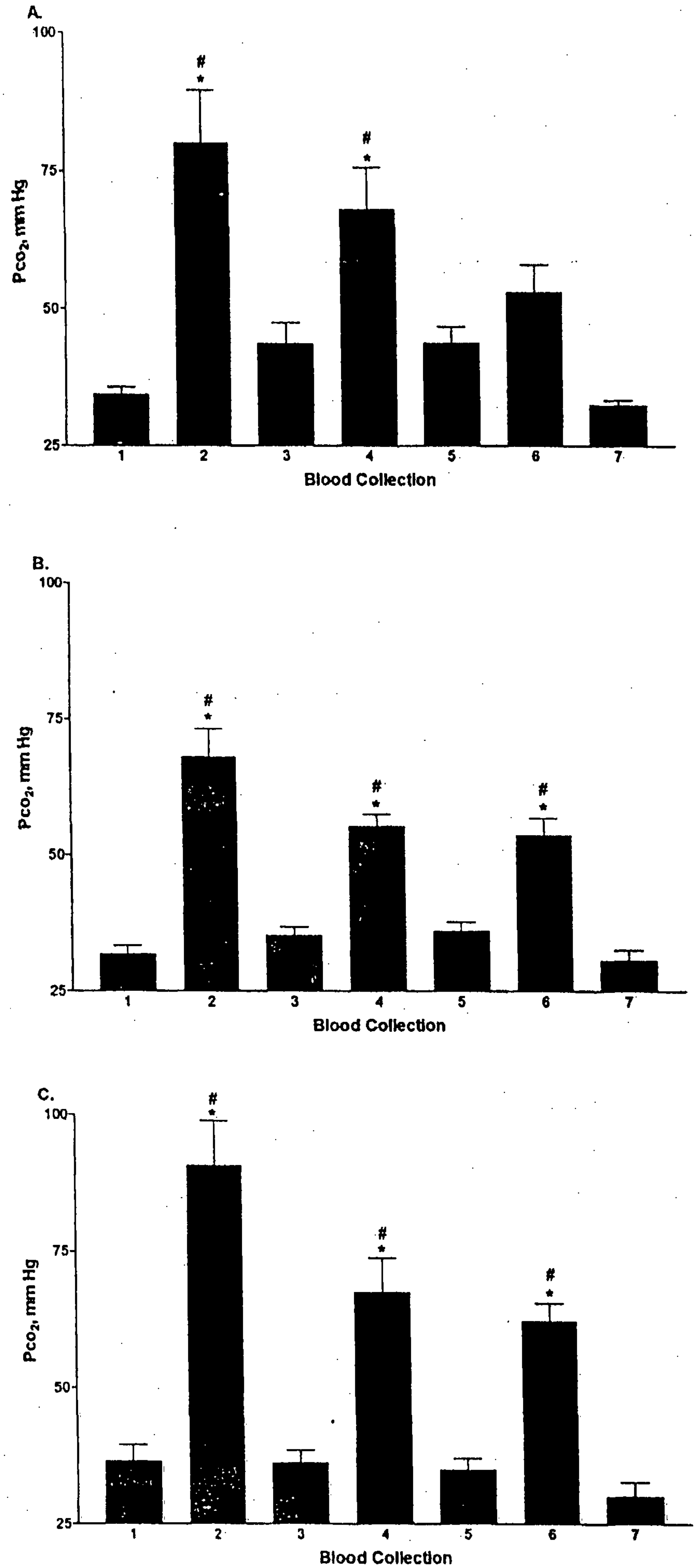
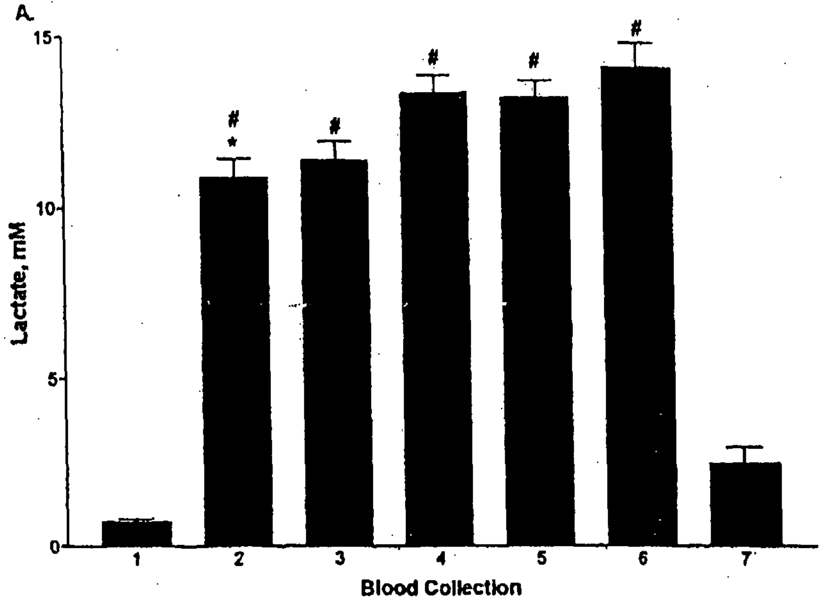
Blood Collection


A.
B.
C.
Pco2, mm Hg
100
75
50
25
1
2
3
4
5
6
7
Blood Collection
#
*

A.



15
10
5
0
Lactate, mM
#
*
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1
2
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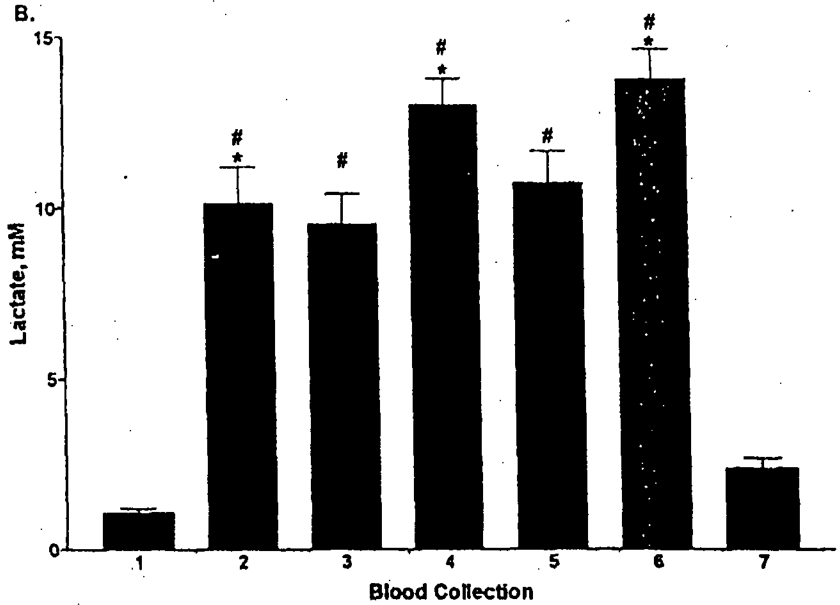
4
5
6
7
Blood Collection

B.



15
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Lactate, mM
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1
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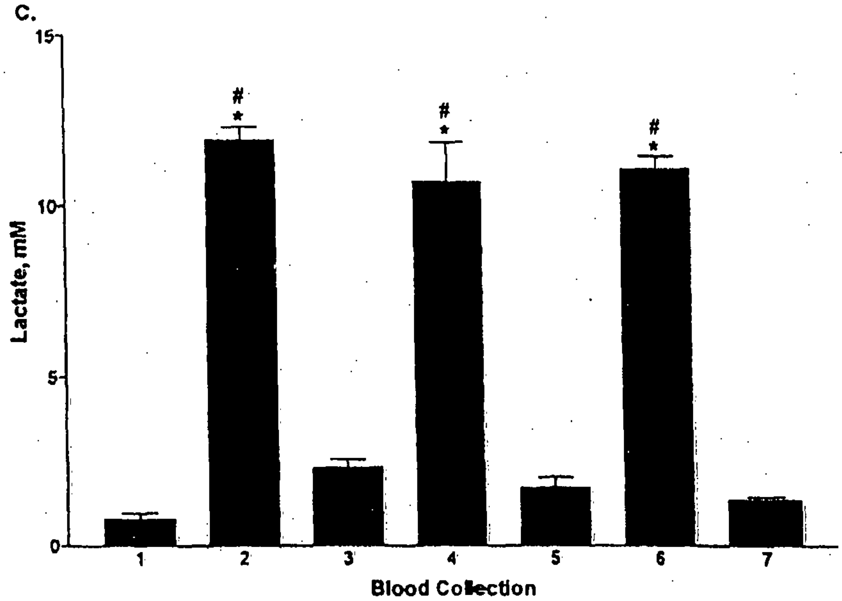
7
Blood Collection

C.



15
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Lactate, mM
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1
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4
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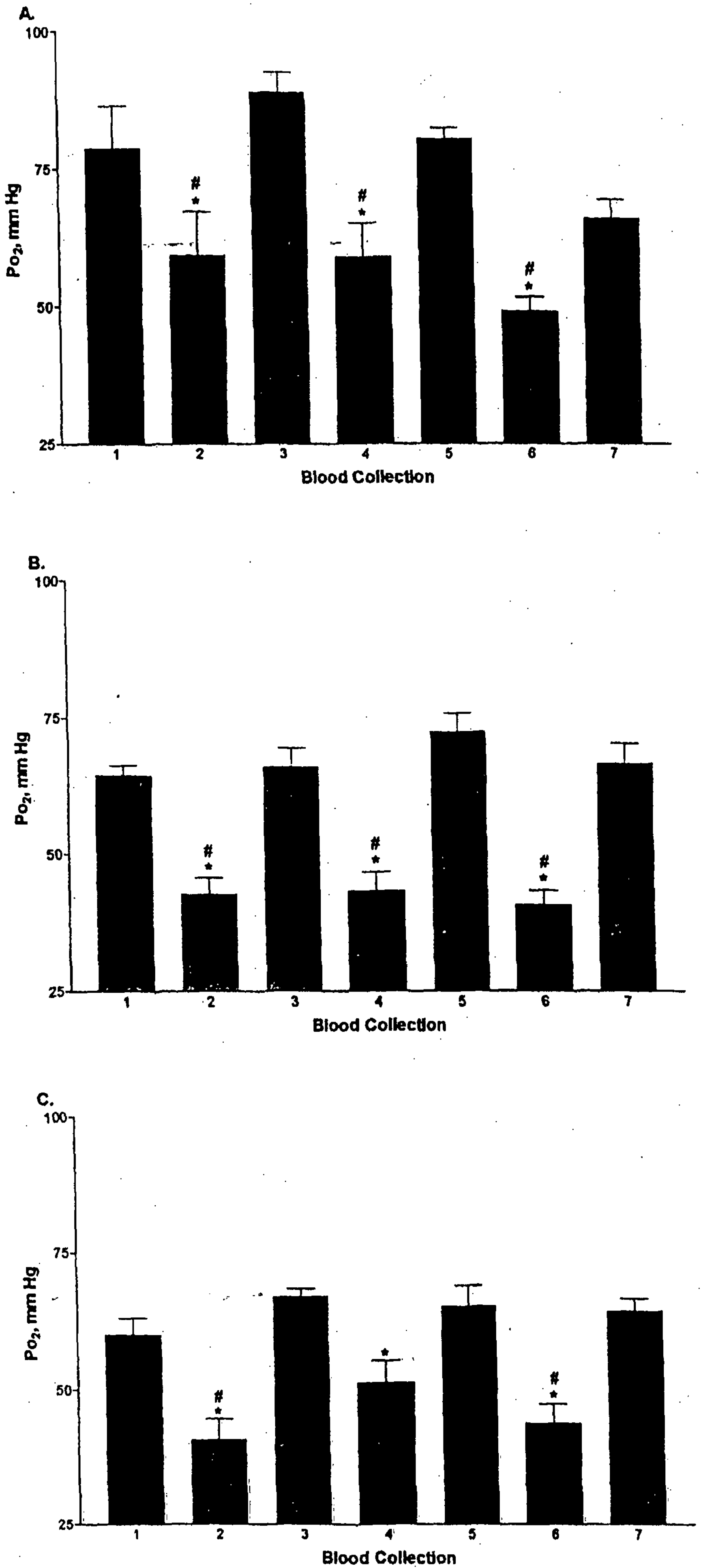
Blood Collection



A.
B.
C.
100
75
50
25
Po2, mm Hg
1
2
3
4
5
6
7
Blood Collection
#
*

Recd from Jeannette Bowers-Altman, New Jersey DEP 9.18.06

Informal Comments Regarding the Biological Assessment: Oyster Creek Nuclear Generating Station – Sea Turtle Impact Assessment. March 2005, Docket No. 50-219, U.S. Nuclear Regulatory Commission

Submitted by: NJ Division of Fish and Wildlife, Endangered and Nongame Species Program, May 2005

The document is well written and covers all pertinent topics. Comments and recommendations are as follows:

- Page 5-19 states that sea turtles were not captured during 20,000 hours of sampling at the intake structures. The described trash racks in front of the screens would have precluded any sea turtles from reaching the Ristroph screen troughs, where sampling by biologists takes place. It would have been impossible for sea turtles to reach the sampling area, thus possibly explaining in part why there were no captures.

- Regarding the thermal plume: the late seasonal captures that have occurred (late September and October) suggest that warm water may have acted as an attractant and possible thermal refuge for these warmer water species. Page 7-5 states that cold stunning may be a possible cause of death for some turtles taken at OCGS. Despite the thermal-plume dispersion descriptions, the conduit waterway, Oyster Creek, and associated lagoons is a large water body that stays uniformly warmer when the plant is operating. The warm waters, during the fall temperature decline, could certainly act as an attractant in and of itself. Additionally, food resources exist there for a longer season. As the ambient water temperatures continue to decline, it may be too late for any sea turtles that took refuge in the area to successfully vacate Barnegat Bay. In an effort to find more comfortable temperatures, some of the sea turtles may have followed the waterways into the intake of the power plant. What about other individuals that may have been in the same area? (Although page 5-18 states that sea turtles are not commonly found in Barnegat Bay, the studies used to support this assumption were performed prior to the 1991 and 1993 modifications to Barnegat Inlet). Are sea turtles travelling/feeding in groups when in the bay? There is an unmeasured potential for sea turtle mortality here. If 4 dead Kemp's Ridley sea turtles represent .18% of the extant population (estimated worst-case annual loss), would 40 represent 1.8%; is this significant? Additional sea turtle mortality could potentially go unnoticed in this situation.

- Just glancing at available NOAA weather data, it looks as though there have been sea turtles reported at OCGS often during high easterly winds or a drop in ambient air temperature, either the day before or on the day of capture (water temperature was not available, but since the bay is so shallow, water temp. and air temp. may be more closely tied). This relationship should be explored further in order to predict when sea turtles will most likely be captured. The role of the Gulf Stream vs. sea turtle occurrences at OCGS should also be examined. If the Gulf Stream came closer to the coast during 2004, it might help explain the increase in sea turtle captures.

In addition to the above-mentioned comments, we recommend the following actions be taken to help minimize sea turtle mortalities at OCGS in the future:

- Increased monitoring of CWS and DWS trash racks during times of eelgrass dieoffs, large influxes of sea lettuce, increased easterly winds or rapid temperature drops in the fall.

- Increased lighting at all trash racks. Although there are high intensity lamps and floodlighting at these locations, page 7-7 states that even with portable spotlights, visibility is limited to approximately 1 meter below the water's surface. This sounds like a problem that could be easily addressed.

- If an interval of sea turtle abundance occurs in the summer, it may be worth a look by boat (if feasible) during the ensuing period of temperature drop to determine the presence of sea turtles that may elect to stay in the warm water areas in Oyster Creek and its confluence with Barnegat Bay

- As recommended by NRC, OCGS staff should develop the capability to perform gross necropsies ASAP after turtle mortality is discovered.

- Investigate the use of video technology to look for surfaced turtles further up the intake canal, thus minimizing the time of impingement by increasing "turtle watch" activities at the racks and screens.

OYSTER CREEK GENERATING STATION
SEA TURTLE PROGRAM

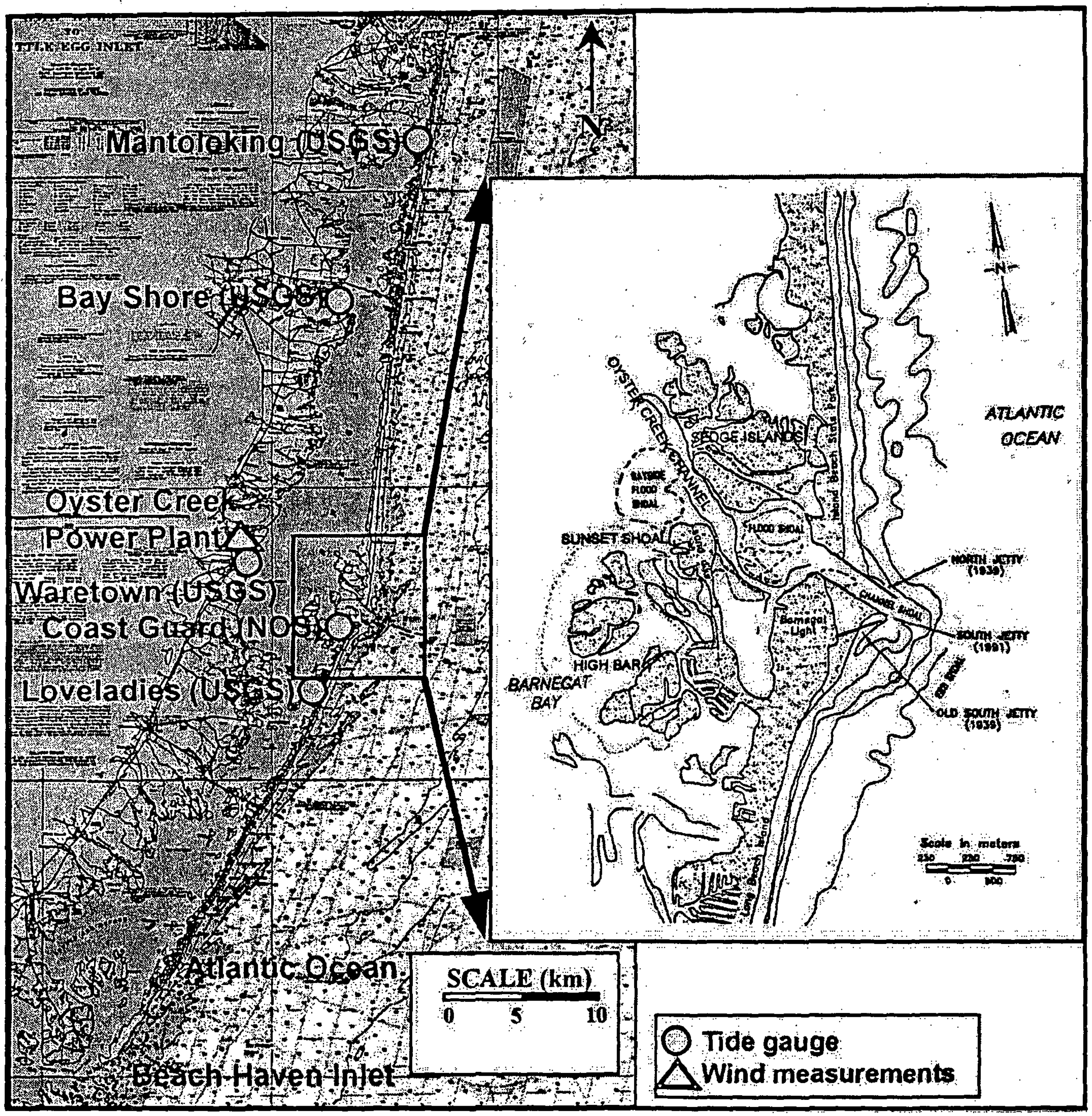
September 19, 2006

Presented @ 9.19.06 meeting between NMFS (Julie Crocker), NRC (Harriet Nash) + AmGen

Attendance Sheet
Oyster Creek Turtle Rescue Program
September 19, 2006

Please verify information. Correct if necessary.

Name	Agency	Phone	Email	Initial
Julie Crocker	NMFS	978-281-6530	julie.crocker@noaa.gov	
Harriet Nash	NRC	301-415-4100	hln@nrc.gov	
Mike Masnic	NRC	301-415-1191	mtm2@nrc.gov	
Ryan Treadway (tentative)	NRC	609-971-4977	Ryan.Ryan@exeloncorp.com	
Jeanette Bowers-Altman	NJ DEP	856-629-0261	jeanette.bowers@dep.state.nj.us	
Paul Schwartz	BNE	609-984-7539	paul.schwartz@dep.state.nj.us	
Terry Schuster	OCNGS	609-971-2333	Terence.Schuster@ exeloncorp.com	
Malcolm Browne	OCNGS	609-971-4124	Malcolm.Browne2@ exeloncorp.com	
Marcia Pruskowski	OCNGS	609-971-4832	Marcia.Pruskowski@ exeloncorp.com	
Jhansi Kandasamy	OCNGS	609-971-4754	Jhansi.Kandasamy@exeloncorp.com	
Craig Baechler	OCNGS	609-971-4371	Craig.Baechler@exeloncorp.com	


N
Mantoloking (USGS)
Bay Shore (USGS)
Oyster Creek
Power Plant
Waretown (USGS)
Coast Guard (NOS)
Loveladies (USGS)
Atlantic Ocean
Beach Haven Inlet
SCALE (km)
0 5 10
ATLANTIC
OCEAN
OYSTER CREEK CHANNEL
SEDGE ISLANDS
SUNSET SHOAL
FLOOD SHOAL
NORTH JETTY
(1939)
CHANNEL SHOAL
SOUTH JETTY
(1991)
OLD SOUTH JETTY
(1939)
HIGH BAR
BARNEGAT
BAY
Scale in meters
Tide gauge
Wind measurements

OYSTER CREEK GENERATING STATION SEA TURTLE INCIDENTAL TAKES, Rev. 09/06

DATE OF TAKE	TIME OF TAKE	SPECIES AND LIFE STAGE	CARAPACE LENGTH (cm) & WEIGHT (kg)	TAKEN AT CWS OR DWS/ (NO. PUMPS OP.)	INTAKE TEMP. deg. F (C)	ALIVE WHEN TAKEN?	FRESH DEAD?	BOAT PROP WOUNDS?	RELEASE SITE
6/25/1992	10:00 PM	Loggerhead juvenile	35.5 cm 9.6 kg	DWS 2 pumps	70.8 F (21.6 C)	No	No	Yes	N/A
9/9/1992	6:00 PM	Loggerhead juvenile	46.7 cm 19.1 kg	CWS 4 pumps	78.2 F (25.6 C)	Yes	N/A	No	NJ
9/11/1992*	2:00 PM	Loggerhead juvenile	46.7 cm 19.1 kg	CWS 4 pumps	79.2 F (26.2 C)	Yes	N/A	No	NJ
10/26/1992	3:00 AM	Kemp's ridley subadult	32.0 cm 5.7 kg	CWS 4 pumps	52.4 F (11.3 C)	Yes	N/A	No	NC
10/17/1993	12:00 Noon	Kemp's ridley juvenile	26.0 cm 3.0 kg	CWS 4 pumps	62.0 F (16.7 C)	No	Yes	No	N/A
6/19/1994	1:30 PM	Loggerhead juvenile	36.8 cm 9.8 kg	CWS 4 pumps	81.1 F (27.3 C)	Yes	N/A	No	NJ
7/1/1994	10:00 AM	Kemp's ridley juvenile	27.7 cm 3.6 kg	DWS 2 pumps	78.3 F (25.7 C)	No	Yes	No	N/A
7/6/1994	6:40 AM	Loggerhead subadult	61.4 cm 40.4 kg	DWS 2 pumps	80.5 F (26.9 C)	No	No	Yes	N/A
7/12/1994	10:40 PM	Kemp's ridley juvenile	26.7 cm 3.3 kg	DWS 2 pumps	83.2 F (28.4 C)	No	Yes	No	N/A
9/4/1997	3:18 AM	Kemp's ridley subadult	48.8 cm 18.1 kg	DWS 2 pumps	73.2 F (22.9 C)	No	Yes	No	N/A
8/18/1998	9:59 AM	Loggerhead subadult	50.8 cm 22.4 kg	CWS 4 pumps	80.5 F (26.9 C)	Yes	N/A	No	FL
9/23/1999	3:10 AM	Kemp's ridley subadult	26.4 cm 2.9 kg	DWS 2 pumps	67.2 F (19.6 C)	Yes	N/A	No	VA
10/23/1999	2:00 AM	Green sea turtle juvenile	27.0 cm 2.8 kg	DWS 2 pumps	62.8 F (17.1 C)	No	Unk	No	N/A
6/23/2000	1:00 AM	Loggerhead juvenile	47.8 cm 17.2 kg	DWS 2 pumps	77.5 F (25.3 C)	Yes	N/A	No	NJ
7/2/2000	3:00 PM	Kemp's ridley juvenile	27.3 cm 3.2 kg	DWS 2 pumps	78.1 F (25.6 C)	No	Unk	No	N/A
8/3/2000	3:25 PM	Green sea turtle juvenile	29.2 cm 3.4 kg	DWS 2 pumps	83.9 F (28.8 C)	Yes	N/A	No	NC
8/28/2000	1:12 AM	Kemp's ridley juvenile	26.2 cm 2.9 kg	DWS 2 pumps	79.8 F (26.5 C)	Yes	N/A	No	NC
9/18/2000	1:10 PM	Loggerhead subadult	57.2 cm 26.5 kg	CWS 4 pumps	68.8 F (20.4 C)	Yes	N/A	No	NC
7/8/2001	2:30 PM	Green sea turtle juvenile	26.7 cm 2.3 kg	CWS 4 pumps	80.1 F (26.7 C)	Yes	N/A	No	NJ
7/22/2001	5:44 PM	Kemp's ridley juvenile	26.0 cm 2.9 kg	DWS 2 pumps	80.4 F (26.9 C)	No	Unk	Possible	N/A
8/14/2001	3:34 AM	Kemp's ridley juvenile	22.8 cm 1.8 kg	DWS 2 pumps	82.0 F (27.8 C)	No	Unk	No	N/A

OYSTER CREEK GENERATING STATION SEA TURTLE INCIDENTAL TAKES, Rev. 09/06

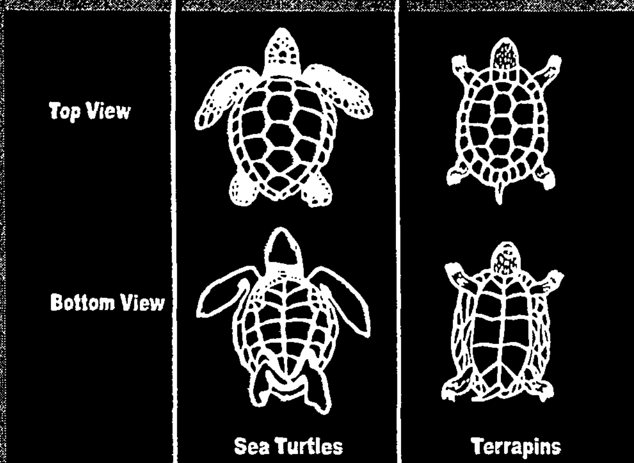
DATE OF TAKE	TIME OF TAKE	SPECIES AND LIFE STAGE	CARAPACE LENGTH (cm) & WEIGHT (kg)	TAKEN AT CWS OR DWS/ (NO. PUMPS OP.)	INTAKE TEMP. deg. F (C)	ALIVE WHEN TAKEN?	FRESH DEAD?	BOAT PROP WOUNDS?	RELEASE SITE
6/29/2002	2:00 AM	Kemp's ridley juvenile	25.4 cm 2.6 kg	CWS 4 pumps	79.2 F (26.2 C)	Yes	N/A	Possible	N/A
7/3/2002	7:55 AM	Kemp's ridley juvenile	35.6 cm 6.0 kg	DWS 2 pumps	82.8 F (28.2 C)	Yes	N/A	No	NJ
9/24/2003	3:10 PM	Kemp's ridley juvenile	31.1 cm 5.2 kg	DWS 2 pumps	73.0 F (22.8 C)	Yes	N/A	No	NJ
10/24/2003	9:10 AM	Green sea turtle juvenile	36.2 cm 6.9 kg	CWS 3 pumps	53.0 F (11.7 C)	Yes	N/A	No	VA
7/4/2004	12:15 PM	Kemp's ridley juvenile	26.5 cm 5.6 kg	DWS 2 pumps	78.0 F (25.6 C)	No	Yes	No	N/A
7/11/2004	14:22 PM	Kemp's ridley juvenile	22.3 cm 1.8 kg	DWS 2 pumps	81.5 F (27.5 C)	Yes	N/A	No	NJ
7/16/2004	11:00 AM	Kemp's ridley juvenile	28.0 cm 3.1 kg	DWS 2 pumps	76.0 F (24.4 C)	Yes	N/A	No	NJ
7/20/2004	12:13 AM	Kemp's ridley juvenile	18.3 cm 0.8 kg	CWS 4 pumps	79.7 F (26.5 C)	No	Yes	No	N/A
8/7/2004	9:00 AM	Kemp's ridley juvenile	27.0 cm 3.2 kg	DWS 2 pumps	72.8 F (22.7 C)	Yes	N/A	No	NJ
9/11/2004	10:10 AM	Kemp's ridley juvenile	22.3 cm 2.2 kg	DWS 2 pumps	75.8 F (24.3 C)	No	Yes	Yes* *Healed	N/A
9/13/2004	11:29 AM	Kemp's ridley juvenile	21 .0 cm 1.4 kg	CWS 4 pumps	76.8 F (24.9 C)	Yes	N/A	No	VA
9/23/2004	9:45 PM	Kemp's ridley juvenile	24.1 cm 1.9 kg	CWS 4 pumps	71.4 F (21.9 C)	Yes	N/A	No	VA
7/4/2005	9:05 AM	Kemp's ridley juvenile	23.2 cm 1.4 kg	DWS 2 pumps	75.8 F (24.3 C)	No	No?	Probable	N/A
8/5/2005	5:00 AM	Kemp's ridley juvenile	23.6 cm 1.9 kg	CWS 4 pumps	82.7 F (28.2 C)	Yes	N/A	Possible	NC
6/30/2006	11:00 AM	Kemp's ridley juvenile	27.3 cm 3.5 kg	DWS 2 pumps	78.1 F (25.6 C)	Yes	N/A	No	NJ
7/17/2006	9:35 AM	Kemp's ridley juvenile	25.2 cm 2.6 kg	DWS 2 pumps	80.1 F (26.7 C)	Yes	N/A	No	NJ
7/19/2006	9:30 PM	Kemp's ridley juvenile	26.7 cm 3.2 kg	CWS 4 pumps	82.5 F (28.1 C)	Yes	N/A	No	NJ
7/25/2006	4:25 AM	Kemp's ridley juvenile	28.5 cm 3.3 kg	DWS 2 pumps	82.2 F (27.9 C)	No	No?	Possible	N/A
8/1/2006	5:07 AM	Loggerhead adult	74.0 cm 50.4 kg	CWS 4 pumps	85.0 F (29.4 C)	Yes	N/A	No	NJ

NOTE: No sea turtles were taken during the first 22 full years of OCGS operation, 1970-1991.

* Loggerhead taken on 09/11/1992 was the same turtle taken on 09/09/1992.

HOW TO DISTINGUISH SEA TURTLES FROM TERRAPINS

Distinguishing Features	Sea Turtles	Terrapins
Limbs	Has swimming fins or flippers.	Lacks flippers, but has walking feet with 4 or 5 claws at the end.
Head	Unable to fully withdraw head inside of shell.	Can withdraw head inside of shell.
Maximum Size	Adult can grow to over three feet in length.	Does not exceed 10 inches in length



Actions Required	Notify control room (x4667) and Enviromental Controls (x4124) immediately	None required. May be gently removed from intake and returned to discharge canal.

SEA TURTLE RESUSCITATION

1. PLACE THE TURTLE ON ITS BREASTPLATE AND RAISE THE HIND FLIPPERS SLIGHTLY ABOVE THE FRONT FLIPPERS
2. PERIODICALLY, ROCK THE TURTLE SLIGHTLY BY LIFTING ONE SIDE, THEN LIFTING THE OTHER SIDE. GENTLY PINCH TAIL TO CHECK FOR RESPONSE.
3. KEEP THE TURTLE SHADED AND MOIST AND OBSERVE FOR 24 HOURS

these posters are
@ the intakes

OCGS SEA TURTLE INCIDENTAL TAKES

1992 - 2006

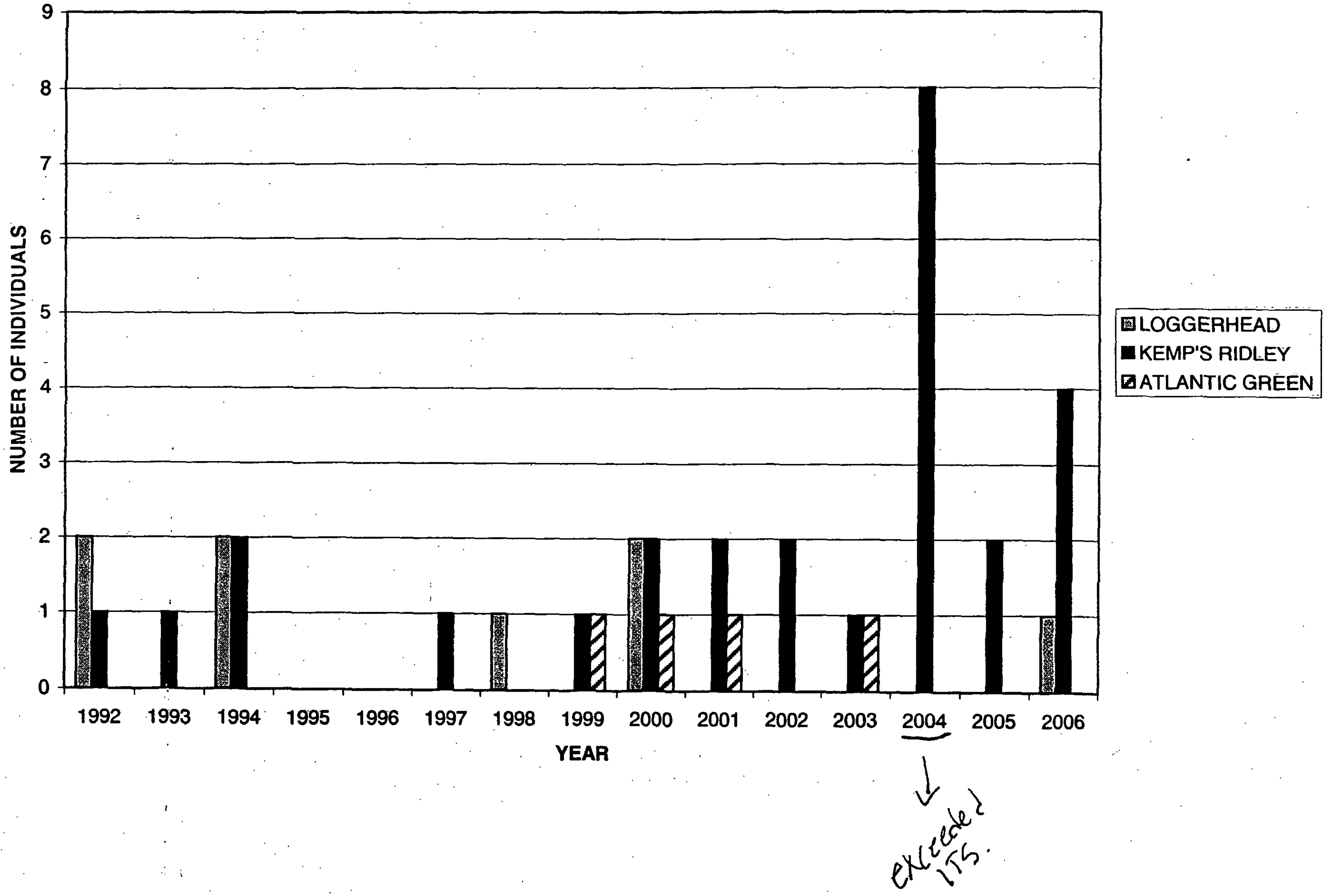
MONTHLY DISTRIBUTION (*)

MONTH	LOGGERHEAD	KEMP'S RIDLEY	GREEN	
January	0	0	0	
February	0	0	0	
March	0	0	0	
April	0	0	0	
May	0	0	0	
June	3	2	0	5
July	1	13	1	15
August	2	4	1	7
September	3	6	0	9
October	~~[illegible]~~ 1	2	2	~~4~~ 5
November	0	0	0	
December	0	0	0	
TOTALS	~~[illegible]~~ 10	27	4	

* Note: Number of incidental takes at OCGS through mid-Sept 2006

Corrected through 10/06.

NUMBER OF SEA TURTLE INCIDENTAL CAPTURES AT THE OYSTER CREEK GENERATING STATION 1992-2006*



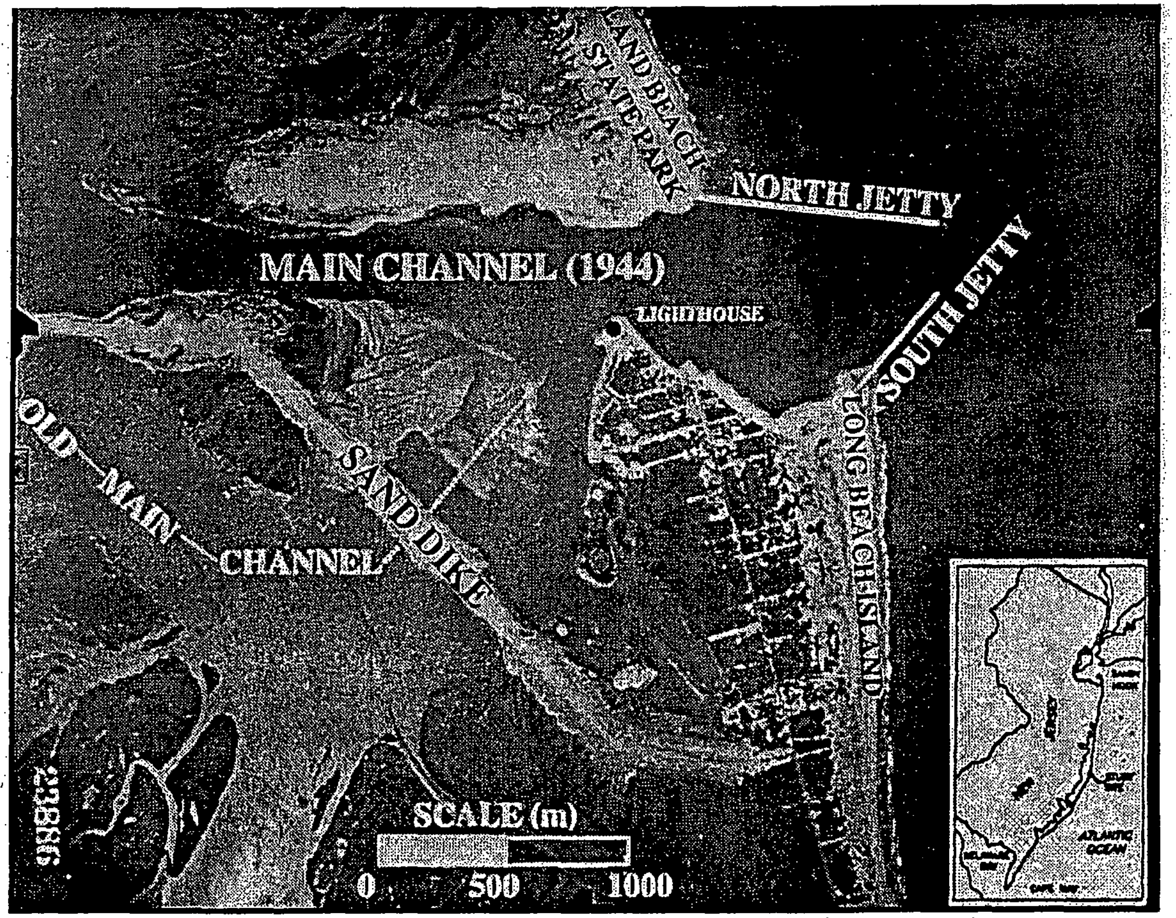


Figure 2. Arrowhead jetties constructed at Barnegat Inlet, NJ, 1939-1940, and sand dike constructed in 1943, photo August 1944

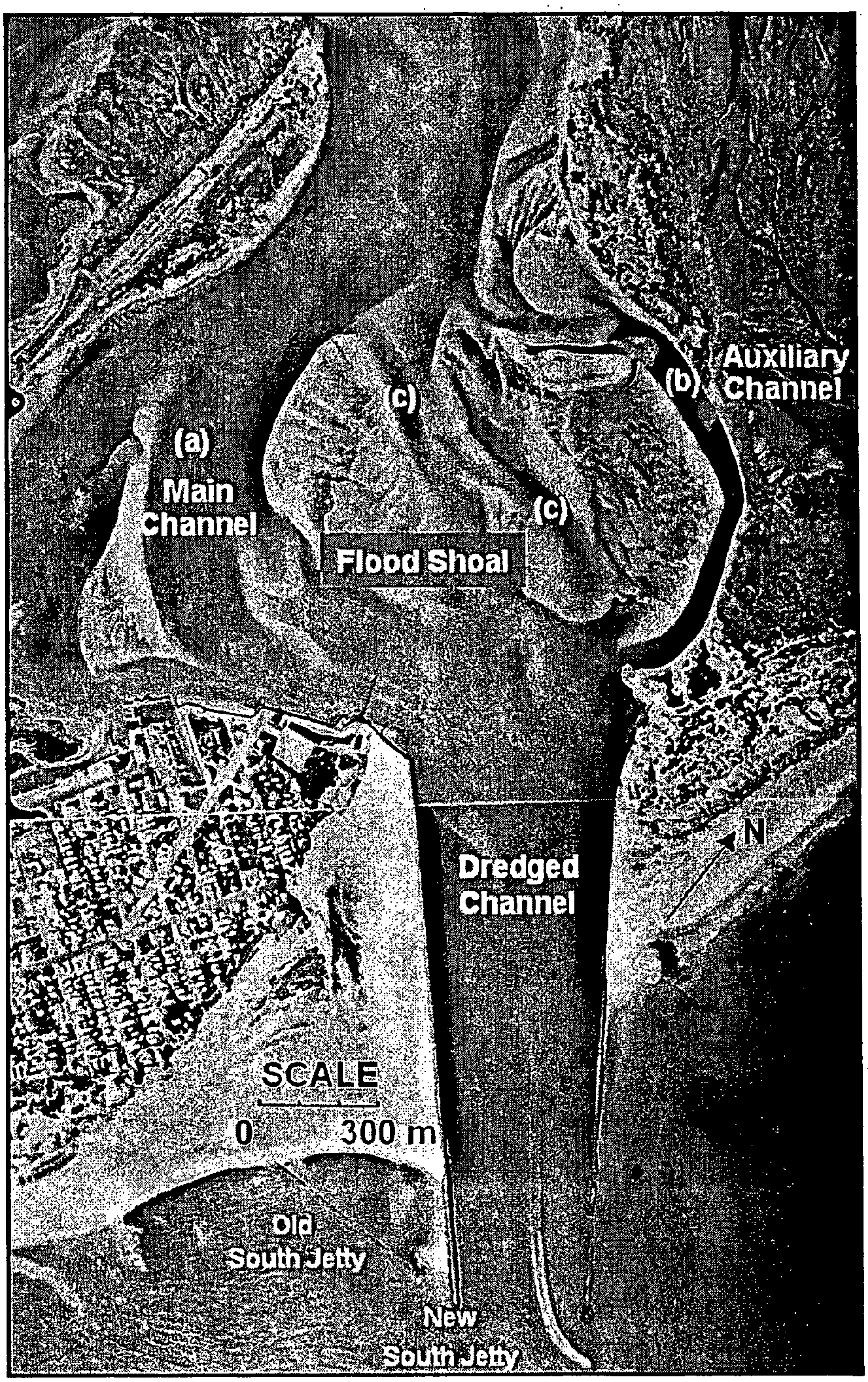


Figure 3. Barnegat Inlet, NJ, and flood shoal inside the inlet, after new south jetty construction was completed in June 1991 (main channel is now on the left side of the flood shoal looking upstream), photo December 1992

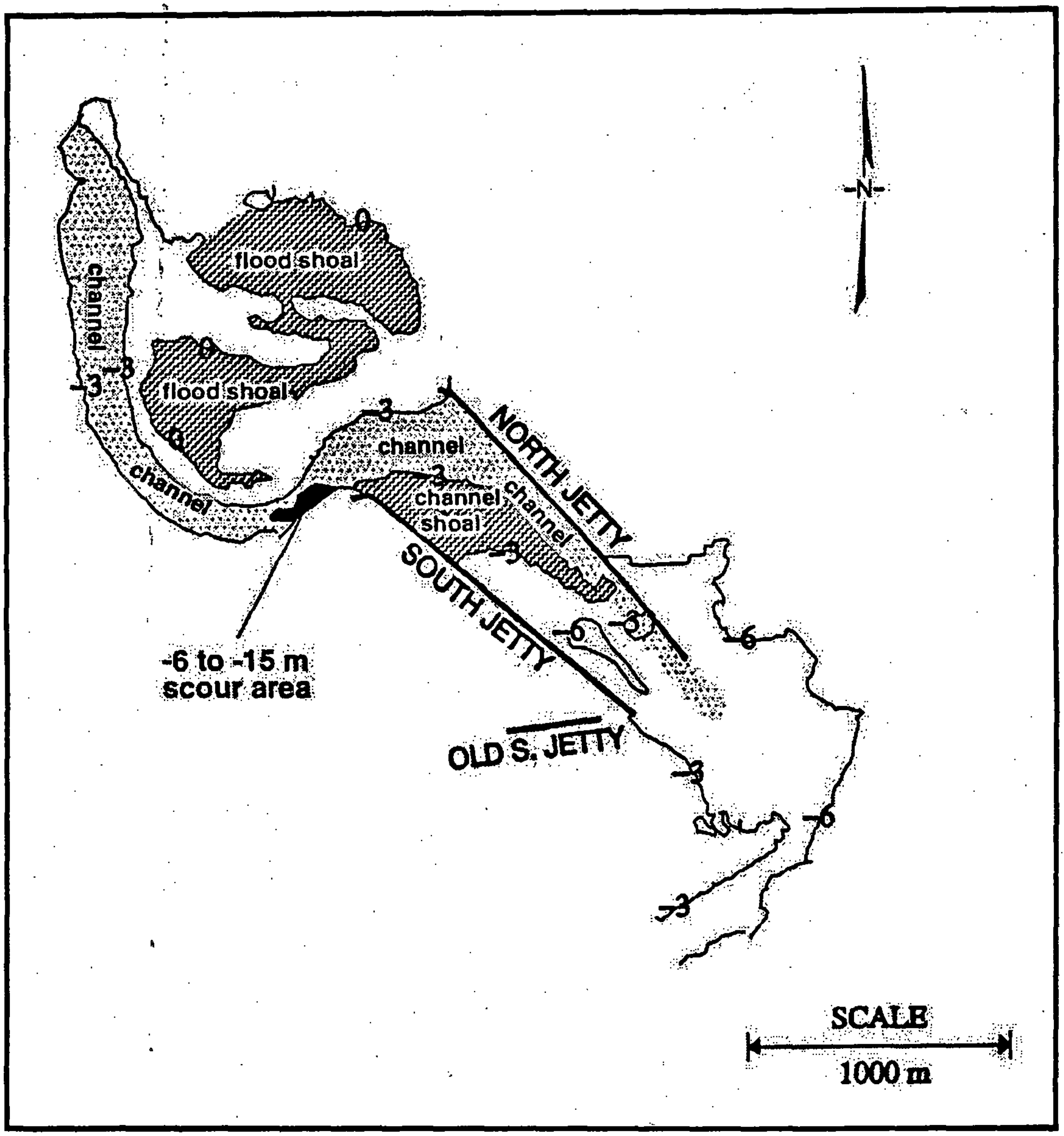


Figure 4. Barnegat Inlet, NJ, bathymetry, November-December 1993 (the project configuration monitored by the MCNP program)

United Stater
Environmental Protection
Agency

Office of Water
Regulations and Standards
Washington, DC 20460

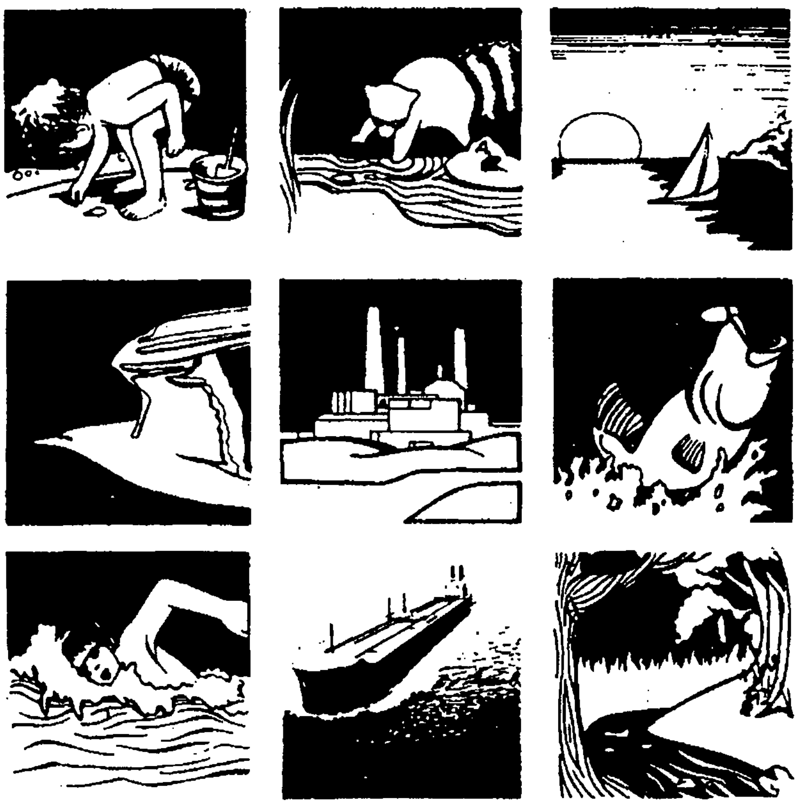
May 1, 1986

EPA

Water

EPA 440/5-86-001

QUALITY CRITERIA for WATER 1986



"EPA 1980

CHLORINE

SUMMARY:

Thirty-three freshwater species in 28 genera have been exposed to TRC and the acute values range from 28 ug/L for Daphnia magna to 710 ug/L for the threespine stickleback. Fish and invertebrate species had similar ranges of sensitivity. Freshwater chronic tests have been conducted with two invertebrate and one fish species and the chronic values for these three species ranged from less than 3.4 to 26 ug/L, with acute-chronic ratios from 3.7 to greater than 78.

The acute sensitivities of 24 species of saltwater animals in 21 genera have been determined for CPO, and the LC50 range from 26 ug/L for the eastern oyster to 1,418 ug/L for a mixture of two shore crab species. This range is very similar to that observed with freshwater species, and fish and invertebrate species had similar sensitivities. Only one chronic test has been conducted with a saltwater species, Menidia peninsulae, and in this test the acute chronic ratio was 1.162.

The available data indicate that aquatic plants are more resistant to chlorine than fish and invertebrate species.

NATIONAL CRITERIA:

The procedures described in the Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected

unacceptably if the 4-day average concentration of total residual chlorine does not exceed 11 ug/L more than once every 3 years on the average and if the 1-hour average concentration does not exceed 19 ug/L more than once every 3 years on the average.

The procedures described in the Guidelines indicate that, except possibly where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration of chlorine-produced oxidants does not exceed 7.5 ug/L more than once every 3 years on the average and if the one-hour average concentration does not exceed 13 ug/L more than once every 3 years on the average.

The recommended exceedence frequency of 3 years is the Agency's best scientific judgment of the average amount of time it will take an unstressed system to recover from a pollution event in which exposure to chlorine exceeds the criterion. A stressed system, for example, one in which several outfalls occur in a limited area, would be expected to require more time for recovery. The resilience of ecosystems and their ability to recover differ greatly, however, and site-specific criteria may be established if adequate justification is provided.

The use of criteria in designing waste treatment facilities requires the selection of an appropriate wasteload allocation model. Dynamic models are preferred for the application of these criteria. Limited data or other factors may make their use impractical, in which case one should rely on a steady-state model. The Agency recommends the interim use of 1Q5 or 1Q10 for Criterion Maximum Concentration design flow and 7Q5 or 7Q10 for

the Criterion Continuous Concentration design flow in steady-state models for unstressed and stressed systems, respectively. These matters are discussed in more detail in the Technical Support Document for Water Quality-Based Toxics Control (U.S. EPA, 1985).

(50 F.R. 30784, July 29, 1985)
SEE APPENDIX A FOR METHODOLOGY

New Jersey Department of Environmental Protection
Division of Water Quality
Bureau of Point Source Permitting - Region 1

FACT SHEET

Masterfile #: 15856 **PI #:** 46400

This fact sheet sets forth the principle facts and the significant factual, legal, and policy considerations examined during preparation of the draft permit. This action has been prepared in accordance with the New Jersey Water Pollution Control Act and its implementing regulations at N.J.A.C. 7:14A-1 et seq. - The New Jersey Pollutant Discharge Elimination System.

PERMIT ACTION: Surface Water Renewal Permit Action

1 Overview of Draft Renewal Permit:

The permittee has applied for a New Jersey Pollutant Discharge Elimination System (NJPDES) Surface Water Renewal Permit Action through an application dated June 3, 1999. Until such time as this renewal permit is finalized, the existing permit remains in full force and effect pursuant to N.J.A.C. 7:14A-2.8.

This draft permit renewal proposes to authorize the intake of waters from Forked River as well as the discharge of wastewater to both Forked River and Oyster Creek. This draft permit renewal incorporates the New Jersey Department of Environmental Protection's (hereafter "the Department") determination with respect to the permittee's request for a thermal variance from surface water quality standards (SWQS) for heat and temperature pursuant to Section 316(a) of the Federal Clean Water Act. Further, this draft renewal permit incorporates the Department's determination pursuant to Section 316(b) of the Clean Water Act and implements the newly effective Federal regulations for Section 316(b) of the Clean Water Act for Phase II facilities.

This fact sheet contains information organized into the following sections:

Table of Contents

2 Name and Address of the Applicant:

AmerGen Energy Company, LLC
Oyster Creek Generating Station
Route 9 South, P.O. Box 388
Forked River, NJ 08731

3 Name and Address of the Facility/Site:

AmerGen Energy Company LLC
Oyster Creek Generating Station
Route 9 South, P.O. Box 388
Forked River, Ocean County, NJ 08731

4 Discharge Location Information:

A copy of the appropriate section of a USGS quadrangle map indicating the location of the facility and discharge points is included towards the end of this Fact Sheet. A schematic of the facility's discharges is also included near the end of the fact sheet.

Description of Outfalls of Most Significant Flow (DSN 001A and 005A)

Outfall 001A: Non-Contact Cooling Water (up to 662.4 MGD)			Outfall 005A: Dilution Water (up to 1123.2 MGD)	
Receiving Water:	Oyster Creek		Receiving Water:	Oyster Creek
Via :	Discharge Canal		Via :	Discharge Canal
Outfall Configuration:	Submerged pipe		Outfall Configuration:	Submerged pipe
Classification:	SE1		Classification:	SE1
Latitude:	39° 48' 40"		Latitude:	39° 48' 48.9"
Longitude:	74° 12' 00"		Longitude:	74° 12' 28.2"
County:	Ocean		County:	Ocean
Municipality:	Forked River		Municipality:	Forked River
Downstream Confluences:	Barnegat Bay		Downstream Confluences:	Barnegat Bay
Receiving River Basin:	Barnegat Bay		Receiving River Basin:	Barnegat Bay
WMA (a):	13		WMA (a):	13
Watershed:	Forked River/Oyster Creek		Watershed:	Forked River/Oyster Creek
Subwatershed:	Oyster Creek (below Rt 532)		Subwatershed:	Oyster Creek (below Rt 532)
HUC 14 (b):	02040301110050		HUC 14 (b):	02040301110050

Description of Other Outfalls (DSN 002A, 004A, 007A, 008A, 009A)

Outfall 002A: Non-Contact Cooling Water (3.5 MGD)			Outfall 004A: Non-Contact Cooling Water, Stormwater, Floor Drains (0.06 MGD)	
Receiving Water:	Forked River		Receiving Water:	Oyster Creek
Via :	Intake Canal		Via :	Discharge Canal
Outfall Configuration:	Submerged pipe		Outfall Configuration:	Submerged pipe
Classification:	SE1		Classification:	SE1
Latitude:	39° 48' 52.9"		Latitude:	39° 48' 47.6"
Longitude:	74° 12' 28.2"		Longitude:	74° 12' 24.9"
County:	Ocean		County:	Ocean
Municipality:	Forked River		Municipality:	Forked River
Downstream Confluences:	Barnegat Bay		Downstream Confluences:	Barnegat Bay
Receiving River Basin:	Barnegat Bay		Receiving River Basin:	Barnegat Bay
WMA (a):	13		WMA (a):	13
Watershed:	Forked River/Oyster Creek		Watershed:	Forked River/Oyster Creek
Subwatershed:	Forked River (below NB including Mid/South Branch)		Subwatershed:	Oyster Creek (below Rt 532)
HUC 14 (b):	02040301110030		HUC 14 (b):	02040301110050

Outfall 007A: Process Wastewater (30 GPD)	
Receiving Water:	Forked River
Via :	Intake Canal
Outfall Configuration:	Submerged pipe
Classification:	SE1
Latitude:	39° 48' 50.9"
Longitude:	74° 12' 55.1"
County:	Ocean
Municipality:	Forked River
Downstream Confluences:	Barnegat Bay
Receiving River Basin:	Barnegat Bay
WMA (a):	13
Watershed:	Forked River/Oyster Creek
Subwatershed:	Forked River (below NB including Mid/South Branch)
HUC 14 (b):	02040301110030

Outfall 008A: Intake Screen Washwater (2.4 MGD)	
Receiving Water:	Oyster Creek
Via :	Discharge Canal
Outfall Configuration:	Submerged pipe
Classification:	SE1
Latitude:	39° 48' 48.8"
Longitude:	74° 12' 27.5"
County:	Ocean
Municipality:	Forked River
Downstream Confluences:	Barnegat Bay
Receiving River Basin:	Barnegat Bay
WMA (a):	13
Watershed:	Forked River/Oyster Creek
Subwatershed:	Oyster Creek (below Rt 532)
HUC 14 (b):	02040301110050

Outfall 009A: Fish Sampling Pool Wastewater	
Receiving Water:	Forked River
Via :	Intake Canal
Outfall Configuration:	Submerged pipe
Classification:	SE1
Latitude:	39° 48' 48.6"
Longitude:	74° 12' 27.9"
County:	Ocean
Municipality:	Forked River
Downstream Confluences:	Barnegat Bay
Receiving River Basin:	Barnegat Bay
WMA (a):	13
Watershed:	Forked River/Oyster Creek
Subwatershed:	Forked River (below NB including Mid/South Branch)
HUC 14 (b):	02040301110030

Footnotes:
(a) WMA = Watershed Management Area
(b) HUC 14 = 14 digit Hydrologic Unit Code

5 Description of Facility:

The Oyster Creek Generating Station (Station) operates a nuclear fueled electric generating station (SIC code 4911). The Station is located between the South Branch of the Forked River and Oyster Creek, two tributaries of Barnegat Bay. The facility consists of a single boiling water reactor rated to produce 670 Megawatts. The unit was constructed between December 1964 and September 1969 where operation commenced in December 1969. The Station operates under a license issued by the United States Nuclear Regulatory Commission (US NRC) where this license expires in April 2009. Any extension of such license is subject to the discretion of the US NRC. The expiration of this permit coordinates with the expiration of the US NRC license where this NJPDES/DSW permit will expire on April 30, 2009.

The facility is classified as a major discharger by the Department in accordance with the United States Environmental Protection Agency (EPA) rating criteria. The design intake flow that is subject to Section 316(b) of the Clean Water Act is 1785.6 MGD which is equivalent to the operation of four circulating water pumps (662.4 MGD) and three dilution pumps (1,123.2 MGD). This value was established in a 1966 Stipulation of the State of New Jersey, Department of Public Utilities, Board of Public Utility Commissioners.

6 Description of Intake:

General

Construction of the Oyster Creek Station resulted in the dredging and widening of the Forked River and Oyster Creek and the construction of man-made canals leading from Forked River to the Station (intake canal) and from the Station to Oyster Creek (discharge canal). The shapes of the intake and discharge canal could connect; however, there is a dike that separates the upstream ends of both canals. A map showing the location of both canals is included as page 29 of this Fact Sheet.

The Station utilizes intake water for two primary purposes. The circulating water and service water systems utilizes up to 662.4 MGD for the purposes of cooling the main condenser. The dilution water system utilizes up to 1123.2 MGD for the purposes of mitigating the thermal effects in the discharge canal. These two systems are described in detail below. While Forked River is the primary source of intake water, an additional source of water used for operations is fresh water from an on-site well.

Sanitary wastewater that is generated on site is diverted to the Lacey Township Municipal Utilities Authority.

Circulating Water and Service Water System

Water is withdrawn from Forked River via the Station's Intake Canal. There are four intake pumps with a capacity of 115,000 gallons per minute (gpm) (165.6 MGD). During normal operations, all four pumps each operate continuously at an average flow rate of 662.4 MGD. This intake water is used to cool the main condenser and the turbine building heat exchangers. This cooling water is then discharged through **DSN 001A** into the discharge canal, which joins Oyster Creek and ultimately Barnegat Bay.

The Station's Intake Canal includes two surface water intake structures namely the Circulating Water Intake, which also services flow for the service water system, and the Dilution Water Intake. The Circulating Water Intake is divided into two sections or bays. Each bay contains three cells. Water enters the cells through trash racks where there is one trash rack per cell. The trash racks are constructed of steel, almost vertically positioned bars on 3 inch centers; so that the trash rack slot opening is about 2 ½ inches. After passing through the trash rack, water is drawn through conventional vertical traveling screens (3/8 inch mesh) modified with "Ristroph" type fish buckets fitted to the base of each screen panel. These fish buckets are intended to prevent aquatic organisms that become trapped on the screens from falling back into the screen well and being repeatedly trapped. They also allow organisms to remain in a water filled bucket when the screen panel is rotated above the water surface. A low pressure wash (approximately 10 to 20 pounds per square inch or psi) is applied that it is intended to wash organisms to a fish return system. High pressure sprays (approximately 30 psi) are then utilized to remove debris from the screen. Screens normally rotate continuously at 1.3 cm/sec (2.5 feet per minute) but speeds can increase via manual control. Water passing through the trash racks and traveling screens is withdrawn by circulating or service water system pumps for use as cooling water. The fish return system is routed to the discharge canal which thereby eliminates the possibility that fish can be immediately reimpinged.

Intake screen washwater is discharged via **DSN 008A** where this flow averages approximately 2.4 MGD. The intake screen washwater removes debris and other organic matter from the Station's traveling intake screens, including the screen washwater system strainers, and discharges to the discharge canal without any additives or treatment. The facility has the option of diverting fish and other organisms removed from the traveling screens to a fish sampling pool where the water from such is drained to the Forked River. The discharge from the fish sampling pool is authorized as **DSN 009A** and has not been operational during the existing permit duration.

Dilution Water System

The permittee also pumps water from the Forked River via the intake canal and discharges it directly to the discharge canal via **DSN 005A** without any addition of heat or other pollutants and without treatment. Dilution pump water is withdrawn via one or two of the Station's three dilution pumps and discharged for the purposes of moderating the temperature of the Station's discharge to Oyster Creek and Barnegat Bay. The dilution water system intake structure is divided into three sections or bays where each section contains two cells. Although the permittee contends that the design of these pumps allow for some impingement and entrainment survivability, these pumps are not currently equipped with any other impingement mortality or entrainment controls. Flow varies according to the number of dilution pumps in operation but averages approximately 708 MGD.

The dilution water system intake is located on the west bank of the Intake Canal, across from the cooling water intake. Three low speed (180 revolutions per minute) axial flow pumps with 7 foot impellers with a design capacity of 260,000 gallons per minute each provide water for the dilution water system. Normally two dilution pumps are used during "winter" and "summer" water conditions (as defined in a 1978 stipulation). The dilution water system intake has two trash racks for each of these three pumps.

Fresh water is drawn from the Station fire protection water system and is used for dilution pump lube oil cooling and pump seal water. This water is discharged through DSN 005A at a rate of 0 to 100 gallons per minute (gpm), depending upon the number of dilution pumps in operation. A small, intermittent component of the fire protection water system flow is the discharge from the emergency diesel fire pump heat exchangers. The two emergency diesel fire pumps are required for emergency purposes, such as fire protection and emergency core cooling. Their operation is limited to 163 hours per year. When the pumps are operated, cooling water from the heat exchangers is discharged through 1.5 inch pipes at a rate of approximately 35 gpm. The increase in temperature is about 11 degrees Fahrenheit and no chemicals are added to the discharge. Most of the cooling water flow is drawn into the flow for the fire protection water system and does not flow back to Oyster Creek. Additionally, on an infrequent basis, small quantities of stormwater that may accumulate in a cable vault in the Dilution Pump intake structure are introduced into the dilution water flow.

7 Description of Discharges:

Discharges to the Intake Canal

Approximately 3.53 MGD of wastewater is discharged by the Station to the intake canal via outfalls DSN 002A, DSN 007A and DSN 009A. **DSN 002A** consists of approximately 3.5 MGD of chlorinated non-contact cooling water from the Station's radioactive waste treatment system's heat exchanger and augmented off-gas heat exchanger. **DSN 007A** consists of approximately 30 GPD of dilution pump seal wastewater, which is treated by an oil/water separator prior to discharge. As described previously, **DSN 009A** is the discharge from the fish sampling pool and is operated on an as needed basis.

Discharges to the Discharge Canal

Approximately 1326 MGD of non-contact cooling water and wastewater is discharged to the discharge canal. **DSN 001A** typically consists of 592 MGD of once through non-contact cooling water from the previously described circulating water and service water system. This water is used to cool the main condenser prior to discharge through the discharge canal. This non-contact cooling water is chlorinated to protect the heat exchanger tubes from marine and organic fouling. The main condenser consists of six sections among which the flow is equally divided. The chlorination injection system (sodium hypochlorite) is designed so that each condenser section is separately chlorinated. Only one section is chlorinated at a time so that the sections are consecutively chlorinated for 20 minutes each during the daily cycle for a maximum of two hours per day of chlorination. The water then passes through the steam condensers and is discharged through DSN 001A.

The Station discharges other wastewater via outfalls DSN 004A, DSN 005A, and DSN 008A to the discharge canal. **DSN 004A** consists of approximately 60,000 GPD of low volume wastewater that includes stormwater, non-contact cooling water from reactor building and emergency service water heat exchangers, laboratory and sampling streams, and various floor drains which emanate from sumps. As described previously, **DSN 005A** is the discharge of approximately 732 MGD (on average) of dilution pump water and **DSN 008A** is the discharge of approximately 2.4 MGD of intake screen washwater.

Stormwater Discharges

The existing permit contains requirements for outfalls DSN 012A, DSN 013A, and DSN 014A which discharge stormwater from sedimentation basins to the South Branch of the Forked River. These discharges are located on a portion of the site that was retained by First Energy when the Station was sold to AmerGen Energy Company, LLC after the existing permit became effective. These outfalls are currently regulated under a general stormwater permit issued to First Energy and therefore are being removed from this permit action.

8 Determinations under Sections 316(a) and (b) of the Clean Water Act:

A. Section 316(a) Determination

1. Regulatory Background - Thermal Surface Water Quality Standards (SWQS) and Section 316(a)

Surface Water Quality Standards (SWQS) for SE1 waters are established in N.J.A.C. 7:9B-1.1 et seq. and are applicable to the Barnegat Bay, Forked River, and Oyster Creek. These standards require that ambient water temperatures in the receiving waters shall not be raised by more than 2.2° C (4° F), from September through May, nor more than 0.8 ° C (1.5 ° F) from June through August, nor cause temperatures to exceed 29.4 ° C (85 ° F), except in designated heat dissipation areas. SWQS provide that "heat dissipation areas" in "streams" (including SE waters) shall not exceed one-quarter (1/4) of the cross section and/or volume of the water body at any time; nor more than two-thirds (2/3) of the surface from shore to shore at any time. SWQS further provide that these "heat dissipation areas" limits:

> "...may be exceeded by special permission, on a case-by-case basis, when a discharger can demonstrate that a larger heat dissipation area meets the tests for a waiver under Section 316 of the Federal Clean Water Act."

SWQS provide that for bays, "heat dissipation areas" will be developed on a case by case basis at N.J.A.C. 7:9B-1.14 (c)(11)(ii)(2).

Section 316(a) of the Federal Clean Water Act regulates the thermal component of surface water discharges. Specifically, Section 316(a) authorizes variances from thermal surface water quality standards where it is shown that the alternative limit proposed will "assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife" in the receiving water.

2. Section 316(a) Determination in 1994 NJPDES/DSW Permit

a. Contractor Review

In 1987, the Department engaged Versar, Inc. as an independent contractor to assist in reviewing the permittee's Section 316(a) and (b) Demonstration. The Section 316 Demonstration was originally submitted in 1974 with supplements in 1978 and July 1986. The 1986 supplement included an analysis of entrainment and impingement studies conducted from November 1984 through December 1985.

Versar was tasked to review and evaluate the Section 316 documents, to evaluate the impact of the facility on the aquatic environment, and to recommend the limitations which should be placed on the intakes and discharges so as to meet the intent of Section 316 and other applicable State and Federal requirements. The Department released Versar's

1988 Advanced Final Report for comment in 1988. In reviewing the permittee's 1988 comments, the Department was made aware that Versar had not been aware of critical data collected by the permittee at that time, namely GPU Nuclear. Upon review of this additional information, Versar submitted a report entitled "Technical Review and Evaluation of Thermal Effects Studies and Cooling Water Intake Structure Demonstration of Impact for the Oyster Creek Nuclear Generating Station, Revised Final Report", dated May 1989 (1989 Versar Report).

As described in the 1989 Versar report, Versar reviewed the extent of the thermal plume from the Station based on dye plume mapping, thermal plume mapping, recirculation studies and hydrothermal modeling submitted by the permittee and other agencies. The 1989 Versar Report indicated that operation of the Station did not appear to produce unacceptable, substantial long-term population and ecosystem level impacts and such operation assures the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife in and on the receiving waters. The 1989 Versar Report recommends, among other things, that the Department grant a thermal variance pursuant to Section 316(a) and that the Department require the permittee to conduct and submit Dilution Pump Optimization Studies. The goal of this study was to develop a decision framework to predictively evaluate the seasonal operation of the dilution pumps in order to minimize the potential for the Oyster Creek cooling system to affect the biota of Barnegat Bay. In other words, the goal of any study would be to predict a schedule for operation of the dilution pumps to ensure that pumps were operated to mitigate thermal effects, but yet minimize operations to minimize entrainment effects. A workplan for this study was completed and submitted in May 1995.

b. Section 316(a) Determination in this Renewal Permit

In the June 30, 1994 draft renewal permit, the Department made a determination that the existing thermal limitations and operating requirements met the 316(a) criteria based on the findings of the permittee's 1987 316(a) study. However, the existing permit requires a number of operating and monitoring conditions to ensure that thermal effects were minimized during critical periods. These conditions have been continued in this renewal permit and can be summarized and justified as follows:

- Planned Winter Shutdown Conditions – The permittee shall not schedule routine shutdowns during the months of December, January, February, and/or March to reduce the possibility of a fish-kill resulting from cold shock. The permittee shall also not schedule routine maintenance that may cause violation of thermal limitations or intake velocity limitations during the months of June, July, August, and/or September. The Department acknowledges that the NJPDES Regulations require the permittee to maintain its plant in good working order and efficient operation and, therefore, some maintenance may be required. This condition is included in Part IV of the permit.

  Basis and Background to Planned Winter Shutdown Condition - Many fish species initiate their autumn migration from temperate estuarine areas such as Barnegat Bay to southern areas or deeper oceanic waters in response to temperature cues. Fish commonly thermoregulate by seeking water having temperature closer to their thermal preference. As a consequence, during the autumn, winter, and spring, fish are attracted to areas such as the Oyster Creek Discharge Canal, which acts to confine heated water from condenser cooling. Upon winter shutdowns of the Station, the thermal discharge from condenser cooling ceases and the temperature of this area quickly reverts towards ambient.

  Provisions in the 1987 NJPDES permit regarding planned winter shutdowns of the Station required the permittee to avoid scheduling shutdowns during the months of December, January, February, and March. These provisions were, for the most part, based on a permit issued by USEPA. The restriction on planned winter shutdowns was included in the 1987 and 1994 NJPDES permits to lessen the probability of winter shutdown fish kills associated with cold shock. This condition has been retained once again in this renewal permit.

- Temperature Monitoring at Route 9 Bridge – The permittee is required to continuously monitor temperature at a point four feet below the surface of Oyster Creek at the Route 9 bridge. A maximum temperature action level of 97 °F (36.1 °C) shall be continued in this permit action. Upon exceedance of this action level, the permittee may be required to conduct and submit an Effluent Temperature Evaluation Study (ETES) as

detailed in Part IV of the permit. Temperature results from this location shall also determine when dilution pumps become operational. This condition is included in Part IV of the permit.

Basis and Background to Temperature Monitoring at Route 9 Bridge - In order to ensure that the temperature of the water at the point it enters Barnegat Bay remains approximately at the temperature that was used in the Section 316(a) determination, the Department is requiring the Station to continue to monitor water temperature at the Route 9 Bridge. If the temperature is monitored above 97°F, the Station is required to submit a written report to the Department stating the reason for such. If the temperature increase is due to (a) unusually high influent temperature, i.e., any influent temperature in excess of 85° F; (b) operation of the Dilution Pumps in accordance with Part IV; or (c) implementation of the alternate effluent limitations in accordance with a Maximum Emergency Generation event as defined in this permit, the Station is required to do no more. If the temperature increase is not attributable to any of the above, the Station is required to conduct an Effluent Temperature Evaluation Study ("ETES") as detailed in Part IV to identify the cause of the temperature increases and to implement measures to prevent the temperature increases from occurring again.

The Station's exceedance of the temperature monitoring action level of 97 degrees Fahrenheit is not a violation of the permit for which an enforcement action could be taken. The Station's failure to report an exceedance, to provide the Department with a written report providing reasons for the exceedance or to conduct the ETES in the time frames and manner established in the permit would, however, constitute violations of the permit for which enforcement action could be instituted.

- Maximum Emergency Generation – The permittee is permitted to increase its heat load, effluent temperature and delta T limitations for outfall DSN 001A during a Maximum Emergency Generation event as ordered by the PJM Interconnection Office of Information Dispatcher in accordance with Section 2 (Capacity Conditions) of the PJM Interconnection Emergency Operations Manual M-13, dated October 10, 1998 and any subsequent revisions thereto. Within 8 hours of the permittee being advised that Maximum Emergency Generation has been ordered, the permittee must notify the Department by telephone declaring that the Station has invoked the use of the alternate thermal limits of the permit. The Station must follow-up the telephone notification within five working days with a written report setting forth the following: the time and date of the telephone notification to the Department, the time and date the Station actually invoked relief under this permit condition, and the time and date it terminated such relief. A similar condition was contained in the 1994 permit issued to this facility; however, the term Emergency Need for Power has been replaced with Maximum Emergency Generation to reflect revisions to the PJM Interconnection Emergency Operations Manual.

In sum, the Department has determined it appropriate to continue those thermal limitations and operating requirements in this permit action. In addition to the above, this continued variance is based on the fact that the facility's operations have not changed appreciably since the time that the existing permit was issued and based on the fact that cooling water intake flow rates have remained relatively constant. Therefore, the Department is hereby granting a thermal variance in accordance with Section 316(a) of the Clean Water Act and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19.

B. Section 316(b) Determination

1. Regulatory Background - Clean Water Act Section 316(b)

Section 316(b) "require[s] that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." The majority of environmental impacts associated with intake structures are caused by water withdrawals that ultimately result in aquatic organism losses. In that regard, cooling water intakes can have two types of effects. The first effect, referred to as *entrainment*, occurs when organisms pass through the facility's intake screens and the cooling system itself. The second effect, referred to as *impingement*, occurs when organisms are caught on the intake screens or associated trash racks.

Impingement takes place when organisms are trapped against intake screens by the force of the water passing through the cooling water intake structure. Impingement can result in starvation and exhaustion (organisms are trapped against

an intake screen or other barrier at the entrance to the cooling water intake structure), asphyxiation (organisms are pressed against an intake screen or other barrier at the entrance to the cooling water intake structure by velocity forces that prevent proper gill movement, or organisms are removed from the water for prolonged periods of time), and descaling (fish lose scales when removed from an intake screen by a wash system) as well as other physical harms.

Entrainment occurs when organisms are drawn through the cooling water intake structure into the cooling system. Organisms that become entrained are normally relatively small benthic, planktonic,and nektonic organisms, including early life stages of fish and shellfish. Many of these small organisms serve as prey for larger organisms that are found higher on the food chain. As entrained organisms pass through a plant's cooling system they are subject to mechanical, thermal, and/or toxic stress. Sources of such stress include physical impacts in the pumps and condenser tubing, pressure changes caused by diversion of the cooling water into the plant or by the hydraulic effects of the condensers, shear stress, thermal shock in the condenser and discharge canal, and chemical toxemia induced by antifouling agents such as chlorine produced oxidants.

EPA issued final regulations for Phase II facilities effective September 7, 2004. Phase II existing facilities, as defined by EPA in their Phase II regulations, are facilities that commenced construction before January 17, 2002 that have design flows over 50 MGD. This facility is eligible under Phase II of the regulations. The term "cooling water intake structure" is defined as the total physical structure and any associated constructed waterways used to withdraw cooling water from waters of the U.S. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source up to, and including, the intake pumps.

2. Section 316(b) Determination in 1994 NJPDES/DSW Permit

a. Summary of Impingement/Entrainment Losses

As described previously under Section 316(a), the Department hired a contractor to review available Section 316 documents. Some of these data are still appropriate for consideration as they give a measure of the impingement and entrainment impacts as well as the Representative Important Species (RIS) used to evaluate the effects. The Section 316 demonstration relied on the following Representative Important Species (RIS) to assess intake impacts at the Station:

Winter Flounder	Bay Anchovy
Sand Shrimp	Hard Clam
Blue Crab	Eelgrass
Opossum shrimp	Atlantic Ridley turtle
Teredo spp.	Bankia gouldi

The RIS impact assessment approach is based on the concept that it is not feasible or cost effective to measure power plant effects on all species inhabiting aquatic environments. In most aquatic ecosystems it is, however, generally possible to identify biota which because of their abundance, distribution, ecological, or economic importance are essential to and/or representative of the maintenance of balanced, indigenous populations of shellfish, fish, and wildlife. These RIS species are used to focus impact assessment efforts, making the assumption that if populations of these surrogate species are protected, then other populations, and the ecosystem as a whole, will also be protected. Because many RIS are near the top of the estuarine food webs or are key links in food webs, changes in the abundance or distribution are indicators of system wide alterations. In order for RIS to be reliable indicators of impact, they should include biota that are sensitive to power plant impacts as well as biota that are representative of all major trophic levels.

As noted in the 1989 Versar report, the following three models were used to evaluate impingement and entrainment losses in the context of population size or biological productivity to understand the potential consequences of losses to Barnegat Bay RIS populations. The models used were:

1. Equivalent Adult Model (EAM) which examines changes in survivorship to sexual maturity or recruitment into a fishery.

2. Production Foregone Model (PFM) which examines fractional reductions in annual net population (weight) production.
3. Spawning/Nursery Area of Consequence Model (SNAC) which estimates fractional (or percent) reduction in RIS populations which are directly attributable to the Oyster Creek facility.

The EAM evaluated the number of RIS which would have survived to adulthood if impingement and entrainment losses had not occurred. The EAM was used since many of the aquatic organisms lost are at early life stages or are juveniles. Results of the EAM in the 1989 Versar report are presented below:

Species	Estimated Adult Loss (Thousands per year)
Bay Anchovy	137,000
Hard Clam	59
Blue Crab	10.4
Winter Flounder	56.4
Opossum shrimp	1,720,000
Sand shrimp	164,000

Versar noted that the projected equivalent adult losses for Bay anchovy, Opossum shrimp, and Sand shrimp are high but the production foregone model provided a better means to evaluate the significance of these losses to ecological functions in the Barnegat Bay. Versar also noted that these calculated equivalent adult losses are highly variable due to large uncertainties associated with entrainment losses.

The PFM estimated percentage declines in annual net production due to entrainment and impingement for those RIS which serve a forage function. Results of Versar's PFM are presented below:

RIS species	**Percent loss**	**Forage Production Lost**
Bay anchovy	12.4%	(354,000 lbs.)
Opossum shrimp	8.7 %	(67,000 lbs)
Sand shrimp	16.5%	(1,650,000 lbs)

The SNAC model estimated percentage declines in populations due to entrainment and impingement at the Oyster Creek facility. Results of Versar's SNAC model in the 1989 Versar Report are presented below:

RIS species	**Percent of Population Decline**
Winter Flounder	2.1%
Bay anchovy	3.2%
Hard clam	1.5%
Blue crab	0.4%
Sand shrimp	16.6%
Opossum shrimp	2.0%

As summarized above, the 1989 Versar report provided information regarding losses to RIS and also provided loss information in the context of populations. Loss data is helpful in assessing what technologies may be available to reduce losses. However, the Department maintains that it is unnecessary to have to prove that an impact to a population must be demonstrated in order to trigger Section 316(b). This rationale is consistent with the Phase II regulations which specify compliance alternatives, including national performance standards, and do not define adverse environmental impact. In other words, a past determination that focuses on any effects to a balanced indigenous population is not directly relevant to attaining the national performance standards defined in the Phase II rule. Available data shows that impingement and entrainment losses are documented and must be minimized consistent with the goal of the Phase II Section 316(b) regulations.

b. Alternative Intake Protection Technologies

As described in the 1994 NJPDES permit, the Department evaluated available information on various technologies, including their technical feasibility, biological effectiveness, and associated costs. The alternative technologies identified by the Department's contractor, Versar, to have the greatest potential for application to reduce impingement and entrainment at the Station were:

1. Replacing the existing 3/8" mesh traveling-screens with fine mesh screen panels.
2. Traveling screens with conventional 3/8" mesh or fine mesh retrofitted in front of the dilution pumps and/or fine-mesh centerflow screens retrofitted in front of the dilution pump.
3. Replacement of intakes with fine-mesh wedgewire screens.
4. Closed cycle cooling (cooling towers).
5. Optimization of dilution pump operations.

As discussed in the 1989 Versar report, the first two alternatives would increase impingement losses while reducing entrainment. The net ecological benefit of these retrofits would depend on the degree to which the reduction in entrainment losses exceeds the gain in impingement losses. Versar looked primarily at the first three physical barrier alternatives as they could be applied without complete replacement of the intake structure so as to avoid the high cost of an entirely new intake structure. Versar was concerned with limited data on the engineering feasibility of some of these alternatives and was not able to recommend that the cost of these technologies could be appropriate in view of the limited benefits of these technologies. In sum, Versar found that none of the screening options reduces losses at the facility by even 50%.

Versar dismissed the wedgewire screen alternative because its costs far exceeded its benefits. Biofouling and detrital clogging would also be a concern in the application of wedgewire screens at the Station.

Versar also considered the alternative of recirculating cooling towers which are a demonstrated, effective technology for reducing entrainment and impingement, as well as thermal discharge impacts. Cooling towers are the most expensive alternative but would reduce water withdrawal by more then 95 percent and provide the highest degree of protection of any single currently available technology as a proportionate reduction in impact would result from the withdrawal (flow) reduction. Cooling towers are expected to be more costly then the physical barrier alternatives and Versar did not recommend cooling towers to be designated the best technology available due to concerns about economic cost. Additionally, Versar concluded that there are ecological costs associated with cooling towers. Natural draft cooling towers are typically several hundred feet high and add considerable visual impact. Mechanical draft towers may be lesser in size thereby imposing less visual impact but would impose noise from tower fans as well as the potential for local salt drift, fogging and icing.

Versar also looked into optimization of dilution pump operations as an alternative for reducing total plant impingement-entrainment losses. Optimization studies would compare the benefits of an altered thermal mortality rate (from the cooling provided by dilution pump flows) with the environmental cost of exposure by entrainment of a greater number of organisms due to dilution pump flows. Versar found that the Section 316 Demonstration did not contain sufficient information to optimize dilution pump operations. Versar found that November through February (potential cold shock) and July and August (potential heat shock) are periods of high risk of increasing total mortality associated with the facility.

In sum, based on the above review of available technologies, the Department determined that the existing cooling water intake structure, in conjunction with the pursuit of Dilution Pump Optimization Studies, was designated Best Technology Available under Section 316(b) in its 1994 permit based upon available Section 316(b) guidance at that time.

3. Implementation of Section 316(b) Regulations

a. Compliance Alternatives

While historical data and information relied upon in the Department's previous Section 316(b) determination is useful, implementation of Section 316(b) in the current permit will be unique in that this is the Station's first permit action in which the newly effective Section 316(b) regulations will be implemented. The existing and proposed renewal permits contain a limit on intake velocity, which aids in minimizing impingement and entrainment losses. The Department also recognizes that the facility has impingement controls of the circulating water system intake, namely Ristroph traveling screens and a fish return system. The Department has required Ristroph traveling screens at a number of other Phase II facilities and finds that they are a proven and effective technology for minimizing impingement effects for some species but have no effect on reducing entrainment. In addition, the Oyster Creek fish return system is designed with gentle slides and collection pools to lessen the impact on impinged fish. As stated previously the permittee contends that the design of the dilution system pumps allow for some impingement and entrainment survivability, however there are no other impingement or entrainment controls at the dilution pumps, which at times exceed the flow volume of the intake. Pursuant to the new Phase II regulations, entrainment survivability is only allowable if it is the subject of a study approved by the Director pursuant to 40 CFR 125.95(b)(6)(B). Therefore, unless closed-cycle cooling is chosen, the permittee must address measures to reduce impingement and entrainment at the dilution pumps as part of its demonstration for compliance under the regulations. The Department recognizes that controls at the dilution pumps were considered costly as part of its BTA determination in the 1995 permit; however, given the fact that these pumps are regulated purusant to 40 CFR 125.93, impingement and entrainment effects must be minimized at this location.

Given the available impingement and entrainment data, the Department is concerned about both impingement and entrainment losses, but is particularly concerned about the entrainment losses. As stated above, this was also raised as a concern in the 1995 Section 316(b) determination. Species of particular concern include hard clam, blue crab, bay anchovy and sand shrimp. Nonetheless, the Department understands that there are limited design and construction technologies available to reduce entrainment at this time. Specifically, the Department recognizes that closed cycle cooling is the only cooling water intake structure technology available to the facility to reduce entrainment. Closed cycle cooling serves to significantly limit the amount of intake flow and thereby reduces both impingement and entrainment. Restoration can be used as a means to offset entrainment; however, there are also some benefits to larger life stages that are typically susceptible to impingement.

The regulations specify compliance alternatives at 40 CFR Part 125.94 and the required submission of a Comprehensive Demonstration Study (CDS) at 40 CFR 125.95. Based upon a review of site-specific factors at the facility, past Department policies and practices in implementing Section 316(b), and given the fact that the facility withdraws water from a tidal river or estuary, the Department has determined that_the following compliance alternatives are available as specified at 40 CFR 125.94(a) to demonstrate compliance with Section 316(b):

1) **Alternative 1:** Reduce intake capacity to a level commensurate with the use of a closed-cycle, recirculating cooling system. This is the Department's preferred alternative. If Alternative 1 is chosen, the permittee would not be required to submit the CDS.

2) **Alternative 2:** If the permittee can demonstrate that Alternative 1 is unavailable to this facility, the Department will allow the permittee to select, install, properly operate and maintain a combination of design and construction technologies, operational measures, and/or restoration measures that will, in combination with any existing design and construction technologies, operational measures, and/or restoration measures, meet the following national performance standards:

Impingement Mortality Performance Standard – Reduce impingement mortality for all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline[1].

Entrainment Performance Standard – Reduce entrainment for all life stages of fish and shellfish by 60 to 90 percent from the calculation baseline[1].

In addition to compliance with the national performance standards, the permittee shall initiate a wetlands restoration and enhancement program of a minimum of 350 acres within the Barnegat Bay estuary to offset any residual impingement and entrainment losses at the facility to realize benefits as soon as possible.

[1] The calculation baseline means an estimate of impingement mortality and entrainment that would occur on-site assuming a shoreline cooling water intake structure with an intake capacity commensurate with a once-through cooling water system and with no impingement and/or entrainment controls.

b. Basis and Background Regarding Compliance Alternatives

The Department recognizes that the Section 316(b) regulation allows for the pursuit of the studies outlined at 40 CFR 125.95 prior to selecting a compliance alternative. Consistent with this regulation, the Department is requiring the submission of a CDS via this permit. The Department is already in receipt of a Proposal for Information Collection (PIC) dated June 29, 2005 and is in the process of review and comment. However, the Department also recognizes that some relevant Section 316(b) data and information is available as part of the Administrative Record. The Department has evaluated these studies and has determined that at this time there are limited technologies available to address entrainment with the exception of closed-cycle cooling. The Department also recognizes that the permittee could develop a restoration plan as part of the CDS where one of the requirements for the Restoration Plan, as specified at 40 CFR Part 125.95(b)5(iii), would be the "Quantification of the ecological benefits of the proposed restoration measures..." In other words, one of the outputs of a Restoration Plan would be an estimated amount of acreage necessary to offset any remaining impingement and entrainment losses not addressed via technological measures to meet the national performance standards.

It is the Department's practice and policy to set forth a Best Technology Available (BTA) determination in its NJPDES permits with respect to Section 316(b). Consistent with past practice, the Department has set forth a BTA determination in this permit based on the site-specific factors at Oyster Creek and available information. Therefore, the Department has determined that BTA for this facility is as follows.

- Option 1 - the implementation of closed-cycle cooling is best technology available.

- Option 2 - BTA consists of the permittee's existing once-through cooling system coupled with a limit on the intake velocity, pursuit of the studies required under the Section 316(b) Phase II Regulations, and the initial restoration requirement.

Acknowledging the limited efficacy of best available technologies, the Department has determined that the initial restoration requirement is an appropriate more stringent condition in accordance with Best Professional Judgement. The Department reserves the right to reconsider BTA in any future decision based on the data and results of the CDS where any such decision would be subject to public comment and notice procedures at N.J.A.C. 7:14A-16.4.

The Department also recognizes that the Phase II Section 316(b) regulation allows for additional time in devising a restoration plan which could include an amount of acreage necessary. The Department has evaluated the approximation of the fish losses based on the 1987 316 study and has estimated the wetlands restoration acreage required to adequately minimize the effects of the Station's losses. The Department utilized a food chain model to estimate the production of fish biomass for the species at issue. Primary productivity per acre of wetland per year and food chain transfer conversion factors were derived from published, peer-reviewed scientific literature and were employed in this calculation. Conservative assumptions were also incorporated in this calculation. Given the fish losses reported in the study, a preliminary calculation as to the amount of restoration acreage in the Barnegat Bay watershed that would be necessary to offset fish losses at Oyster Creek would equal 3500 acres. The Department is only requiring 350 acres at this time and is not requiring implementation of the 3500 acre value. This is a means to allow the permittee to implement a portion of restoration but yet allow time to evaluate whether the 3500 acre estimate is appropriate as part of any Restoration Plan. The Department would be willing to evaluate any alternate estimate developed by the permittee in its CDS.

Restoration is allowable under the Section 316(b) regulations as a means to attain compliance with the National Performance Standards. While the Department recognizes that restoration is not an intake protection technology, the Department concurs that restoration is a viable alternative to minimize the residual effects of cooling water intake structures after the implementation of BTA. Estuarine wetlands are valuable natural resources. Wetland systems provide foraging and refuge habitat, serve as nursery areas for early life stages and juveniles, and provide direct food resources through the production of detrital matter. For these reasons, increased wetlands in the Barnegat Bay watershed will contribute directly to the increased abundance of these species. Because wetlands in the Barnegat Bay area support production of the species at issue, wetlands restoration and enhancement will minimize the effects of

Oyster Creek related losses by increasing productivity of these species. Wetlands restoration and enhancement is particularly valuable towards offsetting entrainment losses given the fact that eggs, larvae and young of year species typically utilize estuarine environments. Wetlands restoration and enhancement also benefits other aquatic and terrestial species dependent on the productivity derived from the wetlands.

c. Methods to Implement Restoration

EPA's National Estuary Program (NEP) was established by Congress in 1987 to improve the quality of estuaries of national importance. In July, 1995, EPA recognized the Barnegat Bay estuary as an estuary of national significance threatened by pollution, development and overuse and was accepted into the NEP. As per the NEP, a Final Comprehensive Conservation and Management Plan was issued in May 2002 by EPA Region II, NJDEP, and interested Ocean County stakeholders. This plan details possible sources of restoration including but not limited to:

- Protect and improve vegetated buffer zones adjacent to coastal wetlands and freshwater tributaries to maintain continuous riparian corridors for habitat protection and low-impact recreational pursuits.

- Control erosion in threatened shoreline areas.

- Manage tidal wetlands to preserve unditched wetlands and to rehabilitate wetlands that have been ditched or otherwise altered (e.g., through Open Marsh Water Management).

- Land acquisition and restoration efforts of threatened sensitive natural areas are outlined in The Trust for Public Land's report entitled The Century Plan. In 1995, TPL published "The Century Plan: A Study of One Hundred Conservation Sites in the Barnegat Bay Watershed," a comprehensive study identifying 103 high-priority conservation and public access sites in the Barnegat Bay. A map showing the 103 sites is included at the end of this Fact Sheet.

The permittee could also implement restoration activities on its own lands. Specifically, a project for the permittee's property is discussed and cited in the United States Army Corps of Engineer's Report entitled "Draft Conceptual Design Alternatives and Associated Tasks for Environmental Restoration Feasibility Study" dated December 6, 2001for the Oyster Creek property.

4. Section 316(b) Requirements

The Department is requiring compliance with the newly effective Section 316(b) regulations in a two fold approach. First, it has included requirements in this permit tailored to the site-specific factors at Oyster Creek. Secondly, because there are already Section 316(b) studies and data available, the Department has specified two compliance alternatives and a schedule for implementing such. The Department's implementation of EPA Phase II regulations set forth in this permit is a more stringent site-specific application based on the Department's past practices, policies and best professional judgment. Such an application is authorized by Section 125.94(e) of the Phase II rule. See, EPA Office of Water letter dated June 29, 2004. A complete summary of all the Section 316(b) requirements are as follows:

a. Compliance Alternatives

Alternative 1: Implementation of Closed-Cycle Cooling

If Alternative 1 is chosen, the permittee must do the following:

- By **September 7, 2005**, the permittee must notify the Department that this is the preferred alternative in its Proposal for Information Collection or in an addendum to such. The Department acknowledges receipt of a PIC dated June 29, 2005.

- Obtain all federal, state, and local construction permits and contract a bid to construct by **EDP + 48 months**.

- Commence construction by **EDP + 59 months.**

- Submission of a CDS is not required under Alternative 1.

Alternative 2: Work Towards Attainment of National Performance Standards via Design and Construction Technologies, Operational Measures and/or Restoration Measures

The Section 316(b) regulations require submission of a CDS and a PIC. The PIC is essentially a workplan that precedes the CDS. As noted previously, existing impingement and entrainment data is available that documents losses at the facility, particularly to hard clam, sand shrimp and blue crab. Given that the impingement controls currently at the facility are not comparable to the impingement reductions of 80 to 95% as specified in the Section 316(b) regulations as national impingement performance standards, the Department has imposed permit requirements for Alternative 2 in addition to the CDS requirements. These Section 316(b) requirements are being imposed in accordance with Best Professional Judgement and are consistent with the intent and direction of the final regulation. These additional requirements are necessary in order to ensure that the minimization of impingement and entrainment effects are realized as soon as possible. Therefore, the Section 316(b) requirements for Alternative 2 are as follows:

1) Proposal for Information Collection – due **September 7, 2005**. The Department acknowledges receipt of a PIC dated June 29, 2005.

- Notify the Department that **Alternative 2** is the preferred alternative.

- Refer to 40 CFR 125.95(b)1 for additional requirements. The Department acknowledges receipt of a PIC dated June 29, 2005.

2) Impingement Mortality and/or Entrainment Characterization Study – due as part of the CDS by **January 7, 2008**

- Refer to 40 CFR 125.95(b)3 for requirements. Please note that since the permittee's Section 316(b) studies are over ten years old, data from these previous studies may be used for comparison purposes but additional data collection is also required.

3) Technology and Compliance Assessment Information for Impingement

a) Design and Construction Technology Plan - Refer to 40 CFR 125.95(b)4. Except for the requirements listed below, the Design and Construction Technology Plan is due by **January 7, 2008**. Additionally, the following site-specific requirements apply:

- Existing Impingement Control Technologies and Enhancements to Minimize Impingement Mortality – The permittee shall detail the technologies and operational measures that are already in place to reduce impingement at the circulating water intake structure and the dilution water intake structure. Information shall be submitted to demonstrate the efficacy of those technologies for RIS to provide a measure of compliance with the impingement national performance standards. This study shall also include an analysis of the location of the fish return system (that currently enters near the dilution pump discharge) and propose alternative fish return points to minimize stress to the aquatic organisms that are returned to the discharge canal via the fish return sluice. This study shall be submitted by **January 1, 2007**.

- Alternate Impingement Controls – The permittee shall address impingement controls at the dilution pumps. In addition, the permittee shall analyze alternate intake protection technologies at the circulating water intake structure to further minimize impingement effects. This study shall be submitted by **January 1, 2007**.

b) Technology Installation Plan – Refer to 40 CFR 125.95(b)3. Except for the requirements listed below, the Technology Installation Plan is due by **January 7, 2008**. Additionally, the following site-specific requirements apply:

- Installation Schedule – Based upon review of the above design and construction technology studies, if the Department concurs that any available technology assessed above in the design and construction technology plan is appropriate in minimizing impingement effects, the permittee shall propose and submit an installation schedule and commence installation by **January 7, 2008.**

4) Technology and Compliance Assessment Information for Entrainment – At this time the installation of closed-cycle cooling and restoration appear to be the only measures that can further minimize or offset entrainment to the levels specified in the national performance standards given the site-specifics of Oyster Creek. If the permittee chooses not to install closed-cycle cooling, the permittee shall review available entrainment technologies with particular attention to any new, improved or developing technologies. Any report shall be submitted by **January 7, 2008**.

5) Restoration Plan - As part of the CDS, the permittee shall prepare a Restoration Plan in accordance with the requirements specified at 40 CFR 125.95(b)5. The Restoration Plan shall take into account the impingement and entrainment losses at the plant and determine the number of acres of wetlands restoration, land preservation or other methods that would offset impingement and entrainment losses (in combination with the existing technologies) to attain the impingement and entrainment national performance standards. This value shall be compared to the Department's preliminary estimate of 3500 acres. Except for the requirements listed below, the Restoration Plan is due by **January 7, 2008**. Additionally, the following site-specific requirements apply:

a) Initial Restoration Requirement – Initiate a wetlands restoration and enhancement program of a minimum of 350 acres within the Barnegat Bay estuary to ensure that benefits of wetland restoration are realized as soon as possible to offset the entrainment losses at the facility. The amount of 350 acres is 10% of the estimated restoration requirement of 3500 acres. The following applies to the Initial Restoration Requirement:

- Identification of Initial Restoration Sites – The permittee shall identify the sites and restoration methods to be employed for the Department's review. A description of the identified sites shall be submitted to the Department by **EDP + 12 months.** Restoration and/or preservation of uplands adjacent or contiguous to Barnegat Bay estuary tidal wetlands (upland buffer) can also count towards the acreage requirements but at a 3:1 basis (three acres of upland buffer equals one acre of Barnegat Bay estuary tidal wetlands). As stated previously, the permittee may elect to conduct restoration on its own lands.

- Peer Review of Initial Restoration Sites – Peer review of the proposed restoration methods for the identified sites is required. The permittee shall designate a minimum of four peer reviewers where their selection shall be approved by the Department. The permittee shall designate at least one member from within the Department. Peer reviewers must have appropriate qualifications in the fields of geology, engineering and/or biology. At least one peer reviewer shall be a member of the Barnegat Bay National Estuary Program. The permittee shall select a peer review group and seek peer approval by **EDP + 12 months**.

- Secure Control of Land – The permittee shall secure control of land selected for the initial restoration requirement and initiate restoration methods by **EDP + 24 months**.

5) Verification Monitoring Plan

- Existing Impingement Controls – a Verification Monitoring Plan, in accordance with 40 CFR 125.95(b)(7), shall be submitted with the CDS by January 7, 2008.

- Future Impingement and/or Entrainment Controls – a schedule for a Verification Monitoring Plan for future impingement and/or entrainment controls shall be submitted with the CDS.

9 Type and Quantity of the Wastes or Pollutants:

The Permit Summary Table near the end of this fact sheet contains a summary of the quantity and quality of pollutants treated and discharged from the facility and the proposed effluent limitations. Effluent data was obtained from the facility's Monitoring Report Forms for the time period specified in the table.

10 Summary of Chemical-Specific Permit Conditions:

The existing and proposed effluent limitations and other pertinent information regarding the draft permit are described below:

A. Basis for Effluent Limitations and Permit Conditions - General:

The effluent limitations and permit conditions in this permit have been developed to ensure compliance with the following:

1. NJPDES Regulations (N.J.A.C. 7:14A),
2. New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B),
3. 1998 "Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey" report,
4. Wastewater Discharge Requirements (N.J.A.C. 7:9-5.1 et seq.),
5. Existing permit limitations in accordance with N.J.A.C. 7:14A-13.19 and 40 CFR 122.44 (antibacksliding requirements),
6. Permit limitations in accordance with N.J.A.C. 7:9B-1.5(d) (antidegradation requirements),
7. Statewide Water Quality Management Planning Rules (N.J.A.C. 7:15),
8. Technology Based Treatment Requirements or Effluent Limitation Guidelines Requirements (N.J.A.C. 7:14A-13.2 to 13.4),
9. 40 CFR Part 423
10. 40 CFR Part 125, Subpart H

Technology based limitations are authorized by Section 301 of the Clean Water Act, 40 CFR 122, N.J.S.A. 58:10A-4, and N.J.A.C. 7:14A-13.2(a)1.ii., 13.3(b), and 13.4. In general, effluent limitations are based on Effluent Limitation Guidelines (ELGs), developed by the United States Environmental Protection Agency (USEPA), or on case-by-case limitations developed through a Best Professional Judgment (BPJ) analysis in cases where ELGs are not available or appropriate. ELGs are minimum technology based requirements applicable on a nation-wide basis and are published in 40 CFR Subchapter N. ELGs consider the category of industry that produce common pollutants taking into account the specific factors unique to a particular type of industry (manufacturing process, type and quantity of pollutants generated, types of treatment facilities available to treat the pollutants, etc.). In cases where ELGs are applicable for surface water dischargers, ELG loading limitations are calculated using the specified concentration value and the production information provided by the permittee. BPJ determinations are authorized by Section 402 (a)(1) of the Clean Water Act.

Effluent Limitation Guidelines (ELGs) are applicable to this facility in accordance with 40 CFR 423, the Steam Electric Power Generating Point Source Category. Where applicable, these guidelines were used to develop effluent limitations for the discharges from this facility unless a more stringent federal, state, or local effluent limitation was applicable.

In accordance with N.J.A.C. 7:14A-13.5, Water Quality Based Effluent Limitations (WQBELs) are imposed when it has been determined that the discharge of a pollutant causes an excursion of criteria specified in the New Jersey Surface Water Quality Standards (SWQS), N.J.A.C. 7:9B-1.1 et seq., and the Federal Water Quality Standards, 40

CFR Part 131. WQBELs are authorized by Section 301 of the Clean Water Act, 40 CFR 122, N.J.S.A. 58:10A-4, and N.J.A.C. 7:14A-13.2 and 13.3. The policies used to develop WQBELs are contained in the State and Federal Standards. Specific procedures, methodologies, and equations are contained in the current USEPA "Technical Support Document for Water Quality-based Toxics Control" (TSD) (EPA- 505/2-90-001) and are referenced in N.J.A.C. 7:14A-13.5 and 13.6.

Expression of all effluent limitations are in accordance with N.J.A.C. 7:14A-13.14 and 13.15.

Whole effluent toxicity limitations are expressed as a minimum as a percent.

B. Basis and Derivation for Effluent Limitations and Monitoring Requirements- Specific:

DSN 001A: Non-Contact Cooling Water (approximately 592 MGD)

1. Flow: This permit does not include a numerical limitation for flow. Monitoring conditions are applied pursuant to N.J.A.C. 7:14A-13.13.

2. pH: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. A condition for monitoring intake pH has been included since a narrative condition regarding pH compliance has been included in Part IV A.1.h.

3. Effluent Temperature, Intake Temperature, Temperature Difference Between Intake and Discharge, Net Rate of Addition of Heat: The effluent limitations and/or monitoring requirements are based on the findings of the permittee's 1987 316(a) study and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. Additional information regarding temperature and heat limitations is included in the Section 316(a) determination discussed previously in this Fact Sheet.

   Consistent with the existing permit, the Department has continued effluent limitations for effluent temperature, temperature difference between intake and discharge, and net rate of addition of heat under two scenarios that are identified in this permit as Option 1 and Option 2 limits. Option 1 limits are applicable when four circulating water pumps are operating for condenser cooling. Option 2 limits shall be applicable during periods of condenser backwash, intake component maintenance or during a Maximum Emergency Generating Event. An explanation of these conditions is also specified as items G.1.g. and G.1.i. of Part IV.

4. Intake Velocity: The daily maximum limitation for intake velocity is based on the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. This limitation was imposed in the existing permit to reduce impingement and entrainment at the cooling water intake. Additional information regarding intake velocity is included in the Section 316(b) determination discussed previously in this Fact Sheet. Upon review of any future 316(b) study as outlined previously, the Department may modify this limit. The intake velocity limit is also indicated as item G.2.a. of Part IV.

5. Chlorine Produced Oxidants (CPO): In accordance with the Surface Water Quality Standards N.J.A.C. 7:9B-1 et seq. Total Residual Chlorine (TRC) is now referred to as CPO. The term CPO is simply a more appropriate name for the compounds which the TRC test measures. The TRC test measures not only residual chlorine, but the sum of free and combined chlorine and bromine as well.

   The daily maximum limitation is based on 40 CFR 423.13(b)(1) and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. A narrative condition has been included in Part IV to ensure that chlorination only occurs for two hours per day consistent with 40 CFR Part 423. An additional CPO limit on a concentration basis applies to the turbine building closed cooling water heat exchanger. Data for this wastestream shall be tracked on monitoring report forms.

6. Whole Effluent Toxicity (WET): Section 101(a) of the Clean Water Act (CWA) establishes a national policy of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters. In addition,

section 101(a)(3) of the CWA and the State's Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B-1.5(a)3 state that the discharge of toxic pollutants in toxic amounts is prohibited. Further, 40 CFR 122.44(d) and N.J.A.C. 7:14A-13.6(a) require that where the Department determines using site-specific WET data that a discharge causes, shows a reasonable potential to cause, or contributes to an excursion above the SWQS, the permitting authority must establish effluent limits for WET.

Acute WET sampling was imposed in the existing permit at a quarterly monitoring frequency. The Department issued a modification on November 26, 1996 that reduced the monitoring frequency to annual. Since January 1995, the permittee has consistently reported an acute result of LC50>100% for this discharge. Therefore, as the permittee has consistently shown no acute toxicity in their discharge, the Department proposes to reduce acute toxicity monitoring to once per permit cycle in accordance with N.J.A.C. 7:14A-14.1(b).

The test species method to be used for acute testing shall be the *Mysidopsis bahia* 96 hour definitive test. Such selection is based on the saline characteristics of the receiving stream, the existing permit, N.J.A.C. 7:9B-1.5 and N.J.A.C. 7:18, the Regulations Governing the Certification of Laboratories and Environmental Measurements (N.J.A.C. 7:18).

<u>DSN 002A</u> - Non-Contact Cooling Water (3.5 MGD)

1. <u>Flow</u>: This permit does not include a numerical limitation for flow. Monitoring conditions are applied pursuant to N.J.A.C. 7:14A-13.13.

2. <u>pH</u>: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. . A condition for monitoring intake pH has been included since a narrative condition regarding pH compliance has been included in Part IV A.1.h.

3. <u>Effluent Temperature, Intake Temperature, Temperature Difference Between Intake and Discharge, Net Rate of Addition of Heat</u>: The effluent limitations are based on the findings of the permittee's 1987 316(a) study and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19.

4. <u>Chlorine Produced Oxidants (CPO)</u>:

   In accordance with the Surface Water Quality Standards N.J.A.C. 7:9B-1 <u>et seq</u>. Total Residual Chlorine (TRC) is now referred to as CPO. The daily maximum limitation is based on 40 CFR 423.13(b)(1) and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19.

5. <u>Whole Effluent Toxicity (WET)</u>:

   Section 101(a) of the Clean Water Act (CWA) establishes a national policy of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters. In addition, section 101(a)(3) of the CWA and the State's Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B-1.5(a)3 state that the discharge of toxic pollutants in toxic amounts is prohibited. Further, 40 CFR 122.44(d) and N.J.A.C. 7:14A-13.6(a) require that where the Department determines using site-specific WET data that a discharge causes, shows a reasonable potential to cause, or contributes to an excursion above the SWQS, the permitting authority must establish effluent limits for WET.

   Acute WET sampling was imposed in the existing permit at a quarterly monitoring frequency. The Department issued a modification on November 26, 1996 that reduced the monitoring frequency to annual. Since January 1995, the permittee has consistently reported an acute result of LC50>100% for this discharge. Therefore, as the permittee has consistently shown no acute toxicity in their discharge, the Department proposes to reduce acute toxicity monitoring to once per permit cycle in accordance with N.J.A.C. 7:14A-14.1(b).

The test species method to be used for acute testing shall be the *Mysidopsis bahia* 96 hour definitive test. Such selection is based on the saline characteristics of the receiving stream, the existing permit, N.J.A.C. 7:9B-1.5 and N.J.A.C. 7:18, the Regulations Governing the Certification of Laboratories and Environmental Measurements (N.J.A.C. 7:18).

DSN 004A - Non-Contact Cooling Water, Stormwater, Floor Drains (0.06 MGD)

1. Flow: This permit does not include a numerical limitation for flow. Monitoring conditions are applied pursuant to N.J.A.C. 7:14A-13.13. Consistent with the existing permit, the permittee is required to monitor and report net flow and heat exchanger flow where net flow shall be used for the purposes of calculating loading values.

2. Total Suspended Solids (TSS), Net: The concentration limitations are based on 40 CFR 423.12(b)(3) and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. The loading limitations are based on the long-term average flow of 0.06 MGD. As the source water for this discharge is the receiving stream, the permittee was allowed under the previous permit to meet these limitations on a 'net' basis and shall be allowed under this renewal permit as well. Therefore, because net limits are applied, monitoring and reporting for intake and effluent TSS is also required as a monthly average and daily maximum.

3. pH: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C. 7:14A-13.19. . A condition for monitoring intake pH has been included since a narrative condition regarding pH compliance has been included in Part IV A.1.h.

4. Effluent Temperature: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19.

5. Petroleum Hydrocarbons: The effluent limitations are based on N.J.A.C. 7:14A-12.8(c). The loading limitations are based on the long term average flow of 0.06 MGD. As the source water for this discharge is the receiving stream, the permittee was allowed under the previous permit to meet these limitations on a 'net' basis and shall be allowed under this renewal permit as well.

6. Total Organic Carbon: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19. The loading limitations are based on the long term average flow of 0.06 MGD.

7. Chlorine Produced Oxidants (CPO):

   In accordance with the Surface Water Quality Standards N.J.A.C. 7:9B-1 et seq. Total Residual Chlorine (TRC) is now referred to as CPO. The daily maximum limitation is based on 40 CFR 423.13(b)(1) and the anti-backsliding provisions as cited in N.J.A.C 7:14A-13.19.

8. Whole Effluent Toxicity (WET):

   Section 101(a) of the Clean Water Act (CWA) establishes a national policy of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters. In addition, section 101(a)(3) of the CWA and the State's Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B-1.5(a)3 state that the discharge of toxic pollutants in toxic amounts is prohibited. Further, 40 CFR 122.44(d) and N.J.A.C. 7:14A-13.6(a) require that where the Department determines using site-specific WET data that a discharge causes, shows a reasonable potential to cause, or contributes to an excursion above the SWQS, the permitting authority must establish effluent limits for WET.

   Acute WET sampling was imposed in the existing permit at a quarterly monitoring frequency. The Department issued a modification on November 26, 1996 that reduced the monitoring frequency to annual.

Since January 1995, the permittee has consistently reported an acute result of LC50>100% for this discharge. Therefore, as the permittee has consistently shown no acute toxicity in their discharge, the Department proposes to reduce acute toxicity monitoring to once per permit cycle in accordance with N.J.A.C. 7:14A-14.1(b).

The test species method to be used for acute testing shall be the *Mysidopsis bahia* 96 hour definitive test. Such selection is based on the saline characteristics of the receiving stream, the existing permit, N.J.A.C. 7:9B-1.5 and N.J.A.C. 7:18, the Regulations Governing the Certification of Laboratories and Environmental Measurements (N.J.A.C. 7:18).

DSN 005A – Dilution Water (732 MGD)

1. Flow: This permit does not include a numerical limitation for flow. Monitoring conditions are applied pursuant to N.J.A.C. 7:14A-13.13. Part IV contains dilution pump operation requirements that are in accordance with the existing permit.

DSN 007A – Miscellaneous Wastewater (30 MGD)

1. Flow: This permit does not include a numerical limitation for flow. Monitoring conditions are applied pursuant to N.J.A.C. 7:14A-13.13.

2. pH: The effluent limitations are based on the anti-backsliding provisions as cited in N.J.A.C. 7:14A-13.19.

3. Petroleum Hydrocarbons: The effluent limitations are based on N.J.A.C. 7:14A-12.8(c) and the anti-backsliding provisions as cited in N.J.A.C. 7:14A-13.19.

DSN 008A – Intake Screen Washwater (2.4 MGD)

1. Flow: Monitoring conditions for flow are applied pursuant to N.J.A.C. 7:14A-13.13 and to allow for a measure of intake screen washwater. A flow limit is not imposed at this outfall. No pollutants are added to this discharge as the discharge consists of canal water used for screen washwater.

DSN 009A – Discharge from Fish Sampling Pool (0 MGD)

1. Flow: Monitoring conditions for flow are applied pursuant to N.J.A.C. 7:14A-13.13 and to ensure that any operations at this discharge point are tracked. A flow limit is not imposed at this outfall. No pollutants are added to this discharge as the discharge consists of canal water used for the purposes of providing water in the fish sampling pool.

C. Intake Monitoring Requirements:

In order to calculate net limitations for outfall DSN 004A, intake monitoring is required for TSS and Petroleum Hydrocarbons, in accordance with N.J.A.C. 7:14A-6.5(b) and 11.2(a) 2, as described previously.

D. Effluent Monitoring Frequencies and Sample Types:

Monitoring frequencies and sample types are in accordance with N.J.A.C. 7:14A-14, unless specified otherwise in the permit. In accordance with N.J.A.C. 7:14A-14.2, the permittee may submit a written request for a modification of the permit to decrease monitoring frequencies for non-limited parameters listed in Part III if site specific conditions indicate the applicability of such a modification.

E. Recommended Quantitation Levels Policy (RQLs):

The Department developed the RQLs to insure that useful data is provided to the Department in order to characterize the discharger's effluent. The Department recommends that the permittee achieve detection levels that are at least as sensitive as the RQLs found in Part III. The Department has determined that the quantitation levels listed therein can be reliably and consistently achieved by most state certified laboratories for most of the listed pollutants using the appropriate procedures specified in 40 CFR Part 136. FAILURE TO ATTAIN A QUANTITATION LEVEL AS SENSITIVE AS A LISTED RQL IS NOT A VIOLATION OF THE PERMIT, BUT DOES TRIGGER SOME ADDITIONAL REPORTING REQUIREMENTS FOR THE PERMITTEE AS SPECIFIED IN PART IV A.1.c. OF THE PERMIT.

F. Reporting Requirements:

All data requested to be submitted by this permit shall be reported on the Discharge Monitoring Reports (DMRs), Waste Characterization Reports (WCR), and Residual Transfer Reports (RTR) as appropriate and submitted to the Department as required by N.J.A.C. 7:14A-6.8(a).

G. General conditions:

In accordance with N.J.A.C. 7:14A-2.3 and 6.1(b), specific rules from the New Jersey Administrative Code have been incorporated either expressly or by reference in Part I and Part II.

H. Operator Classification Number:

The operator classification requirement is no longer included in the permit. To obtain or determine the appropriate licensed operator classification for the treatment works specified, the permittee shall contact the Bureau of Engineering South at (609) 984-6840.

I. Residuals/Sludge Conditions:

All treatment works with a discharge regulated under N.J.A.C. 7:14A must have permits that implement applicable technical standards for residuals management. Generally, the permit issued to the treatment works generating the residual will include applicable residual quality monitoring as well as other general conditions required by N.J.A.C. 7:14A-6. In addition, the permit may include conditions related to any aspect of residual management developed on a case-by-case basis where the Department determines that such conditions are necessary to protect public health and the environment.

The permit may also include conditions establishing requirements for treatment works that send residual to other facilities for final use or disposal. Thus, **ALL** residual preparers (that is, generators as well as persons who manage the residual) are required to submit basic information concerning their residual use and disposal practices. This basic information is submitted by compliance with the Sludge Quality Assurance Regulations (N.J.A.C. 7:14C).

The documents listed below have been used to establish the residual conditions of the Draft Permit:

a. United States Environmental Protection Agency "Standards for the use or disposal of sewage sludge" (40 CFR Part 503),
b. "New Jersey Pollutant Discharge Elimination System" (N.J.A.C. 7:14A),
c. Technical Manual for Residuals Management, May 1998,
d. USEPA Part 503 Implementation Guidance, EPA 833-R-95-001, October 1995. This document is a compilation of federal requirements, management practices and EPA recommended permit conditions for sewage sludge use and management practices,
e. USEPA A Plain English Guide to the EPA Part 503 Biosolids Rule, EPA/832/R-93/003, September 1994,

f. New Jersey "Statewide Sludge Management Plan", November 1987 and
g. New Jersey "Sludge Quality Assurance Regulations" (SQAR), N.J.A.C. 7:14C.

J. Biocides or Other Cooling Water Additives:

The Department has approved the permittee's request to chlorinate non-contact cooling water. In accordance with 40 CFR 423.13(b)(2), chlorine produced oxidants may not be discharged from any single generating unit for more than two hours per day. Simultaneous multi-unit chlorination is permitted.

If the permittee decides to begin using any additional additives in the future, the permittee must notify the Bureau of Point Source Permitting – Region 1 at least 180 days prior to use so that the permit may be reopened to incorporate any additional limitations deemed necessary.

11 Description of Procedures for Reaching a Final Decision on the Draft Action:

Please refer to the procedures described in the public notice that is part of the draft permit. The public notice for this actions is published in the *Ocean County Observer* and in the DEP Bulletin.

12 Contact Information

If you have any questions regarding this permit action, please contact Susan Rosenwinkel, Bureau of Point Source Permitting at (609) 292-4860.

13 Permit Summary Tables

Unless otherwise noted all effluent limitations are expressed as maximums. Dashes (--) indicate there is no effluent data, no limitations, or no monitoring for this parameter depending on the column in which it appears.

DSN 001A

PARAMETER (1)	UNITS	AVERAGING PERIOD	WASTEWATER DATA (2)	EXISTING LIMITS	FINAL LIMITS
Flow	MGD	Monthly Avg. Daily Max.	597 662.4	MR MR	MR MR
Temperature Difference Between Intake and Discharge (Option 1)	°C	Monthly Avg. Instant Max.	10.64 12.2	MR 12.8	MR 12.8
Temperature Difference Between Intake and Discharge (Option 2)	°C	Monthly Avg. Instant Max.	10.3 17.2	MR 18.3	MR 18.3
Effluent Temperature (Option 1)	°C	Monthly Avg. Instant Max.	28.7 41.1	MR 41.1	MR 41.1
Effluent Temperature (Option 2)	°C	Monthly Avg. Instant Max.	21.2 40	MR 43.3	MR 43.3
Intake Temperature	°C	Monthly Avg. Instant Max.	20.9 31.1	MR MR	MR MR
Effluent pH	Su	Instant Min. Instant Max.	7.3 8.2	6.5 (3) 8.5 (3)	6.5 (3) 8.5 (3)
Intake pH	Su	Instant Min. Instant Max.	7.5 8.3	MR MR	MR MR
Chlorine Produced Oxidants – Normal Operations (Option 1)	kg/d	Monthly Avg. Daily Max.	8.9 33.43	MR 41.7	MR 41.7
Chlorine Produced Oxidants – Normal Operations (Option 1)	mg/L	Monthly Avg. Daily Max.	0.1 0.2	MR 0.2	MR 0.2
Chlorine Produced Oxidants – During operation of the turbine building closed cooling water heat exchanger (Option 2)	mg/L	Monthly Avg. Daily Max.	0.1 0.1	MR 0.2	MR 0.2
Intake Velocity	Ft/sec	Monthly Avg. Daily Max.	0.675 1.5	MR 2.2	MR 2.2
Net Rate of Heat	MBTU/hr	Monthly Avg. Daily Max.	4156 4483	MR 5420	MR 5420
Net Rate of Heat	MBTU/hr	Monthly Avg. Daily Max.	2693 4446	MR 5700	MR 5700
Acute Toxicity, LC50	%	Minimum	>100	MR	MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Consistent with the existing permit, the Department has continued effluent limitations for effluent temperature, temperature difference between intake and discharge, net rate of addition of heat, and CPO under two scenarios that are identified in this permit as Option 1 and Option 2 limits. Option 1 heat and temperature limits are applicable when four circulating water pumps are operating for condenser cooling. Option 2 heat and temperature limits shall be applicable during periods of condenser backwash, intake component maintenance or during a Maximum Emergency Generating Event. Option 1 CPO limits are applicable to DSN 001A. Option 2 CPO limits are applicable during periods of chlorination of the turbine building closed CW heat exchanger. An explanation of these conditions is also reiterated as items A.1.j.(CPO), G.1.g., G.1.j and G.1.i.. of Part IV.

(2) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

(3) During periods when the pH of the intake water is less than 6.5, the pH of the effluent shall not be less than that of the intake; or, during periods when the pH of the intake water is greater than 8.5, the pH of the effluent shall not be greater than that of the intake.

(4) Monitoring of the parameters listed above for DSN 001A is not required when there is no flow and/or heat load across the Station's main condensers.

DSN 002A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	EXISTING LIMITS	FINAL LIMITS
Flow	MGD	Monthly Avg. Daily Max.	3.16 5.4	MR MR	MR MR
Temperature Difference Between Intake and Discharge	°C	Monthly Avg. Instant Max.	3.5 11	MR 18.3	MR 18.3
Effluent Temperature	°C	Monthly Avg. Instant Max.	18.1 34.3	MR 45	MR 45
Intake Temperature	°C	Monthly Avg. Instant Max.	17.1 30.6	MR MR	MR MR
Effluent pH	Su	Instant Min. Instant Max.	7.2 8.3	6.5 (2) 8.5 (2)	6.5 (2) 8.5 (2)
Intake pH	Su	Instant Min. Instant Max.	7.5 8.3	MR MR	MR MR
Chlorine Produced Oxidants	mg/L	Monthly Avg. Daily Max.	0.1 0.2	MR 0.2	MR 0.2
Net Rate of Addition of Heat	MBTU/Hour	Monthly Avg. Daily Max.	7.4 41	MR 790	MR 790
Acute Toxicity, LC50	%	Minimum	>100	MR	MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

(2) During periods when the pH of the intake water is less than 6.5, the pH of the effluent shall not be less than that of the intake; or, during periods when the pH of the intake water is greater than 8.5, the pH of the effluent shall not be greater than that of the intake.

DSN 004A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	FINAL LIMITS
Net Flow (2)	MGD	Monthly Avg. Daily Max.	0.06 0.06	MR MR
Effluent Flow	MGD	Monthly Avg. Daily Max.	8.66 8.66	MR MR
Heat Exchanger Flow	MGD	Monthly Avg. Daily Max.	8.60 8.60	MR MR
Effluent Temperature	°C	Monthly Avg. Instant Max.	20.3 30	MR 37.2
Effluent pH	S.U.	Instant Min. Instant Max.	7.8 8.2	6.0 (3) 9.0 (3)
Intake pH	S.U.	Instant Min. Instant Max.	7.5 8.3	MR MR
Chlorine Produced Oxidants	Mg/L	Monthly Avg. Daily Max.	0.1 0.1	MR 0.2
Total Organic Carbon	Mg/L	Monthly Avg. Daily Max.	4.6 7	MR 50
Net Petroleum Hydrocarbons	Mg/L	Monthly Avg. Daily Max.	0.0 0.0	10 15
Net Petroleum Hydrocarbons	Kg/day	Monthly Avg. Daily Max.	0.0 0.0	MR 4.54
Effluent Petroleum Hydrocarbons	Mg/L	Monthly Avg. Daily Max.	- 0.64 19.6	MR MR
Intake Petroleum Hydrocarbons	Mg/L	Monthly Avg. Daily Max.	- 0.148 4.4	MR MR
Net Total Suspended Solids	Mg/L	Monthly Avg. Daily Max.	22.2 43.4	30 100
Net Total Suspended Solids	Kg/day	Monthly Avg. Daily Max.	-0.148 4.4	MR 22.7
Effluent Total Suspended Solids	Mg/L	Monthly Avg. Daily Max.	22.2 43.4	MR MR
Intake Total Suspended Solids	Mg/L	Monthly Avg. Daily Max.	22.8 49.8	MR MR
Acute Toxicity, LC50	%	Minimum	>100	MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

(2) Net flow shall be used for calculating loading values only for this outfall. The equation Qnet = Qactual – Qheat exchanger.

(3) During periods when the pH of the intake water is less than 6.0, the pH of the effluent shall not be less than that of the intake; or, during periods when the pH of the intake water is greater than 9.0, the pH of the effluent shall not be greater than that of the intake.

DSN 005A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	FINAL LIMITS
Flow	MGD	Monthly Avg. Daily Max.	696 749	MR MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

DSN 007A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	FINAL LIMITS
Flow	GPD	Monthly Avg. Daily Max.	26.6 26.6	MR MR
Petroleum Hydrocarbons	mg/L	Monthly Avg. Instant Max.	<0.5 <0.5	10 15

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04. A discharge only occurred during the months of 5/04 and 6/04.

DSN 008A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	FINAL LIMITS
Flow	MGD	Monthly Avg. Daily Max.	2.4 4.4	MR MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

DSN 009A

PARAMETER	UNITS	AVERAGING PERIOD	WASTEWATER DATA (1)	FINAL LIMITS
Flow	MGD	Monthly Avg. Daily Max.	No Discharge No Discharge	MR MR

Footnotes and Abbreviations:

MR Monitor and report only

(1) Wastewater data originates from the information submitted on the monitoring report forms from 1/04 to 12/04.

14 Contents of the Administrative Record

The following items are used to establish the basis of the Draft Permit:

1. 33 U.S.C. 1251 et seq., Federal Water Pollution Control Act. [C]
2. 40 CFR Part 131, Federal Water Quality Standards. [A] [C]
3. 40 CFR Part 122, National Pollutant Discharge Elimination System. [C]
4. N.J.S.A. 58:10A-1 et seq., New Jersey Water Pollution Control Act. [A] [B]
5. N.J.A.C. 7:14A-1 et seq., New Jersey Pollutant Discharge Elimination System Regulations. [A] [B]
6. N.J.A.C. 7:9B-1 et seq., New Jersey Surface Water Quality Standards. [A] [B]
7. N.J.A.C. 7:9-5.1 et seq., Wastewater Discharge Requirements. [A] [B]
8. N.J.A.C. 7:15, Statewide Water Quality Management Planning Rules. [A] [B]
9. N.J.A.C. 7:14C, Sludge Quality Assurance Regulations. [B]
10. "Field Sampling Procedures Manual", published by the NJDEP. [A]
11. "Discharge Monitoring Report (DMR) Instructional Manual", published by the NJDEP. [A]
12. "EPA Technical Support Document for Water Quality-based Toxics Control", EPA/505/2-90-001, March 1991. [A]
13. 1998 "Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey" report. [A] [B]
14. NJPDES/DSW Permit Application dated 6/3/99. [A]
15. Existing NJPDES/DSW Permit NJ0005550, issued 10/21/94 and effective 12/1/94. [A]
16. Major Modification to NJPDES/DSW Permit NJ0005550, issued 4/17/96 and effective on 6/1/96.[A]
17. Major Modification to NJPDES/DSW Permit NJ0005550, issued 11/27/96 and effective on 12/1/96.[A]
18. Site visits on November 6, 2003 and March 4, 2005.
19. DMR data, 1/02 – 6/03.
20. "Final Comprehensive Conservation and Management Plan", issued May, 2002 by EPA Region II, NJDEP, and interested Ocean County stakeholders.
21. Section 316(b) Regulations for Phase II facilities, 40 CFR 125, effective 9/7/04.
22. Existing NJPDES/DSW Permit NJ0005622 issued to PSEG-Salem on 6/29/99 and effective 8/1/2001.
23. Plan of Study for Analysis of Alternatives for Dilution Pump Operation at the Oyster Creek Nuclear Generating Station, May 1995 (EA Engineering, Science, and Technology).
24. Technical Review and Evaluation of Thermal Effects Studies and Cooling Water Intake Structure Demonstration of Impact for the Oyster Creek Nuclear Generating Station, Revised Final Report, Versar, Inc., May 1989.
25. Technical Review and Evaluation of Thermal Effects Studies and Cooling Water Intake Structure Demonstration of Impact for the Oyster Creek Nuclear Generating Station, Advanced Final Report, Versar, Inc., 1988 and comments received thereon.
26. Jersey Central Power & Light Company Section 316 Demonstration for Oyster Creek and Forked River Nuclear Generating Stations, May 1978.
27. 40 CFR Part 423, Steam Electric Power Generating Point Source Category.
28. 1966 Stipulation of the State of NJ, Department of Public Utilities, Board of Public Utility Commissioners.
29. United States Army Corps of Engineer's Report entitled "Draft Conceptual Design Alternatives and Associated Tasks for Environmental Restoration Feasibility Study" dated December 6, 2001.

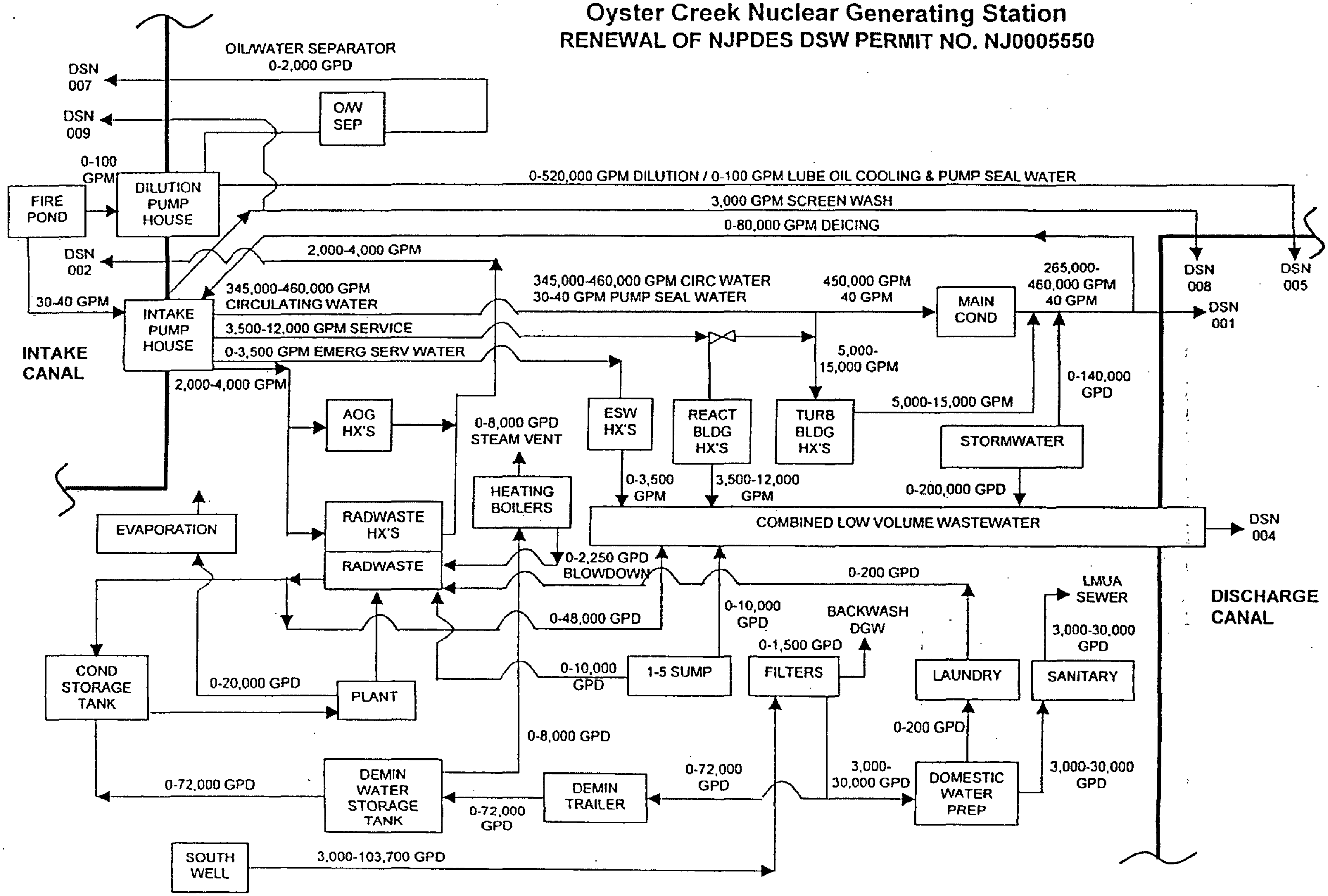
Footnotes:

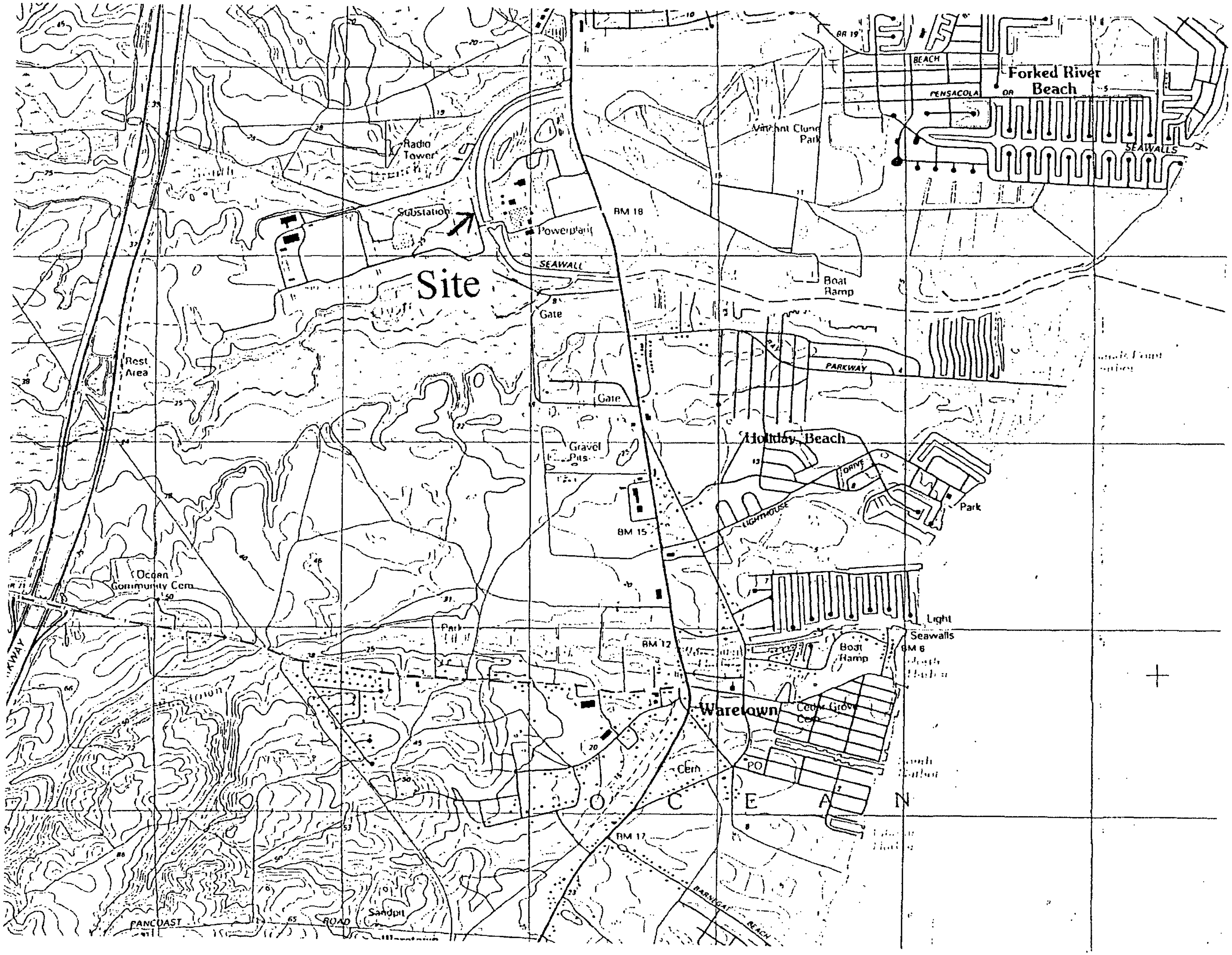
[A] Denotes items that may be found in the NJPDES/DSW Administrative Record Library located in the NJDEP Central File Room, 401 East State Street, Trenton, New Jersey.

[B] Denotes items that may be found on the New Jersey Department of Environmental Protection (NJDEP) website located at "http://www.state.nj.us/dep/".

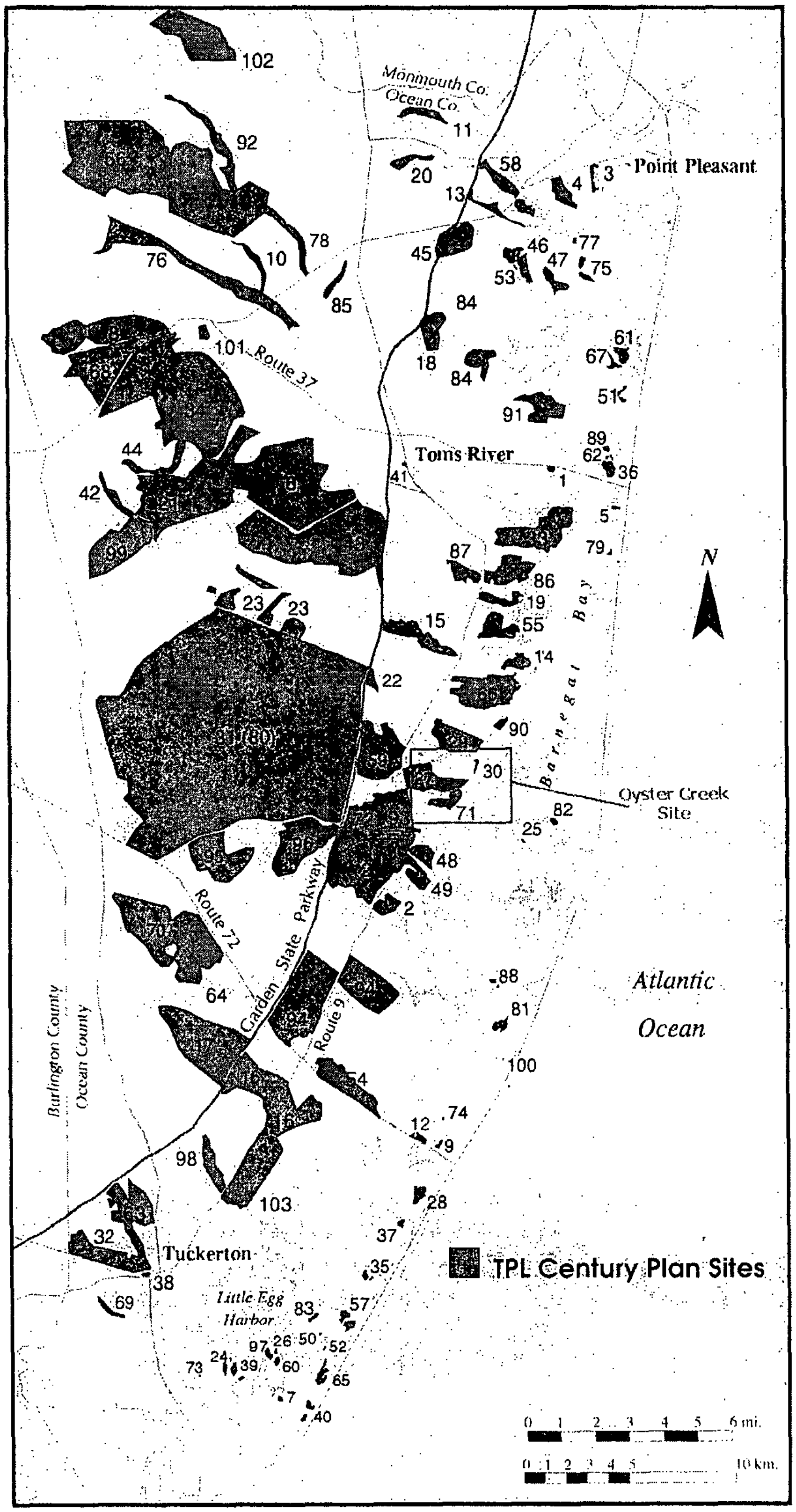
[C] Denotes items that may be found on the United States Environmental Protection Agency (USEPA) website at "http://www.epa.gov/".

Figure 1. Form C Item 3.B. Line Drawing
Oyster Creek Nuclear Generating Station
RENEWAL OF NJPDES DSW PERMIT NO. NJ0005550



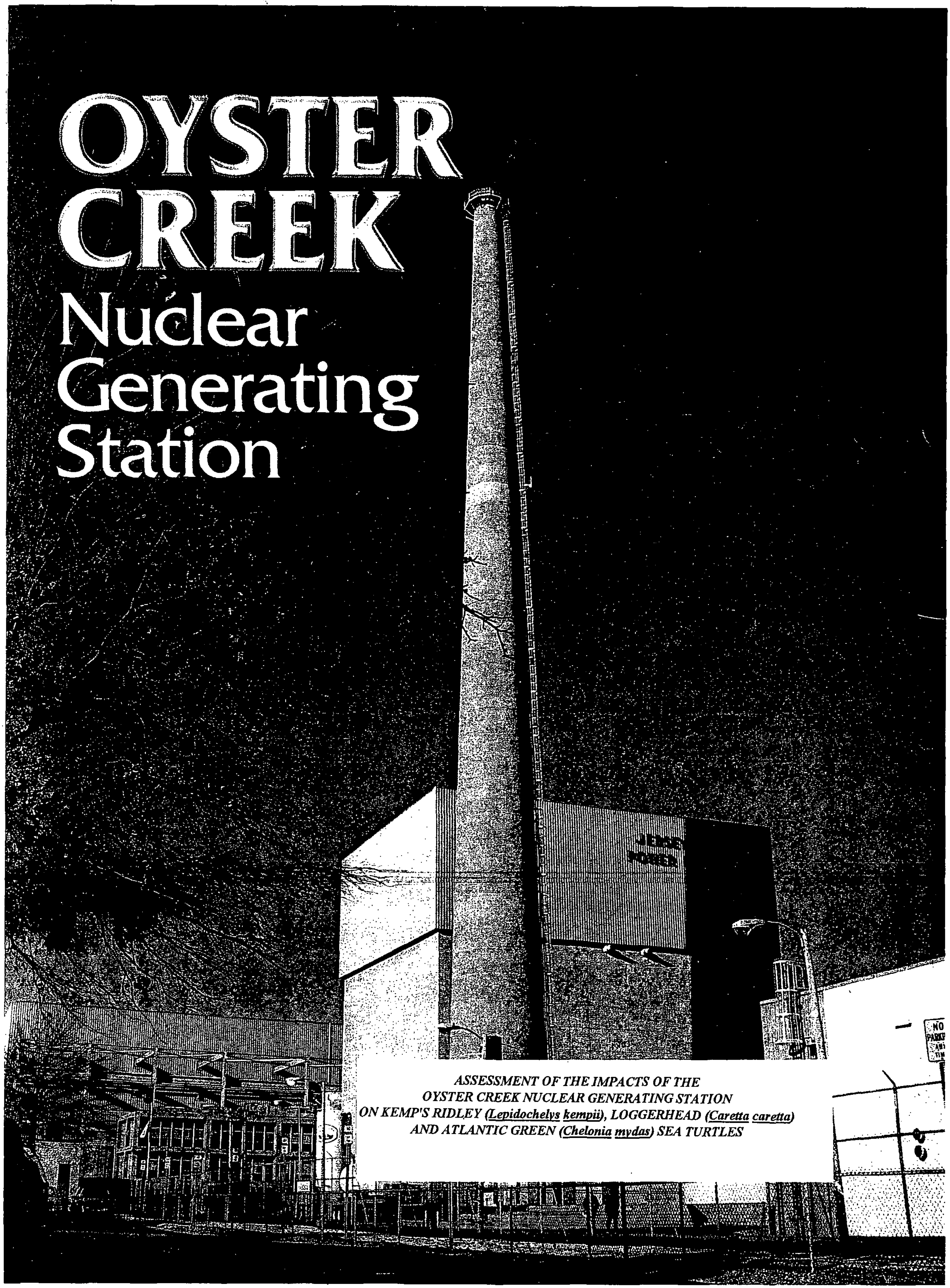

Site
Forked River Beach
Radio Tower
Substation
Powerplant
SEAWALL
Boat Ramp
Gate
Rest Area
Vincent Clune Park
BEACH
PENSACOLA
DR
SEAWALLS
PARKWAY
BM 18
Gravel Pits
Holiday Beach
DRIVE
LIGHTHOUSE
Park
BM 15
Ocean Community Cem
Light
Seawalls
BM 12
Boat Ramp
BM 6
Waretown
Cem
PO
O C E A N
BM 17
BARNEGAT BEACH
PANCOAST
ROAD
Sandpit

Trust for Public Land Century Plan Sites



This map portrays the Trust for Public Land's one hundred original Century Plan *sites (1995) and three additional sites selected by Herpetological Associates.*

1. Anchor Reef Marina
2. Barnegat Bay Beach Island Area
3. Beaver Dam Creek/North Branch
4. Beaver Dam Creek/South Branch
5. Berkeley Harbor Marina
6. Berkeley Triangle
7. Blake Whale Sedge
8. Black and Ruckels Branches
9. Bonnet Island
10. Cabin Branch
11. Cabinfield Branch
12. Cedar Bonnet Island
13. Cedar Bridge Branch
14. Cedar Creek Point/Lanoka Harbor
15. Cedar Creek South
16. Cedar Run Creek/East of Parkway
17. Cedar Run Creek/Northwest Extension
18. Church Road Property
19. Clamming Creek
20. Cotterals Branch
21. Davenport Branch West
22. Deer Head Lake North
23. Double Trouble State Park Out Parcels
24. Drag Sedge and Hester Sedge
25. Dredge Spoil Islands
26. East Sedge
27. Finninger Farm
28. Flat Island and Islets
29. Forked River Annex and Adjacent Uplands
30. Forked River Beach
31. Forked River Mountains and Vicinity
32. Giffords Mill Branch
33. Good Luck Point
34. Green, Big Wrangle, and Run Branches
35. Ham Island and Islets
36. Harbor Island (with Al's Island)
37. High Island
38. Historic Seaport Project
39. Hither Island
40. Holgate Marshes
41. Huddy Park/Proposed Expansion
42. Irish Branch
43. Jake's Branch Corridor
44. Keswick Lake Corridor
45. Kettle Creek/Green Branch
46. Kettle Creek North
47. Kettle Creek Peninsula (Chamberlain Point)
48. Liberty Harbor
49. Lighthouse Camp and Bowker Property
50. Little Island
51. Little Sedge Island
52. Lower Little Island (Post Island)
53. Mallard Point
54. Manahawkin Baptist Church Tract
55. Maple Creek
56. Maple Root Branch and Long Brook
57. Marsh-Elder Island
58. Metedeconk River/Forge Pond
59. Middle Branch/Forked River
60. Middle Sedge
61. Middle Sedge Island
62. Mike's Island with Bill's and Wilde's Island
63. Mill Branch/Tuckerton Creek
64. Mill Creek West
65. Mordecai Island
66. Murray Grove/Stouts Creek
67. Northwest Point Island
68. Old Hurricane Brook
69. Otis Bogs/Willis Creek (Tuckers Bog)
70. Oxly Tract
71. Oyster Creek/Sands Point Harbor
72. Pancoast Inland Area
73. Parkers Island
74. Petit Island
75. Reedy Creek Additions
76. Ridgeway Branch
77. Riverside Woods
78. Riverwood Park Extensions
79. Roberts Avenue Marsh
80. Sand and Gravel Mining Sites
81. Sandy Island
82. Sedge Island
83. Shelter Island
84. Silver Bay Westward Extensions
85. Slab Branch
86. Sloop Creek Road Area
87. Sloop Creek Western Extension
88. Sloop Sedge and Islet
89. Stooling Point Island
90. Sunrise Beach
91. Tilton Point
92. Toms River/Dove Mill Branch
93. Waretown Creek
94. Waterford
95. Wells Mills Girl and Boy Scout Camps
96. Wells Mills Park - Area 'E'
97. West Sedge
98. Westecunk Creek
99. Whiting Clay Pits
100. Woods Island
101. Lakehurst Bog
102. South Branch/Metedeconk River
103. Coxtown



ASSESSMENT OF THE IMPACTS OF THE
OYSTER CREEK NUCLEAR GENERATING STATION
ON KEMP'S RIDLEY (Lepidochelys kempii), LOGGERHEAD (Caretta caretta)
AND ATLANTIC GREEN (Chelonia mydas) SEA TURTLES

OYSTER CREEK NUCLEAR GENERATING STATION
Forked River, New Jersey

The 650 MW plant is a single-unit, five-loop General Electric Boiling Water Reactor (BWR). The site, about 800 acres, is in Lacey and Ocean Townships of Ocean County. Located approximately nine miles south of Toms River, it is about 50 miles east of Philadelphia, and 60 miles south of Newark.

Construction began in December 1963. The station began commercial operation on December 23, 1969, and at that time was the largest nuclear facility in the United States solely financed by a private company.

The Reactor Building, Turbine Building and Ventilation Stack are the most prominent structures at the site. The Reactor Building stands approximately 150 feet high with 42 feet extending below grade. The Reactor Building serves as a secondary containment and houses the primary containment (drywell), the reactor vessel and its auxiliary systems which comprise the Nuclear Steam Supply System. The drywell, which houses the reactor vessel, is constructed of high-density reinforced concrete with an inner steel liner measuring 120 feet high and 70 feet in diameter.

The reactor vessel is 63 feet high and 18 feet in diameter. The 652-ton reactor contains 560 fuel assemblies, each with 62 fuel rods that are 12 feet long, and 137 control rods. The reactor operates at a nominal pressure of 1,020 pounds per square inch and an average temperature of 540 degrees Fahrenheit.

The Turbine Building houses the turbine-generator, control room main condensers, power conversion equipment and auxiliary systems. The turbine-generator consists of one high-pressure turbine, three low-pressure turbines, a generator and an exciter. The turbines and generator turn at 1,800 revolutions per minute to generate three-phase, 60-cycle electricity at 24,000 volts. The electricity generated is provided to the grid by two transformers which boost the voltage to 230,000 volts.

Steam is supplied to the high-pressure turbine from the reactor. After being used to drive the turbines and generator, the steam is condensed in the main condensers and returned to the reactor vessel in the form of water through the condensate and feedwater pumps.

The main condensers consist of three horizontal, single pass, divided water hoses containing 44,000 tubes having a total length of about 1,875,000 feet. Cooling water is provided from Barnegat Bay, through the South Branch of the Forked River and passes through the condensers and discharges into Oyster Creek for return to Barnegat Bay. The water is pumped by four 1,000-horsepower pumps, each of which moves abut 115,000 gallons per minute through the 6-foot-diameter pipes that feed the condensers.

The ventilation stack is 368 feet high with 26 feet extending below grade. The stack provides ventilation for the Reactor Building, Turbine Building and Radwaste Facilities.

Oyster Creek is owned by Jersey Central Power & Light (JCP&L) Company and operated by GPU Nuclear (GPUN) Corporation. JCP&L and GPUN are units of the GPU System.

JCP&L

A GPU COMPANY

ASSESSMENT OF THE IMPACTS OF THE OYSTER CREEK NUCLEAR GENERATING STATION ON KEMP'S RIDLEY (*Lepidochelys kempii*), LOGGERHEAD (*Caretta caretta*) AND ATLANTIC GREEN (*Chelonia mydas*) SEA TURTLES

Prepared by
Oyster Creek Nuclear Generating Station

July 2000

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SECTION 1.0
SUMMARY AND CONCLUSIONS

This "biological assessment" was prepared by Environmental Scientists at the Oyster Creek Nuclear Generating Station (OCNGS) for submittal to the U.S. Nuclear Regulatory Commission and the National Marine Fisheries Service to comply with Section 7 of the Endangered Species Act (the Act). The purpose of this assessment is to examine the potential impacts associated with the continued operation of the OCNGS on sea turtle species protected under the Act, and to support the renewal of the Incidental Take Statement issued on September 21,1995.

OCNGS is located along the western shore of Barnegat Bay between the South Branch of Forked River and Oyster Creek, in Ocean County, New Jersey. Monthly mean salinity values observed in western Barnegat Bay near OCNGS vary seasonally from approximately 18.5 ppt to over 28 ppt. Monthly mean ambient water temperatures in this portion of the Bay range from a winter mean of 1°C (33.8°F) to approximately 28°C (82.4°F) during the summer (Kennish and Lutz, 1984).

OCNGS consists of a single boiling water nuclear reactor with an electrical capacity of approximately 650 megawatts. When OCNGS is in operation, water flows from Barnegat Bay into Forked River and OCNGS, where some of the flow is used to cool the powerplant condensers. Heated water discharged from OCNGS flows eastward in Oyster Creek back into Barnegat Bay.

OCNGS has two water intake structures, the circulating water system intake and the dilution water system intake. During normal operation, the circulating water system moves approximately 1740 m^3/min (0.46 million gpm) of water through the main condensers for cooling purposes. Additionally, up to two dilution pumps (each with a 984 m^3/min or 0.26 million gpm capacity) divert water from the intake canal to the discharge canal to reduce the temperature of the circulating water discharge (Kennish, 1978). Both intakes utilize trash bars to remove debris from the water. The circulating water system intake has vertical traveling screens which have been modified with Ristroph fish buckets and a fish return system.

Four species of sea turtles have been reported from coastal New Jersey waters. These sea turtle species are: loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), Atlantic green turtle (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*).

Two of these sea turtles species, Kemp's ridley and leatherback, are listed as endangered and two, the loggerhead and Atlantic green turtle, are listed as threatened. Only the loggerhead and Kemp's ridley turtles, as well as a single Atlantic green turtle, have been captured at the OCNGS.

The loggerhead sea turtle is the most common sea turtle in the coastal waters of the United States and occurs in many other locations throughout the world. Population numbers along the south Atlantic Coast (North Carolina to Florida) have been estimated at 387,594 turtles (NMFS 1987). The loggerhead population in the southeast is considered to be stable by most investigators but the population is threatened by reductions in nesting and foraging habitat due to the continued development of coastal areas and losses resulting from incidental capture in shrimp trawls. An estimated 5,000 to 50,000 turtles have been lost annually from trawling without the use of turtle exclusion devices (TED's) (NMFS 1991a).

The Kemp's ridley is the most endangered of the sea turtle species. There is only a single known colony of this species, almost all of which nest near Rancho Nuevo, Mexico and represent the world population for this species. The population level has been estimated at 2,200 turtles (Márquez 1989). The ridley population is also impacted by coastal development and shrimp trawling. Incidental take by the shrimp industry has been identified as the largest source of mortality (between 500 and 5,000 killed annually) for L. kempii (Magnuson et al. 1990). However, subsequent to the implementation of the NMFS TED regulations in 1989, strandings of drowned sea turtles have been dramatically lower and nesting activity has increased (Crouse et al. 1992).

Sea turtles have been observed and incidentally captured at OCNGS during 1992 through 2000, but were never captured during more than 10 years of field sampling associated with the station, which began in 1975. Their scarcity in Barnegat Bay is largely attributable to the fact that access to the bay is extremely limited. The only direct access to Barnegat Bay from the Atlantic Ocean is via a single, narrow inlet, approximately 300 m (1,000 ft) wide.

Only fourteen sea turtles have been captured at OCNGS during more than 30 years of operation. At the circulating water intake, three live loggerheads, as well as one live and one dead Kemp's ridley were captured. At the dilution water intake, one live loggerhead and one live Kemp's ridley were collected. Two loggerheads, apparently dead on arrival due to boat prop wounds, four Kemp's ridleys and one Atlantic green turtle, all recently deceased, were also collected from the dilution water intake. One of the dead Kemp's ridleys apparently drowned on the trash bars. The cause of death of the other three Kemp's ridleys and the Atlantic green turtle is unknown, pending the completion of necropsies, but may have been the result of drowning. All specimens captured at OCNGS were subadults or juveniles.

The occurrence of fourteen sea turtles at the OCNGS between 1992 and 2000, although none had been observed before despite intensive sampling efforts, may be attributable to at least two factors. Modifications to Barnegat Inlet, completed in 1991, and subsequent dredging conducted in 1992 and 1993 have resulted in significant increases in the depth of the inlet and the volume of water passing through the inlet during each tidal exchange. These changes may have made Barnegat Bay more accessible to sea turtles migrating up the Atlantic coast. In addition, sea turtle population levels may have increased as a result of the implementation of the NMFS TED regulations in 1989.

It remains to be seen whether or not the changes to Barnegat Inlet will be permanent or, as has happened in the past, shoaling will occur over time, reducing access to Barnegat Bay via the inlet. Similarly, additional data on sea turtle populations and commercial fishing by-catch must be gathered in order to fully evaluate the effectiveness of the TED regulations on reducing sea turtle mortality.

The primary concern with sea turtles at OCNGS is whether or not any station related losses of these endangered or threatened species "jeopardizes their continued existence." Federal regulation defines this term as engaging in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of that species." A comparison was made of sea turtle losses at OCNGS, assuming worst case losses, with population estimates for each turtle species. This worst case estimate of losses includes turtles that died prior to becoming impinged at the OCNGS intake as well as turtles captured alive at OCNGS and returned to the wild. Calculated accordingly, the maximum, estimated, annual loss of loggerheads at the station is three turtles, which represents approximately 0.0008 percent of the population in the southeast U.S. The estimated, worst-case annual loss of Kemp's ridleys at OCNGS is three turtles, which would represent 0.14 percent of the population. Because less than one percent of reported sea turtle strandings in New Jersey are Atlantic green sea turtles (Schoelkopf 1994) and only one Atlantic green sea turtle has ever been observed at OCNGS, the occurrence of the species in this vicinity is expected to remain highly unlikely. Therefore, the estimated worst-case annual loss of Atlantic green turtles at OCNGS is one turtle. It is unlikely that losses at these levels would "appreciably reduce" the distribution or numbers of any of these species. Losses to reproduction would be restricted to "production foregone" due to the loss of juvenile/subadult animals which could potentially be recruited into the breeding population at some time in the future.

Thermal impacts from the operation of OCNGS, such as acute and chronic thermal impacts and coldshock, are not a concern. The thermal effluent from the station forms only a shallow thermal plume within Barnegat Bay. Both species of sea turtles, which have

strong swimming ability, can avoid thermally affected areas which exceed their temperature preferences. In addition, no sea turtles have ever been observed within the discharge canal.

In order to minimize the impact of OCNGS operations on threatened or endangered sea turtles, a variety of measures have been instituted, including all of the "reasonable and prudent measures necessary to minimize the impact on listed species" specified in the Incidental Take Statement dated September 21, 1995. To ensure the timely removal of sea turtles from the intake structures, and optimize their chances for survival, a formal procedure has been developed for station personnel which defines the surveillance, handling and reporting requirements necessary to minimize the impact on sea turtles incidentally captured at the OCNGS. The procedure requires an inspection of the intake structures for the presence of sea turtles at least twice per 8-hour shift, and the cleaning of the intake trash bars on at least a daily basis, throughout the sea turtle season. This represents a doubling of the frequency of intake structure inspections previously specified. The intake structures are provided with high intensity lamps and flood-lighting to facilitate inspection and removal efforts. Guidance on the identification, handling, and resuscitation of sea turtles is also included in the procedure and large color posters, which illustrate the distinguishing features of sea turtles, resuscitation techniques, and reporting requirements, are prominently posted at the intake structures. Custom-made dipnets and a lift net designed to facilitate the gentle removal of sea turtles from the intake are stored at the intake structures during the sea turtle season. The procedure also includes precautions to be taken during routine cleaning of the intake trash bars to ensure that any sea turtles mixed in with the accumulated debris are removed and properly handled.

In accordance with the requirements of the Incidental Take Statement, the National Marine Fisheries Service, as well as the Nuclear Regulatory Commission, have been notified of all sea turtle captures at the OCNGS, within 24 hours by telephone and by written report within 30 days. All live sea turtles have been taken to the Marine Mammal Stranding Center, in Brigantine, NJ, an authorized agent of the Sea Turtle Stranding and Salvage Network. Dead sea turtles were submitted to Cornell University for necropsy. Annual reports of sea turtle captures have been provided as part of the Annual Environmental Operating Report for the OCNGS.

In summary, the continued operation of OCNGS will not jeopardize the continued existence of the loggerhead, Kemp's ridley or Atlantic green sea turtle. The estimated losses of these species attributable to the operation of the station, particularly the water intakes, will not "appreciably reduce" the distribution or numbers of these species. Losses to reproduction would be restricted to "production foregone" due to the loss of juvenile or subadult animals, which could potentially be recruited into the breeding female population in the future.

SECTION 2.0
INTRODUCTION

2.1 PURPOSE

This "biological assessment" is submitted to the U.S. Nuclear Regulatory Commission (NRC) by the Oyster Creek Nuclear Generating Station (OCNGS) in compliance with Section 7 of the Endangered Species Act of 1973 (as amended) [the Act], and in support of the renewal of the Incidental Take Statement issued on September 21, 1995.

The purpose of this assessment is to examine the potential impacts associated with the continued operation of the OCNGS on sea turtle species protected under the Act. The primary species of concern are the Kemp's ridley (Lepidochelys kempii) and loggerhead (Caretta caretta) sea turtles, both of which have been captured on the circulating water or dilution intake trash bars at OCNGS. The U.S. Fish and Wildlife Service, "List of Endangered and Threatened Wildlife and Plants," lists the status of the Kemp's ridley sea turtle as endangered and the loggerhead sea turtle as threatened (50 CFR 17.11). One specimen of Atlantic green turtle (Chelonia mydas), which is listed as threatened in U.S. waters, has been captured at OCNGS. The leatherback turtle (Dermochelys coriacea) is also listed as endangered in U.S. waters and are known to occur in New Jersey waters, but has not been observed at OCNGS. The National Marine Fisheries Service (NMFS) has jurisdiction for these species (50 CFR 222.23(a) and 50 CFR 227.4(b)).

2.2 ENDANGERED SPECIES ACT

This "biological assessment" is part of the formal consultation process provided under Section 7 of the Endangered Species Act. Detailed procedures for this consultation process are defined in 50 CFR 402.

2.3 CHRONOLOGY OF EVENTS LEADING UP TO THIS ASSESSMENT

A review of the sea turtle strandings at OCNGS was requested in a letter from the NMFS to the NRC in November 1993 (Mantzaris 1993). This letter followed communications between OCNGS, NRC and NMFS regarding the capture of sea turtles at OCNGS during 1992 in spite of OCNGS having operated for many years (1969-1991) prior to any being taken.

The issue of sea turtles at OCNGS was initially addressed in 1992 when sea turtles were first observed at the station's circulating water and dilution structure intake trash bars. The matter was discussed jointly by OCNGS, NRC, and NMFS (informal Section 7 review). Subsequent to an additional sea turtle being captured in

1993, NMFS advised NRC that a formal consultation process including preparation of a Biological Assessment would be required (Mantzaris 1993). The OCNGS Environmental Affairs Department requested that they be authorized to prepare the Biological Assessment.

This document, which is the "Assessment of the Impacts of the Oyster Creek Nuclear Generating Station on Kemp's ridley (Lepidochelys kempii), Loggerhead (Caretta caretta), and Atlantic Green (Chelonia mydas) Sea Turtles" and which was originally prepared in 1994, has now been updated in 2000 to include information on sea turtle incidental captures and rescues which have occurred at OCNGS since 1994.

SECTION 3.0
SITE DESCRIPTION

3.1 LOCATION

The Oyster Creek Nuclear Generating Station is located along the eastern edge of the coastal pine barrens of New Jersey in Lacey and Ocean Townships, Ocean County (Figure 3-1). The OCNGS site is located to the west of U.S. Route 9, and is bounded on the north, south and west by the South Branch of Forked River, Oyster Creek, and the man-made intake and discharge canals. Barnegat Bay forms the eastern site boundary (Figure 3-2). The power plant structures are situated approximately midway between Oyster Creek and the South Branch of Forked River and about 425 meters (1,394 ft) west of Route 9.

The station site is approximately 55 km (34 mi) north of Atlantic City, New Jersey and 70 km (44 mi) east of Philadelphia, Pennsylvania. Approximately 15 km (9 mi) north of the site are several small residential communities: Toms River, South Toms River, Beachwood, Pine Beach, Ocean Gate, Island Heights and Gilford Park. West of the Garden State Parkway the land is primarily undeveloped woodland, and wooded wetlands are found along the banks of small creeks to the north, south and west of the site. East of the station along the shoreline of Barnegat Bay, the land is characterized by alternating sections of residential development and undeveloped coastal wetlands and adjacent uplands. The terrain surrounding the site is relatively flat along the shoreline to gently rolling inland.

3.2 BARNEGAT BAY MORPHOLOGY AND BATHYMETRY

The OCNGS utilizes Barnegat Bay as a source of cooling water, via the South Branch of Forked River, and the bay serves as the receiving water body for thermal discharges, via Oyster Creek (Figure 3-2). Barnegat Bay is a shallow, lagoon-type estuary typical of the back bay systems of barrier island coastlines. The long axis of Barnegat Bay extends approximately 50 km (31 mi) in roughly a north-south direction and parallels the mainland, forming an irregular tidal basin ranging from 1 to 6 km (0.6 - 3.7 mi) in width and 0.3 to 6 m (1 - 20 ft) in depth (Kennish and

Olsson 1975; Kennish 1978). The bay is bordered on the west by the New Jersey mainland, on the north by Point Pleasant and Bay Head, on the east by Island Beach and Long Beach Island, and on the south by Manahawkin Causeway. Island Beach and Long Beach Island comprise a barrier island complex breached only at Barnegat Inlet, which is located 10.5 km (6.5 mi) southeast of OCNGS. This single, relatively narrow inlet, provides the only direct access to the bay from the Atlantic Ocean (Figure 3-1).

The surface area and volume of Barnegat Bay have been estimated to be 1.67×10^8 m^2 (64.5 square miles) and 2.38×10^8 m^3 (8.40×10^9 ft^3), respectively (U.S. Atomic Energy Commission 1974). About 73% of the estuary is less than 2 m (6.6 ft) deep at mean low water, which is characteristic of lagoon-barrier island systems (Barnes 1980). The bay's eastern perimeter is shallower (less than 0.9 m or 3.0 ft) than the central and western sectors which are 0.9 to 4.0 m (3.0 - 13.0 ft) deep, with extensive shoal areas exposed at low tide (Chizmadia et al. 1984). The greatest depths of 3 to 4 m (10 - 13 ft) occur along the Intracoastal Waterway, a narrow channel traversing the length of the bay. The Intracoastal Waterway is heavily utilized by both recreational boaters and commercial fishing boats, and is maintained at a depth of approximately 2 m (6.6 ft) for navigation purposes by the U.S. Army Corps of Engineers (Marcellus 1972).

3.3 HYDROLOGY OF BARNEGAT BAY

The bay communicates with Manahawkin Bay to the south and, via the Bay Head-Manasquan Canal, with the Manasquan River to the north (Chizmadia et al. 1984). The primary exchange of ocean and bay water occurs through Barnegat Inlet, where Carpenter (1963) estimated an exchange rate of 7% per tide and a net discharge rate of 56.7 m^3/sec (2,002 ft^3/sec).

The salinity regime and circulation patterns within the bay are affected by the inflow of relatively high salinity waters originating in the Atlantic Ocean which enter the northern and central bay via the Bay Head-Manasquan Canal and Barnegat Inlet, respectively. Because the proportion of bay water which escapes seaward each tidal cycle is relatively small, Chizmadia et al. (1984) estimate that 96 tidal cycles are required for complete turnover of estuarine water to take place. Marcellus (1972) reported a mean tidal current through Barnegat Inlet of 1.1 m/sec (3.6 ft/sec) during flood tide and 1.3 m/sec (4.3 ft/sec) during ebb tide. Ashley (1988) measured peak flood tide flow velocities

of 1.1 m/sec (3.6 ft/sec) and peak ebb velocities of 1.0 m/sec (3.3 ft/sec).

3.3.1 INFLUENCE OF BARNEGAT INLET MODIFICATIONS ON BARNEGAT BAY HYDROLOGY

Beginning in 1988, a multi-year project by the U.S. Army Corps of Engineers was undertaken to re-align the south jetty at Barnegat Inlet and to dredge accumulated sediments from within the inlet. The new alignment of the inlet's south jetty so that it is nearly parallel to the north jetty was completed in 1991. The new jetty configuration has not changed the effective width of the inlet, which remains approximately 300 meters (1000 ft) wide, through which Atlantic Ocean waters can enter Barnegat Bay. The mean tidal range at Barnegat Inlet was reported by Ashley (1988) to be approximately 0.6 m (2 ft) prior to the jetty modifications, and the tide range became progressively damped in a landward direction. The small size of Barnegat Inlet and the shallowness of the bay both restrict tidal flow and attenuate tidal energy, thereby minimizing tidal fluctuations. The depth of the inlet was significantly increased via dredging recently, which permits a freer interchange of ocean and bay waters. The less restricted tidal flow due to recent dredging and jetty modifications has resulted in a significantly greater volume of water passing through Barnegat Inlet during a given tidal cycle (Table 3-1). Preliminary U.S. Army Corps of Engineers data indicate that the average tidal prism has more than doubled since completion of the modifications, and the mean tide range at Barnegat Inlet has increased by over 30% (Gebert 1994).

3.4 BARNEGAT BAY SALINITY

Maximum Barnegat Bay salinities of over 30 ppt are found near Barnegat Inlet due to the input of Atlantic Ocean water. Most freshwater, however, enters the estuary from surface runoff and ground water seepage along the western shore of the bay (Chizmadia et al. 1984). Several tributaries which drain the New Jersey Pine Barrens provide a mean surface runoff of 10.2 m^3/sec (360 ft^3/sec). Toms River provides the greatest freshwater input (5.7 m^3/sec; 201 ft^3/sec) to the estuary, and Cedar Creek provides an additional 3.1 m^3/sec (110 ft^3/sec) (U.S. Atomic Energy Commission 1974). Other significant tributaries of the bay include the Metedeconk River, Kettle Creek, Forked River, Oyster Creek, and Manahawkin Creek (Figure 3-1). The freshwater input from these tributaries creates a slight salinity gradient from west to east. The

salinity of the central bay, in the vicinity of the OCNGS, is typically about 25 ppt (Chizmadia et al. 1984).

A relatively pronounced salinity gradient occurs along the north-south axis of the bay due to the freshwater input of Pine Barrens streams in the northwestern portion and the location of Barnegat Inlet in the southern portion of the bay (Figure 3-3). Relatively high salinity waters entering the northernmost section of the bay through the Bay Head-Manasquan Canal result in elevated salinities in that portion of the bay (Chizmadia et al. 1984).

3.5 WATER TEMPERATURE IN BARNEGAT BAY

Barnegat Bay is a meteorological transition zone between the continent and the ocean. The temperature extremes of both the summer and winter seasons are moderated within the bay by the proximity of the ocean. On an average annual basis, the warmest months of the year are July and August, and the coldest months are January and February. Tatham et al. (1977) reported winter water temperatures in western Barnegat Bay as low as $-1.5^{o}C$ ($29.3^{o}F$) and summer temperatures approaching $30^{o}C$ ($86^{o}F$). Periods of relatively rapid temperature change occur in spring and fall. Atlantic Ocean water that enters the estuary exhibits a somewhat less extreme annual range of temperature.

Ice typically forms each winter adjacent to the shoreline of Barnegat Bay, but more extensive ice covering across a major portion of the bay has occurred only during the coldest of recent winters. Periodically, during winter or early spring, ice from Barnegat Bay is drawn into the OCNGS intake canal.

3.6 WATER TRANSPARENCY IN BARNEGAT BAY

Water transparency in Barnegat Bay, as measured by Secchi depth, ranges from 0.2 to 2.5 m (0.7 - 8.2 ft). The annual average Secchi depth in the vicinity of Oyster Creek is 1.1 m (3.6 ft) (Vouglitois 1983).

Table 3-1. Barnegat Inlet average tidal prisms, adjusted to mean tidal conditions (from Ashley, 1988; Gebert, 1994).

Date	Average Tidal Prism (10^7 m^3)
June 1932	2.29
December 1940	3.21
April 1941	3.45
November 1941	3.31
September 1943	2.12
June 1945	2.01
May 1968	1.39
March 1980	1.17
September 1987	1.17
June 1993	2.55*

*Based upon preliminary U.S. Army Corps of Engineers data (Gebert 1994).

NOTE: New south jetty constructed 1988-1991; most recent maintenance dredging in Barnegat Inlet completed 1993.

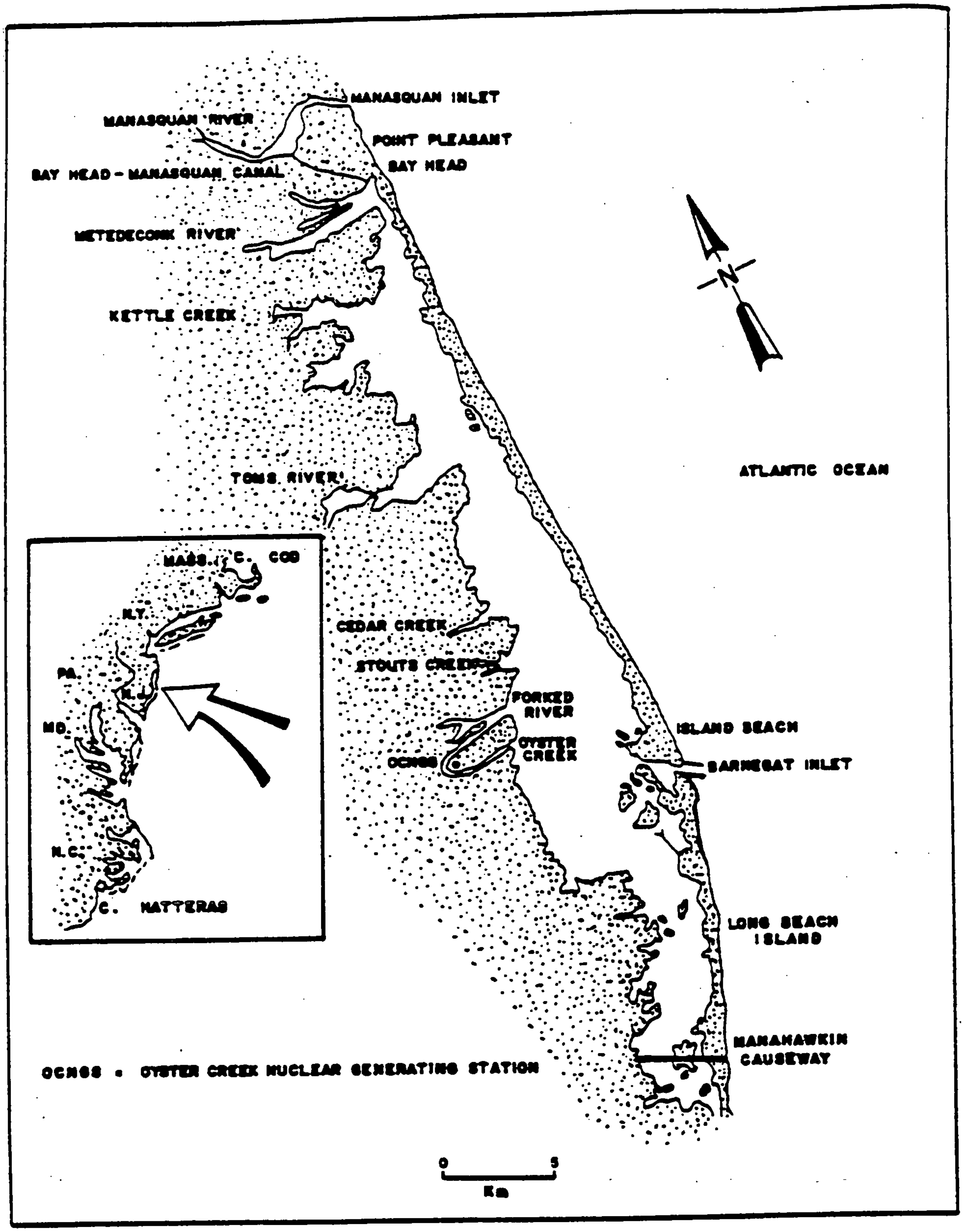


Figure 3-1. Map of Barnegat Bay, New Jersey and Oyster Creek NGS. Inset shows Barnegat Bay in relationship to the Mid-Atlantic Bight. (After Kennish and Lutz, 1984).

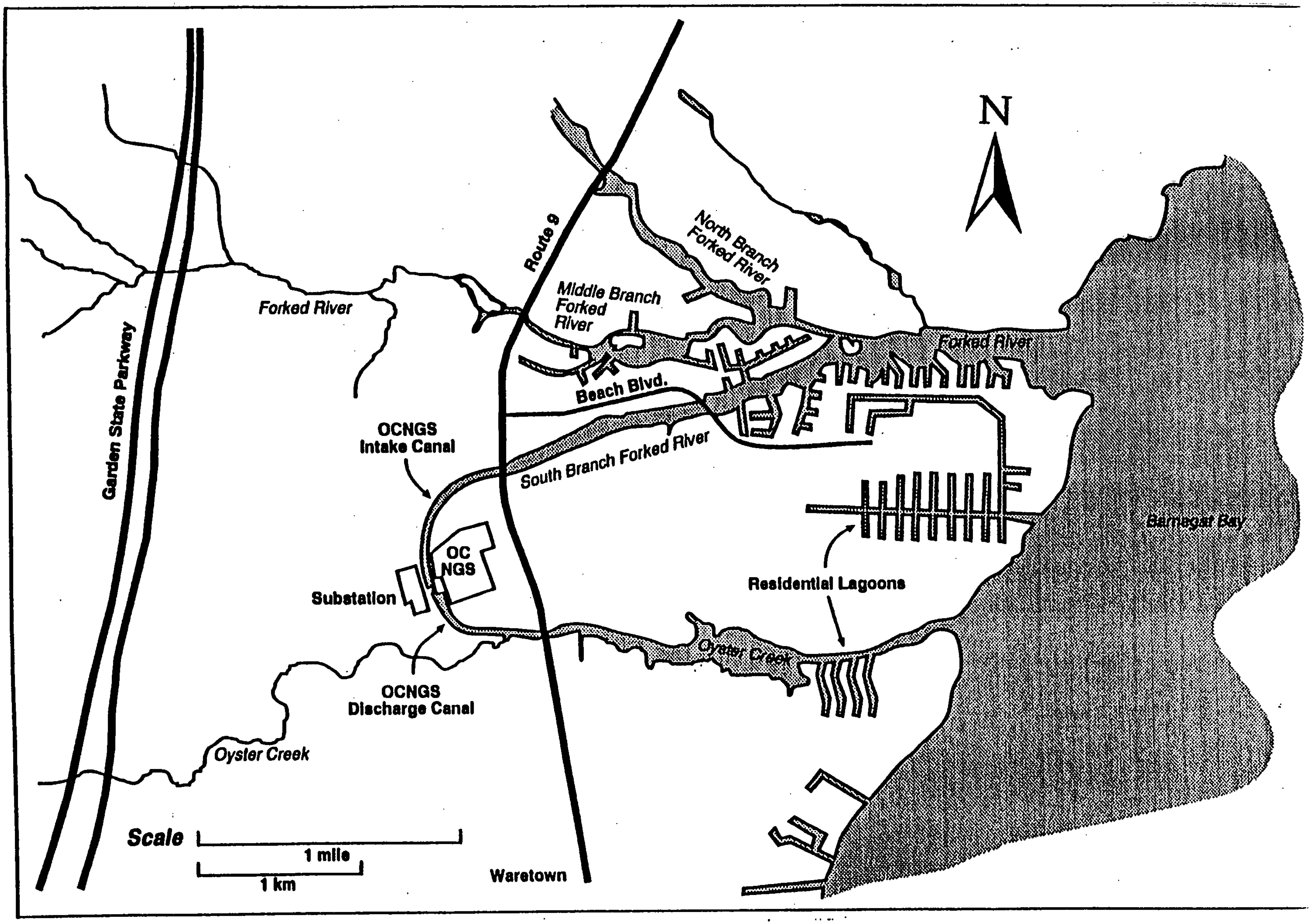


Figure 3-2. Location map of OCNGS and vicinity.

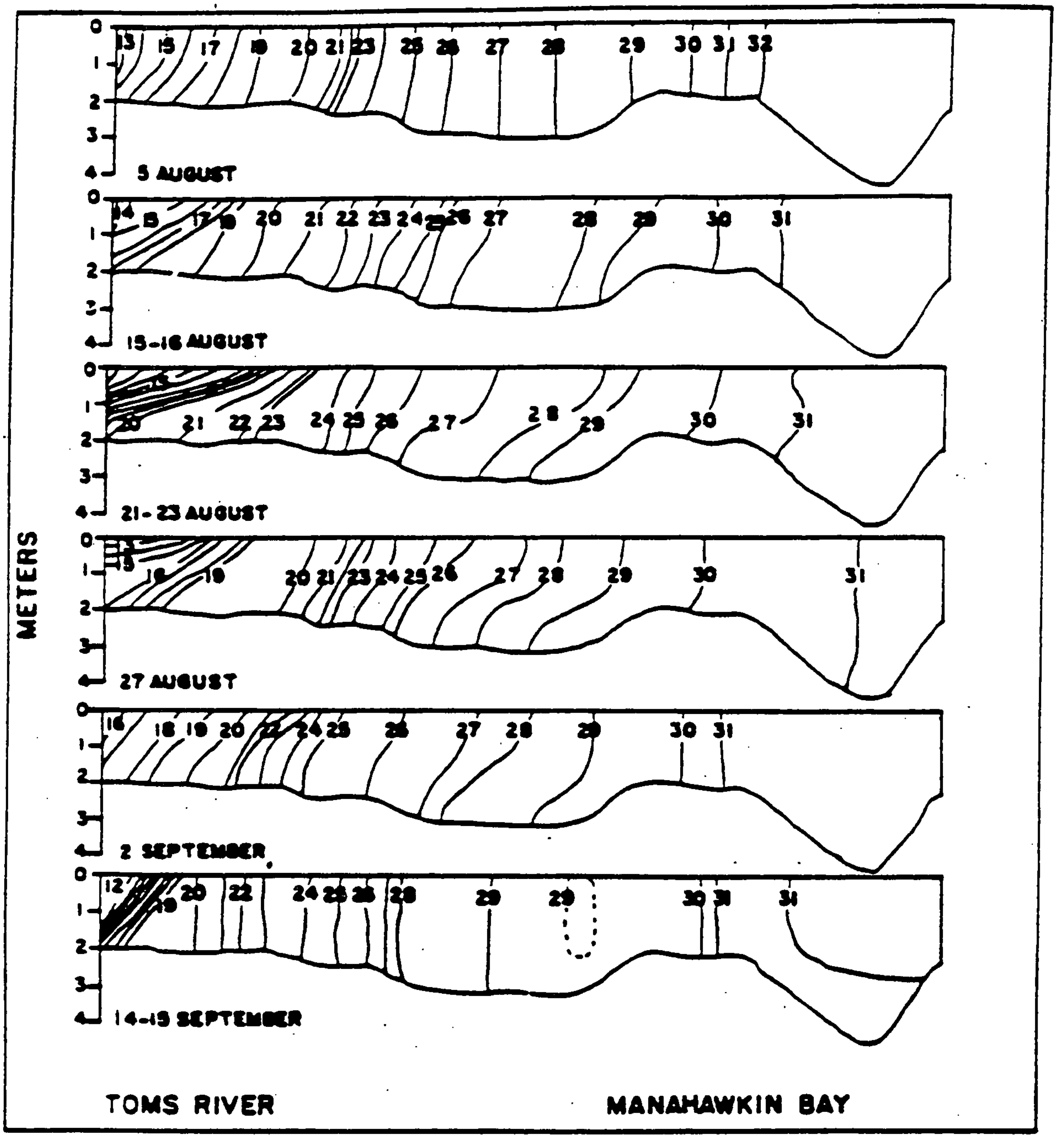


Figure 3-3. Salinity profile of Barnegat Bay from Toms River to Manahawkin Bay for August and September 1963. (After Carpenter, 1963).

SECTION 4.0
OYSTER CREEK NUCLEAR GENERATING STATION DESCRIPTION

4.1 OYSTER CREEK NUCLEAR GENERATING STATION

Oyster Creek Nuclear Generating Station (OCNGS) consists of a boiling water nuclear reactor with an electrical capability of approximately 650 megawatts. OCNGS began commercial operation late in 1969.

The containment structure housing the reactor and the turbine, auxiliary and service buildings for OCNGS are located on a semicircular plot of land bounded by the intake and discharge canals and by U.S. Route 9 (Figure 4-1). Two separate intake structures withdraw water from the intake canal (Figs. 4-2 through 4-9). The circulating water system intake (CWS) provides cooling water for the main condensers and also provides cooling water for safety-related heat exchangers and other equipment within the station. The dilution water system (DWS) minimizes the thermal effects on the discharge canal and Barnegat Bay by "thermally diluting" the circulating water from the condenser with colder water drawn from the intake canal. Water from both systems is discharged via discharge tunnels to the head of the discharge canal, located immediately west of the plant (Fig. 4-2).

4.1.1 CIRCULATING WATER SYSTEM

The once-through CWS is designed to remove waste heat from the stations main condensers. The CWS withdraws cooling water from the intake canal, routes it to the condensers, and returns warmed water to the discharge canal (Figure 4-2). During normal plant operation, four 435 m^3/min (0.115 million gpm) circulating water pumps (Figs. 4-3 and 4-4) withdraw a total of 1740 m^3/min (0.46 million gpm). The typical temperature rise across the condensers in this operating mode is 11^{o}-$12.8^{o}C$ (20^{o}-$23^{o}F$). Measurements of the intake velocity of water approaching the CWS intake ports show flows of 17-20 cm/sec (0.56-0.66 ft/sec) with four circulating water pumps operating and all six intake bays open.

The station's New Jersey Pollutant Discharge Elimination System (NJPDES) Discharge to Surface Water Permit regulates the intake velocity as well as the effluent characteristics of the CWS. The maximum permissible average intake velocity for water approaching the CWS intake ports is 30 cm/sec (1 ft/sec). The maximum temperature difference between the intake and discharge water is $12.8^{o}C$ ($23^{o}F$); the maximum effluent temperature is $41.1^{o}C$ ($106^{o}F$). Both of these temperature limits apply during normal operating conditions (i.e; when four circulating water pumps are operating

and condenser backwashing is not underway.)

When fewer than four circulating water pumps are operating, or during condenser backwashing, alternate temperature limitations apply. The maximum temperature difference between the intake and discharge water under those conditions is 18.3°C (33°F); the alternate maximum effluent temperature is 43.3°C (110°F). The operation of dilution pumps (see Section 4.1.2) reduces the water temperature in the discharge canal by approximately 2.8°C (5°F) for each pump operated. Two dilution pumps are typically operated during the summer months, thereby providing a 5.6°C (10°F) reduction in discharge canal temperature.

4.1.1.1 CIRCULATING WATER SYSTEM INTAKE STRUCTURE

The CWS intake consists of six separate, independent intake bays or port cells (Figures 4-3 and 4-4). Each intake port is equipped with its own trash bars and traveling screens. Provisions for stop logs are made within each port to facilitate dewatering the intake bays for maintenance.

Originally, the circulating water intake structure consisted of trash bars followed by conventional traveling screens whose primary purpose was to collect and remove debris from intake water. Traveling screens were intermittently cleaned via a front wash, high pressure spray system activated by differential pressure, a timer, or manual intervention.

To mitigate fish impingement losses, modifications have been made to the original installation by adding: horizontal, water-filled fish survival buckets on the traveling screen baskets (Ristroph modification); a low pressure rear spray wash fish removal system; and a modified fish and trash sluiceway system specifically designed to gently return fish to the discharge canal.

4.1.1.1.1 TRASH BARS AND TRASH RAKE ASSEMBLY

Six sets of trash bars protect each of the six intake ports from large debris, mats of eel grass, marine algae or detritus entrained in the intake water flow (Fig. 4-5). The trash bar assemblies, sometimes referred to as trash racks, are 7.3 m (24 ft) high and extend from the deck of the CWS intake structure at elevation +6.0 ft MSL (mean sea level) to the bottom of each CWS intake port, elevation -18.0 MSL, and are approximately 3.3 m (11 ft) wide. Constructed of 0.95 cm (3/8 in) wide steel bars on 7.5 cm (3.0 in) centers, the openings between the trash bars are 6.6 cm (2.6 in) wide.

The trash bars are inspected at least twice during each 8-hr work shift, throughout the sea turtle season (see Section 7 and Appendix I), and debris is removed as needed by a mobile mechanical trash rake. The trash rake/trash cart assembly is a self-contained unit which traverses the entire width of the intake on rails; it contains a trash hopper which transports the material removed from the bars to a debris container at the south end of the intake. Figures 4-5 through 4-8 illustrate the trash rake/trash cart assembly at the CWS and DWS intake structures.

The trash rake is 1.8 m (6.0 ft) wide and is controlled by a single operator from a manual pushbutton control panel which is mounted on the unit's frame assembly. The trash rake unit consists of an integral frame assembly which houses the traversing drive, hoisting machinery, hopper and hydraulic control assemblies. The hoisting machinery includes a cable-operated raking device which is designed to remove large floating or submerged objects which may accumulate on the trash bars. Wide-flanged wheels permit the raking device to travel along the face of the inclined trash bars and guide the cleaning device vertically over the bars. The curved tines of the trash rake extend approximately 2.5 cm (1.0 in) beyond the plane of the trash bars to ensure effective cleaning of the trash bars.

Lighting of the intake bays and trash bars is provided by nearby high-intensity lamps, as well as downward-facing floodlights mounted on each corner of the trash cart (Figs. 4-5 and 4-8). Personnel cleaning the CWS and DWS intake trash racks during the June 1 -October 31 period observe the trash rake during the cleaning operation so that the rake may be stopped if a sea turtle is sighted. The debris gathered from the trash racks is hand raked into the trash car hopper. Personnel performing this task are instructed to look for sea turtles and to take particular care to ensure that sea turtles are not mistaken for horseshoe crabs. The floodlights attached to the trash rake unit are utilized during the evening hours to aid station personnel in spotting sea turtles.

4.1.1.1.2 TRAVELING SCREENS

Each CWS intake cell is equipped with a vertical traveling screen. Each traveling screen unit contains thirty-five, stainless steel mesh (0.95 cm; 3/8 inch) fish-removal type screen panels. Each screen panel has a 5.1 cm (2 in) wide lip, which creates a water-filled bucket. As the screen is raised through and out of the water, most impinged organisms such as small fish or invertebrates drop off the screen into the bucket, which prevents them from falling back into the screen well and becoming re-impinged. These organisms are subsequently washed into a fish-return system which gently returns them to the discharge canal.

Normally the screens operate at a speed of 75 cm/sec (2.5 ft/sec). They can be operated at an alternate speed of 300 cm/sec (10 ft/sec) in order to accommodate large debris loads.

For maximum fish survival, the screen wash operates with both low-pressure and high-pressure spray headers. As the screen basket travels over the head sprocket, organisms slide onto the screen face and are washed by one low-pressure spray header located outside the screen unit, and two low-pressure spray headers located inside the screen unit, into an upper sluice. This spray wash is designed to minimize descaling and other injuries that would occur with conventional high-pressure spray headers. Subsequently, heavier debris is washed into a lower sluice by two high-pressure spray headers.

Because all sea turtles captured at OCNGS have measured at least 26 cm (10 in) carapace length, it is not anticipated that a sea turtle

small enough to pass through the 6.6 cm (2.6 in) openings of the trash racks will ever occur at OCNGS. However, in the unlikely event that such a small sea turtle occurs at OCNGS, the fish return system would gently return it to the discharge canal automatically (i.e., without the need for manual intervention by OCNGS personnel).

4.1.1.1.3 CIRCULATING WATER PUMPS

There are four circulating water pumps located on the CWS intake structure (Fig. 4-4). They are vertical wet-pit type pumps rated at 435 m^3/min (0.115 million gpm) which discharge through 1.7 m (6.0 ft) lines to the main condensers and ultimately to a 3.2 m (10.5 ft) square concrete discharge tunnel. The once-through cooling system piping running from the intake to the discharge is approximately 200 m (650 ft) in length. A 1.5 m (5 ft) concrete recirculation pipe for ice control runs below the water level from the discharge tunnel back to the intake structure. The area in close proximity to the CWS intake is kept from freezing due to the intake deicing system and the turbulence induced by the circulating water and dilution pumps.

4.1.1.1.4 SEA TURTLE RETRIEVAL/RESCUE EQUIPMENT

As indicated in Section 4.3.2 of Procedure 106.12, "Sea Turtle Surveillance, Handling and Reporting Instructions" for Operations personnel (Appendix I), a rescue sling suitable for lifting large sea turtles (in excess of 20 kg or 44 lbs) is kept in the fish sampling pool at the Circulating Water System intake structure. The sea turtle rescue sling/lift net (Figure 4-10) consists of a weighted tubular metal frame of 2.5 cm (1 in) O.D. stainless steel measuring 120 cm (48 in) on a side from which 6.4 cm (2.5 in) mesh nylon netting is suspended. Ropes attached at each corner of the rescue sling are joined into a bridle and single lift rope which are designed to allow the user to drop the sling below a turtle at the trash bars, then lift it out of the water to the intake structure deck.

Custom made long-handled dipnets suitable for retrieving the smaller turtles most commonly encountered at OCNGS have also been fabricated for use at the CWS and DWS intake structures (Figure 4-11). The turtle dipnets are constructed of 3.3 cm (1.3 in) O.D. aluminum tubing and consist of a 240 cm (8 ft) handle attached to a rounded rectangular net frame measuring 75 x 45 cm (2.5 x 1.5 ft). Nylon netting of 0.63 cm (1/4 in) mesh is suspended from the dipnet frame. These dipnets will be stored within easy reach, attached to fences, railings, or buildings at the CWS and DWS intake structures during the sea turtle season (June 1 - October 31).

Both the rescue sling and the long-handled dipnets are only adequate for retrieving turtles from the water surface or within about 1 m (3.3 ft) of the surface because the use of either device requires that the sea turtle be visible from the surface.

4.1.1.1.5 OTHER EQUIPMENT

Screen Wash and Fish-Return Systems

The high pressure and low pressure screen wash systems remove marine life and debris from the CWS intake traveling screens. The contents of the upper fish and lower debris sluices are returned to the discharge canal through return sluices at the CWS intake. The fish-return system has been designed to return the fish and marine life washed from the traveling screens as gently and gradually as possible to the plant's receiving waters.

4.1.1.2 CONDENSERS

There are three sections to the main condenser, one located immediately below each low pressure turbine (Fig. 4-9). There are 14,560 tubes in each main condenser section carrying circulating water from the intake canal. This provides approximately 13,000 m^2 (139,880 ft^2) of cooling surface area. Each section is 12.2 m (40 ft) long by almost 6.1 m (20 ft) wide and 9.9 m (32.5 ft) high. Two 1.8 m (6 ft) diameter pipes deliver circulating water to each section of the main condensers.

The discharge piping from the main condenser is joined through 1.8 m (6 ft) lines into a common 3.2 m (10.5 ft) square concrete discharge tunnel. The discharge tunnel transports the condenser cooling water across the site to the discharge canal (Figs. 4-2 and 4-9).

4.1.2 DILUTION WATER SYSTEM

The dilution water system (DWS) is designed to minimize thermal effects on the environment by withdrawing ambient temperature water from the intake canal and routing it to the discharge canal where it mixes with the main condenser discharge flows (Fig. 4-2). The dilution flow is provided by three low speed, 984 m^3/min (0.26 million gpm) axial flow dilution pumps, with 2.1 m (7ft) diameter impellers (Fig. 4-6). The number of dilution pumps operated is governed by the station's NJPDES Discharge to Surface Water Permit and a maximum of two pumps (1,968 m^3/min; 0.52 million gpm) are operated at one time.

In order to reduce the attraction of migratory fish to the station's discharge canal in the fall, when these species would normally leave Barnegat Bay, two dilution pumps are put into operation when the ambient (intake) water temperature is less than 15.5°C (60°F). In order to reduce the temperature of the discharge canal during the summer months, when the water temperature as measured at the U.S. Route 9 bridge over Oyster Creek (Fig. 4-1) exceeds 30.5°C (87°F), one dilution pump is put into operation. If, after one dilution pump has been in operation for at least two hours, the water temperature at the U.S. Route 9 bridge continues to exceed 87°F, a second dilution pump is put into operation. The station's third dilution pump is held in reserve to be put into operation within 40 minutes of such time as an insufficient number of dilution pumps are operable in order to meet the intent of the permit requirements described above.

The operation of two dilution pumps during the seasonal periods required by the NJPDES permit reduces the discharge canal

temperature by approximately 5.6°C (10°F). During the remainder of the year, one dilution pump is typically operated, providing a temperature reduction of approximately 2.8°C (5°F). Following this seasonal operational regime results in the operation of two dilution pumps during about 70 percent of the June-October sea turtle season.

The average intake velocity in front of the DWS intake, with two pumps in operation, is approximately 73 cm/sec (2.4 ft/sec).

4.1.2.1 DILUTION WATER SYSTEM INTAKE STRUCTURE

The DWS intake is a reinforced concrete structure located on the west side of the intake canal (Figs. 4-2 and 4-6). It consists of six intake bays. Each intake bay is fitted with trash bars identical to those employed at the CWS intake (Figs. 4-5 and 4-6). Unlike the CWS, there are no travelling screens at the DWS intake structure.

4.1.2.1.1 TRASH BARS

The DWS trash bars are 0.95 cm (3/8 in) steel bars set on 7.5 cm (3.0 in) centers. There are six DWS trash bar assemblies, each 3.3 m (11 ft) wide. The DWS is fitted with a mobile mechanical trash rake similar in design and operation to the trash rake used at the CWS intake (Figures 4-5 through 4-8). The process of inspecting and cleaning the trash bars at the DWS is identical to that describied for the CWS in Section 4.1.1.1.1, Section 7.3, and Appendix I.

4.1.2.1.2 OTHER EQUIPMENT

Floating Debris/Ice Barrier

A floating barrier has been designed and installed upstream of the CWS and DWS intake structures to divert floating debris such as wood, eelgrass or ice away from the CWS intake and towards the DWS intake. The barrier is intended to prevent excessive amounts of debris or ice from accumulating on the CWS traveling screens or trash bars. The floating barrier is of wooden construction and extends approximately 60 cm (2 ft) below the surface from just upstream of the CWS intake to just upstream of the DWS intake (Figure 4-2).

4.1.3 THERMAL PLUME STUDIES

Heated condenser cooling water discharged from the CWS and ambient temperature intake canal water discharged from the DWS meet and mix in the discharge canal and ultimately are returned to Barnegat Bay via the discharge canal (Figure 4-1).

The cooling water discharged from OCNGS has been studied on several occasions to determine the distribution, geometry, and dynamic behavior of the thermal plume. Dye studies as well as real-time mobile mapping of the plume track have been performed (Carpenter 1963; Starosta et al. 1981; JCP&L 1986).

Three rather different thermal regimes can be observed in Oyster Creek and Barnegat Bay. In Oyster Creek, initial mixing of the condenser discharge with dilution water produces a reduction in discharge temperature of between 2.8 to 5.6°C (5 to 10°F) depending upon whether one or two dilution pumps is operating; little temperature decay is observable east of U.S. Route 9 until the discharge reaches Barnegat Bay. Minimal horizontal or vertical temperature change occurs in Oyster Creek between U.S. Route 9 and the bay because of the relatively short residence time and the lack of turbulence or additional dilution. In Barnegat Bay, temperatures are rapidly reduced as substantial mixing with ambient temperature bay water and heat rejection to the atmosphere occurs. In the bay, the plume spreads on the surface, thereby abetting atmospheric heat rejection. Thus, there is a very small area near the OCNGS condenser discharge of relatively high excess temperature in which turbulent dilution mixing produces rapid temperature reductions; a somewhat larger area in Oyster Creek between OCNGS and Barnegat Bay in which little further temperature reduction occurs; and a still larger area in the bay in which the plume spreads on the surface.

About 150 m (492 ft) east of the mouth of Oyster Creek the water depth decreases from approximately 3.4 m (11 ft) to 1.5 m (5 ft), causing turbulence and mixing and directing the plume toward the surface. In general, excess temperatures do not impinge on the bottom of the bay except in the area immediately adjacent to the mouth of Oyster Creek. Shoreline plumes may extend from the surface to the bottom since the water depths are usually less than 1.5 m (5 ft). In Barnegat Bay, the plume occupies a relatively large surface area with low excess temperatures where the balance of the heat discharged by OCNGS is dissipated to the atmosphere or diluted by entrained bay water. The surface excess temperature isotherm of 2.2° (4°F) under all operating conditions is contained in a rectangle approximately 1.6 km (1 mi) along the east-west axis and 5.6 km (3.5 mi) along the north-south axis bounding the mouth of Oyster Creek. For the 0.8°C (1.5°F) isotherm, the rectangle is 2.4 km (1.5 mi) by 7.2 km (4.5 mi). All measured plumes exhibited a plume length of approximately two to three times their width (JCP&L 1986).

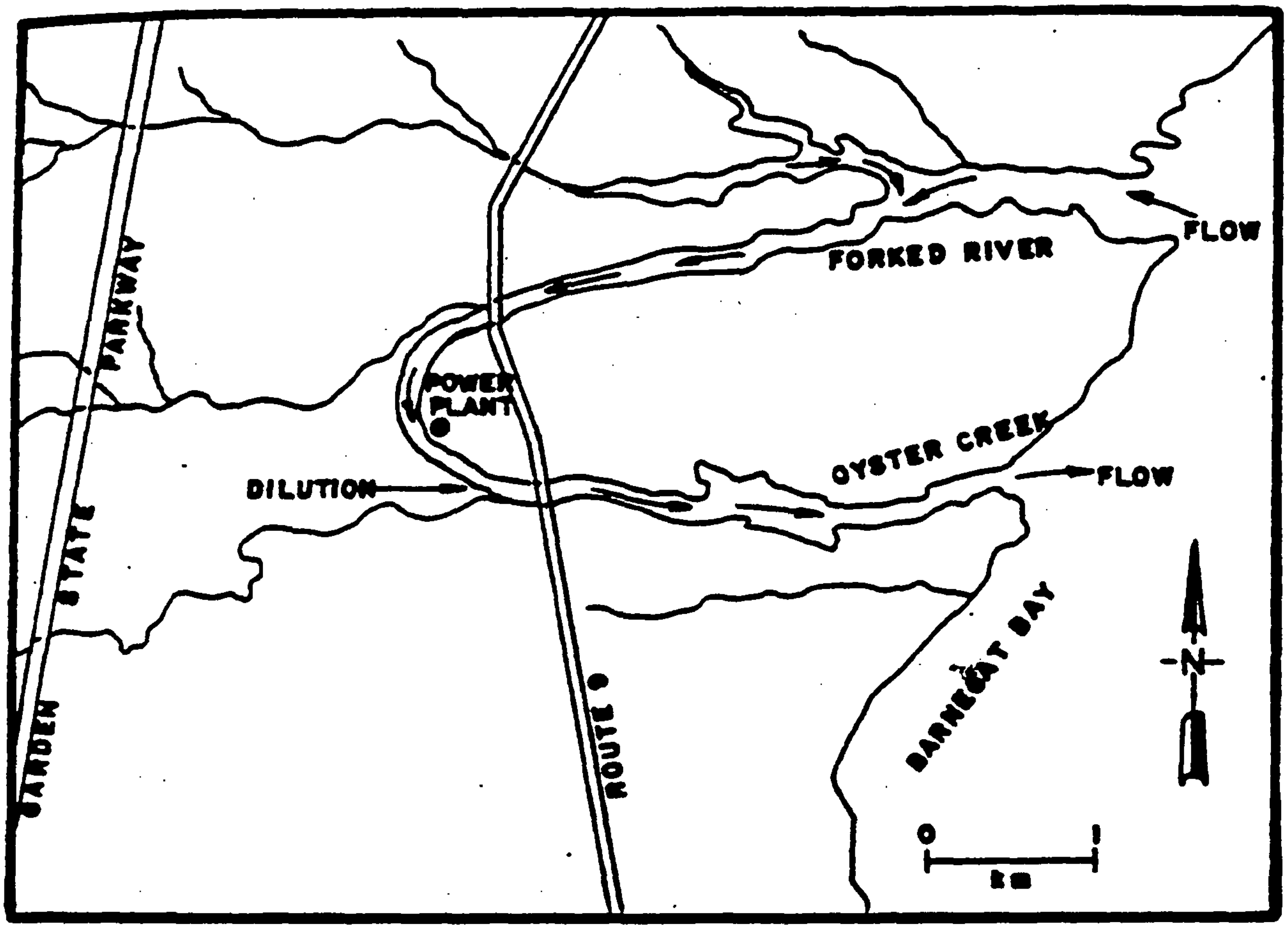


Figure 4-1. Flow characteristics at Forked River, Oyster Creek, and adjacent bay localities. (After Kennish and Olsson, 1975).

Figure 4-2. Schematic diagram of the OCNGS circulating water system (CWS) and dilution water system (DWS) flows.

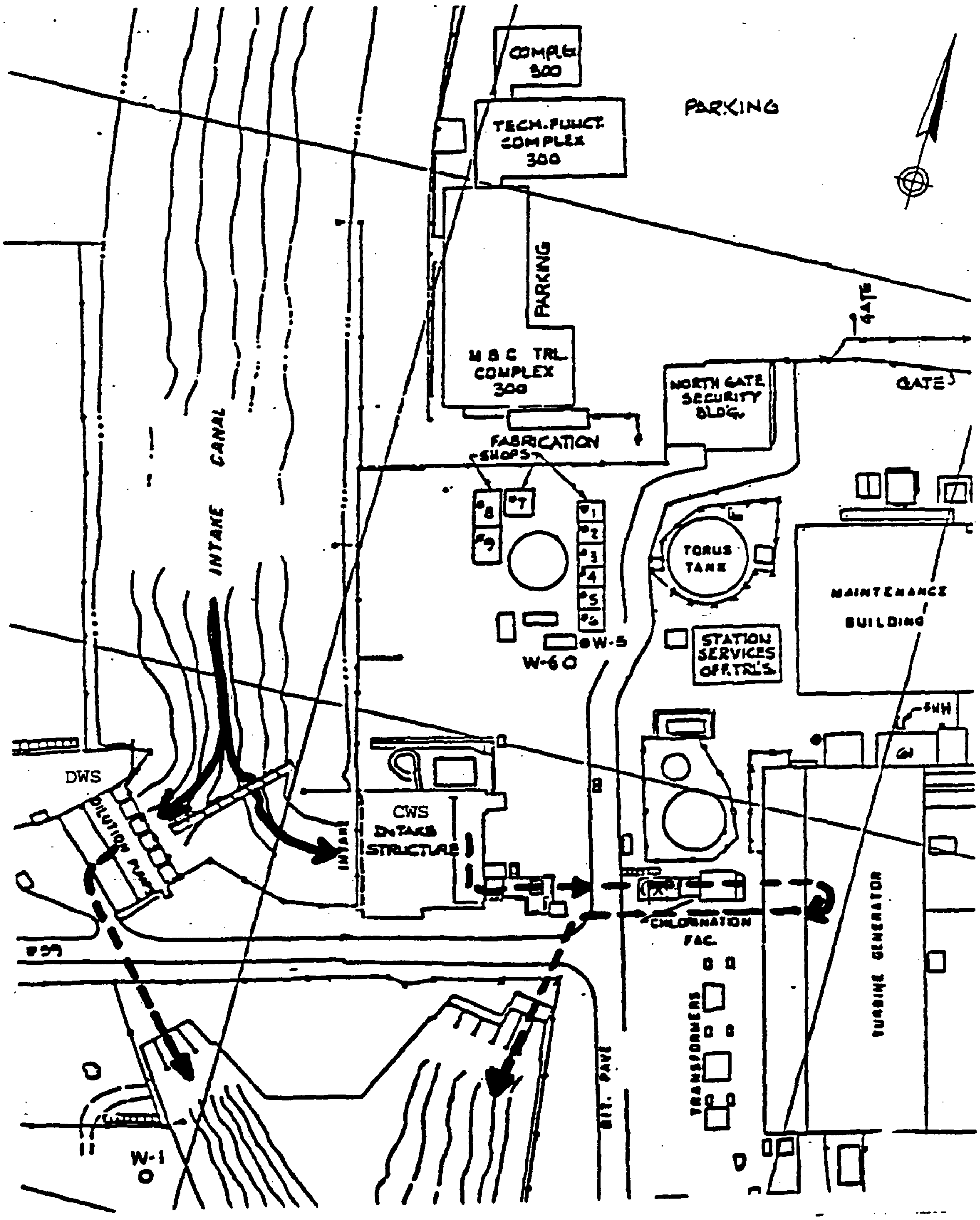
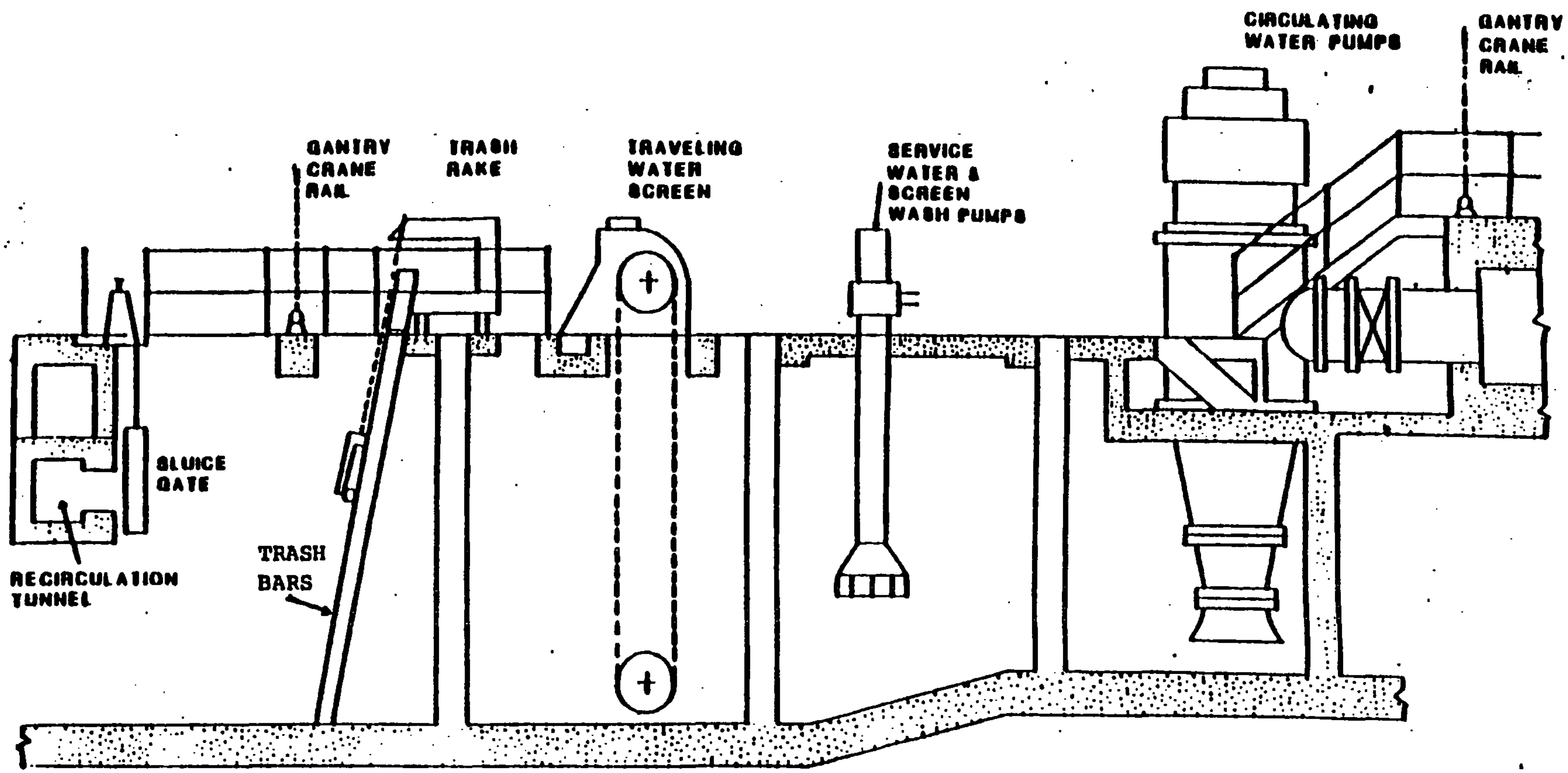


Figure 4-3. OCNGS Circulating System Intake Structure, section view.



INTAKE STRUCTURE, SECTION

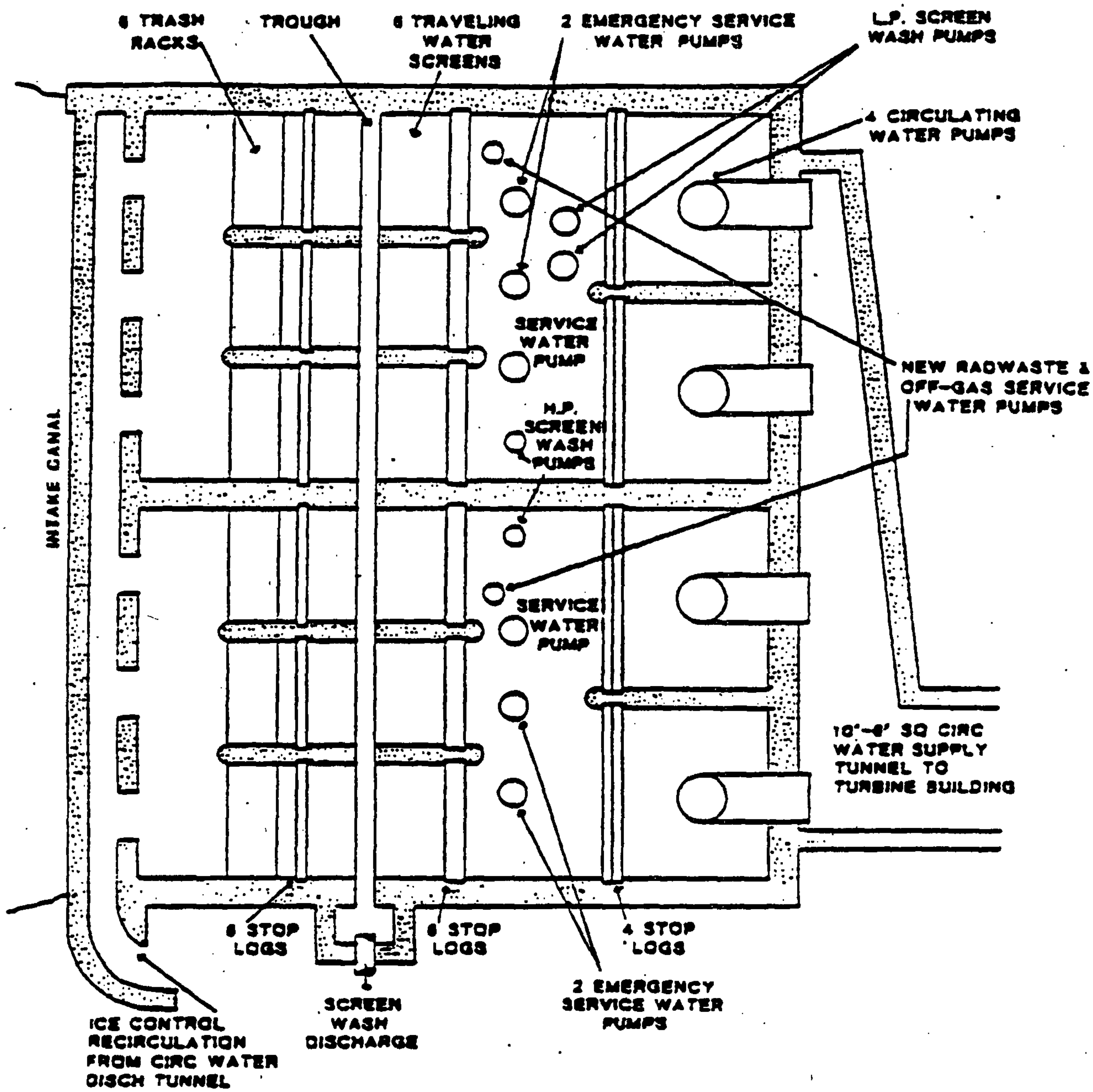


Figure 4-4. OCNGS Circulating Water System Intake Structure in plan view.

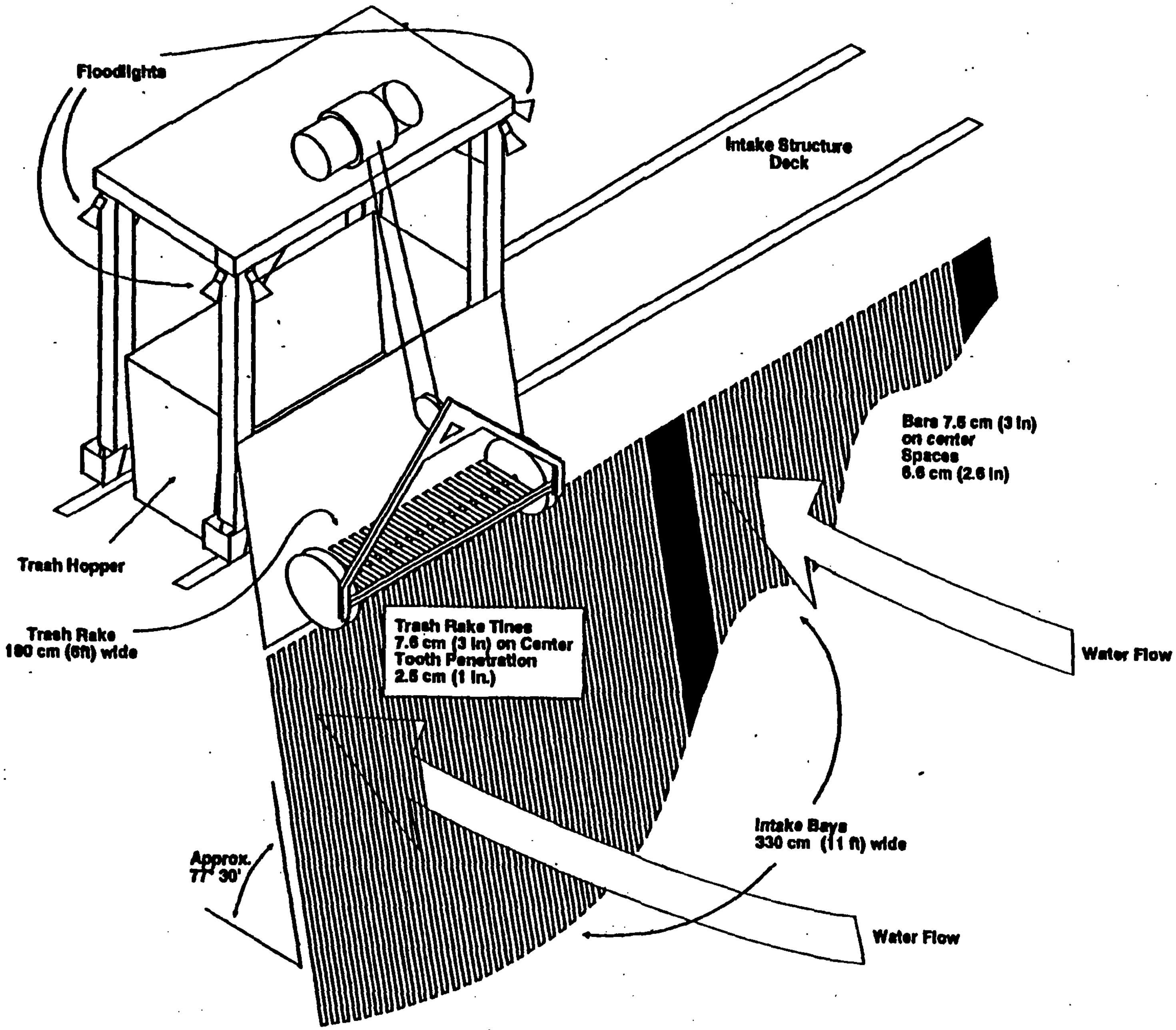


Figure 4-5. Schematic of Circulating Water System (CWS) and Dilution Water System (DWS) intake structures showing trash cart, trash rake & trash bars.

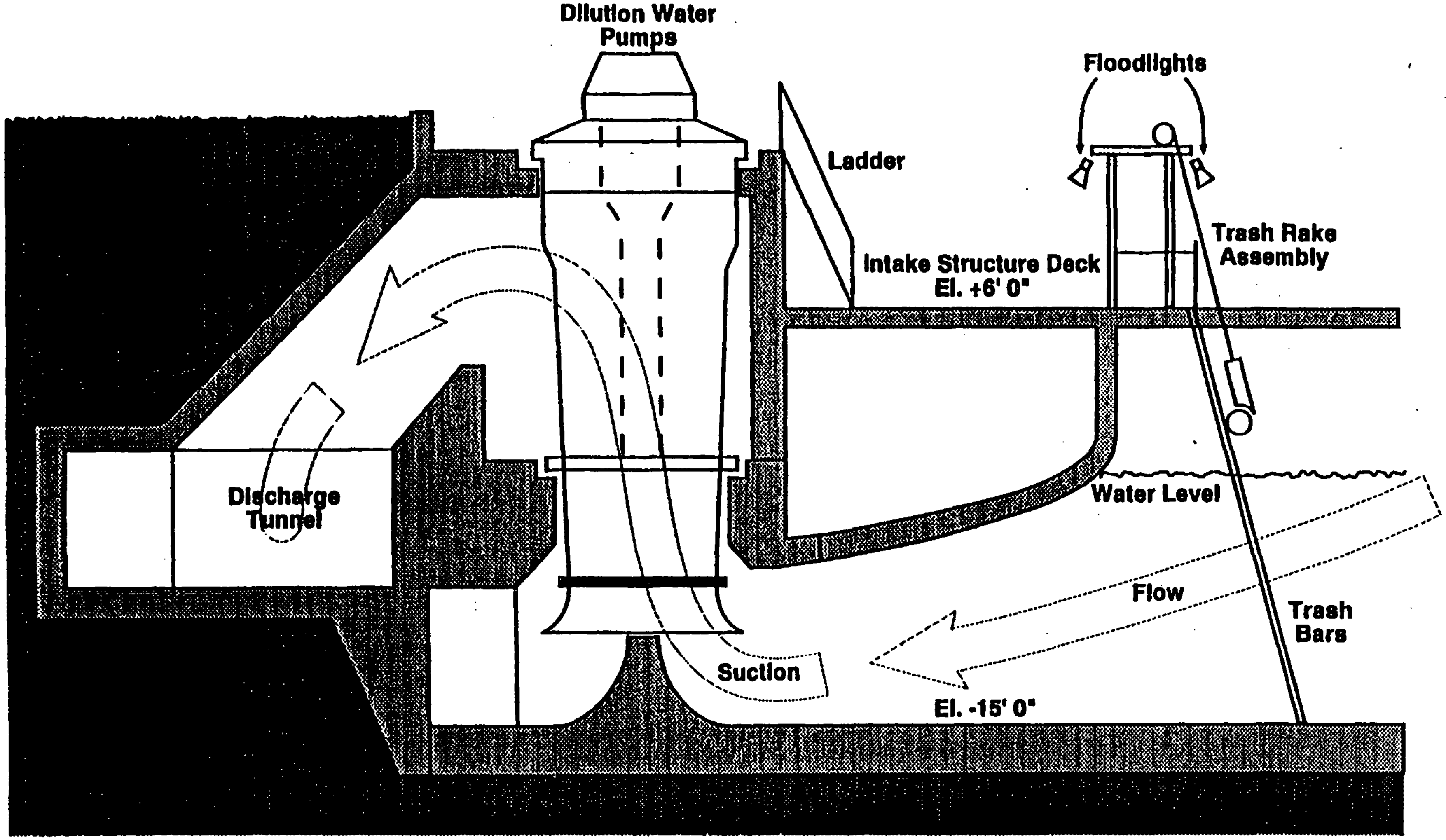
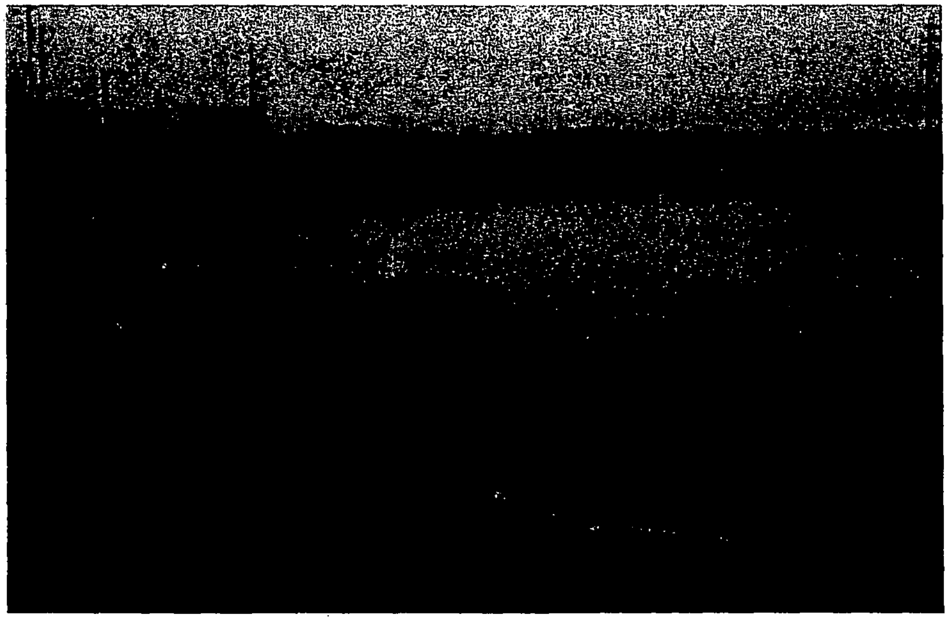


Figure 4-6. OCNGS Dilution Water System Intake Structure, Section View.



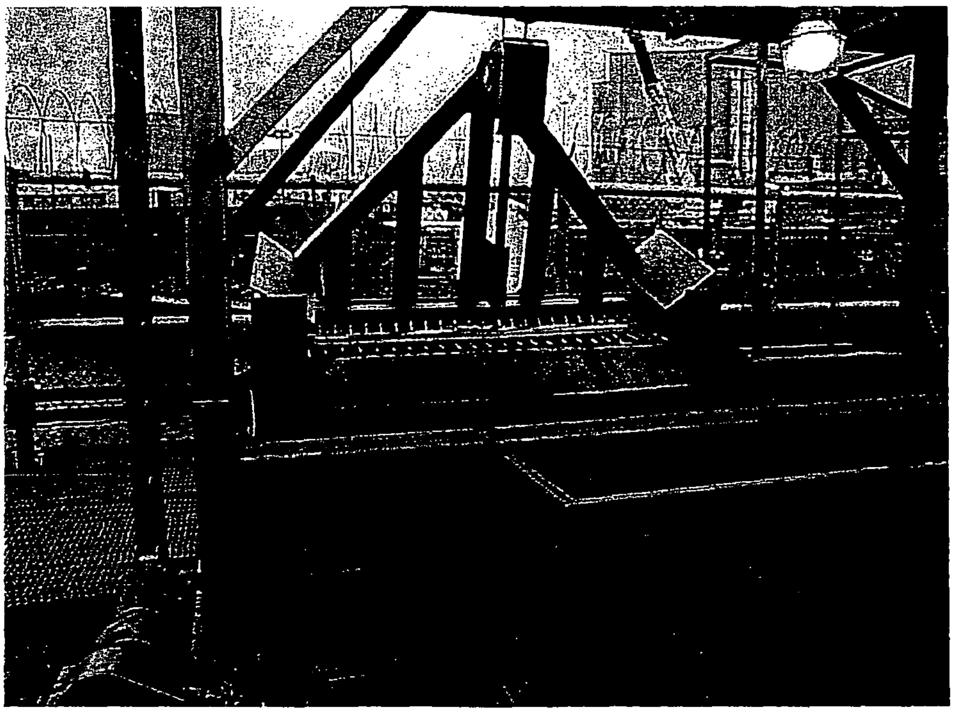
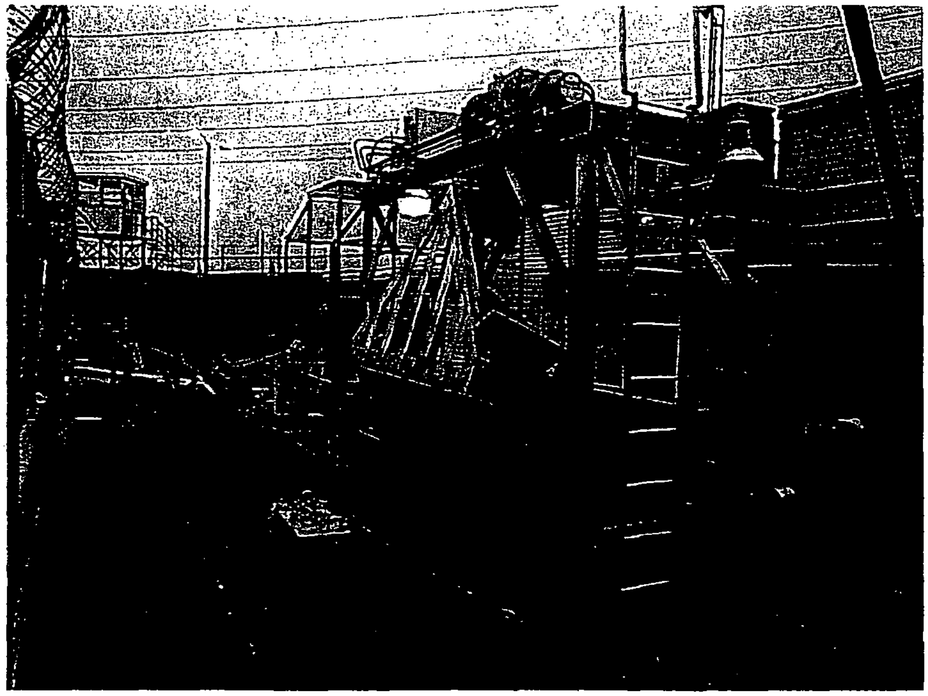


Figure 4-7. View of OCNGS Intake Canal looking upstream from Dilution Water System Intake (top); closeup of trash rake & trash cart (bottom).



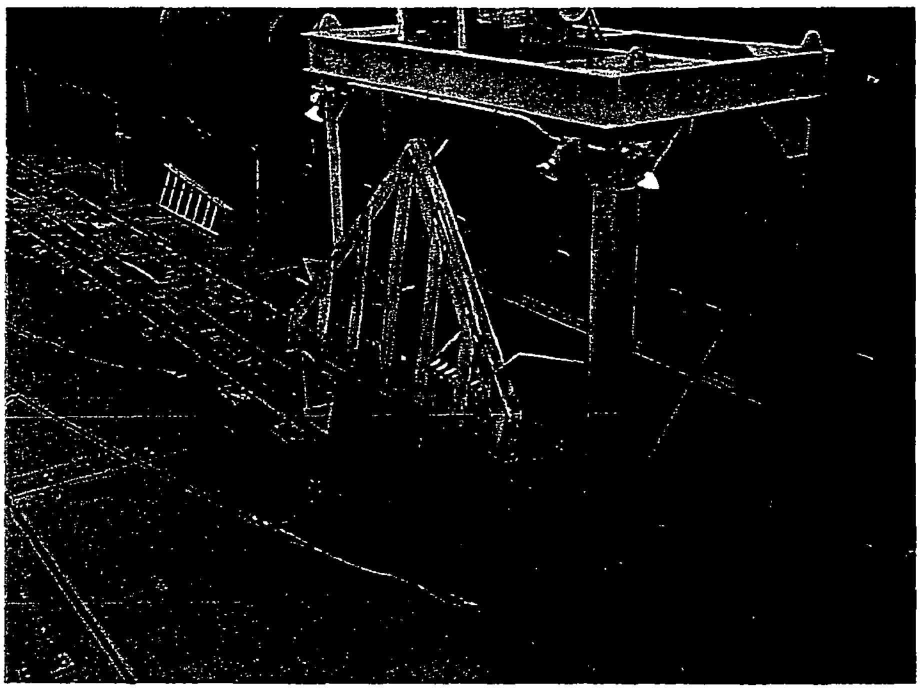


Figure 4-8 Trash rake and trash cart apparatus at the Dilution Water System (top) and the Circulating Water System (bottom) intakes. Note floodlights attached to trash carts.

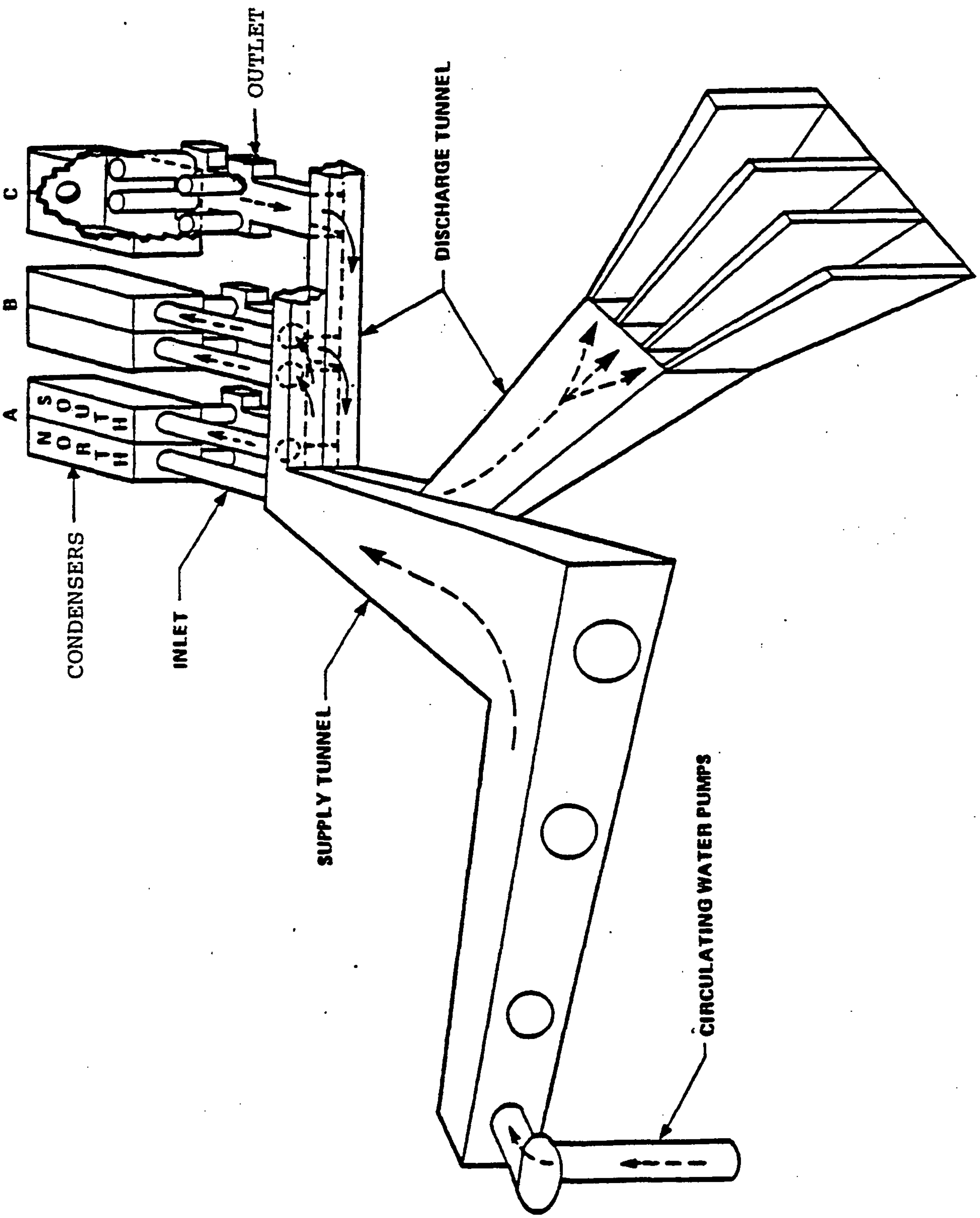


Figure 4-9 Schematic (oblique view) of OCNGS intake and discharge tunnels.

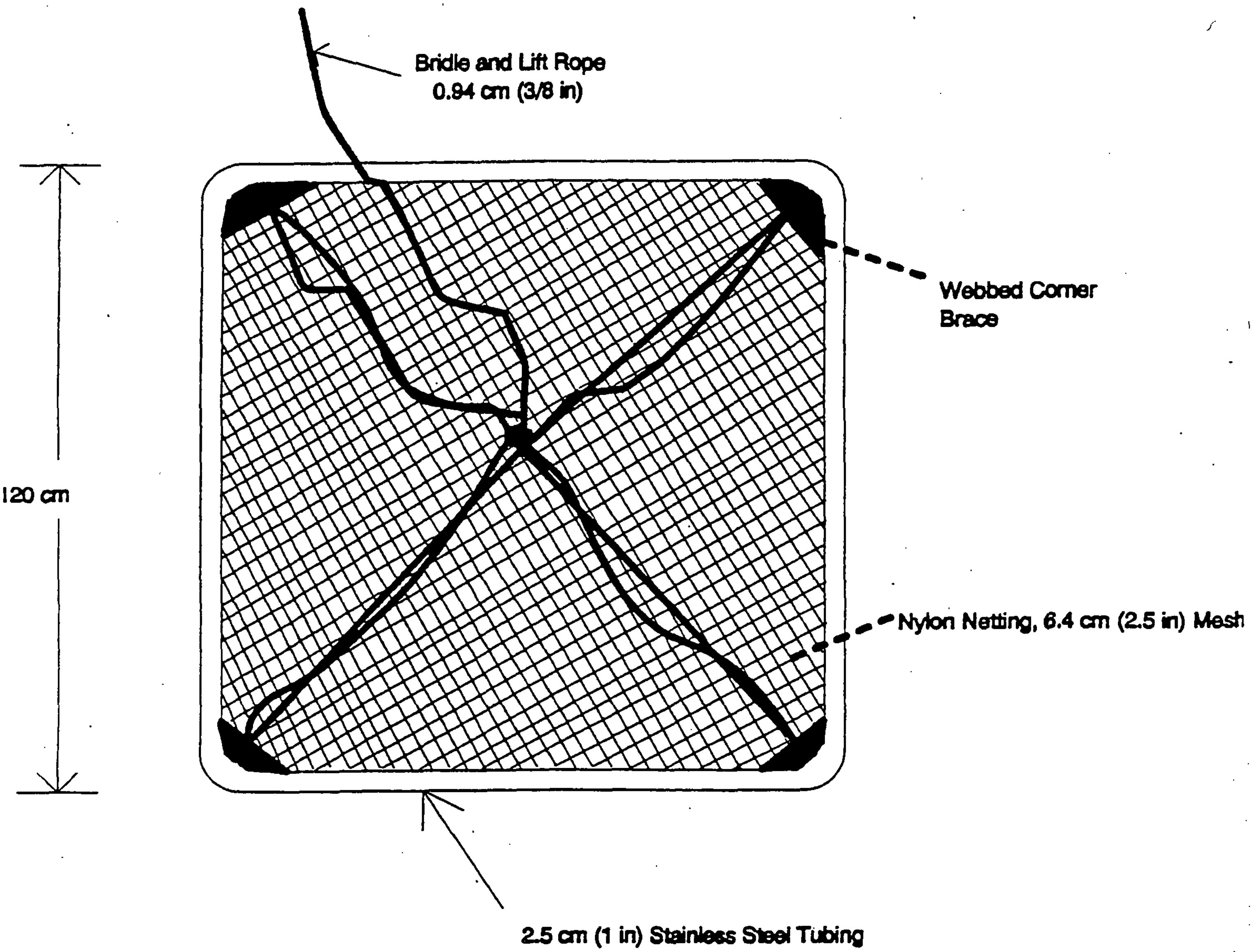


Figure 4-10. Sea Turtle Rescue Sling/Lift Net.

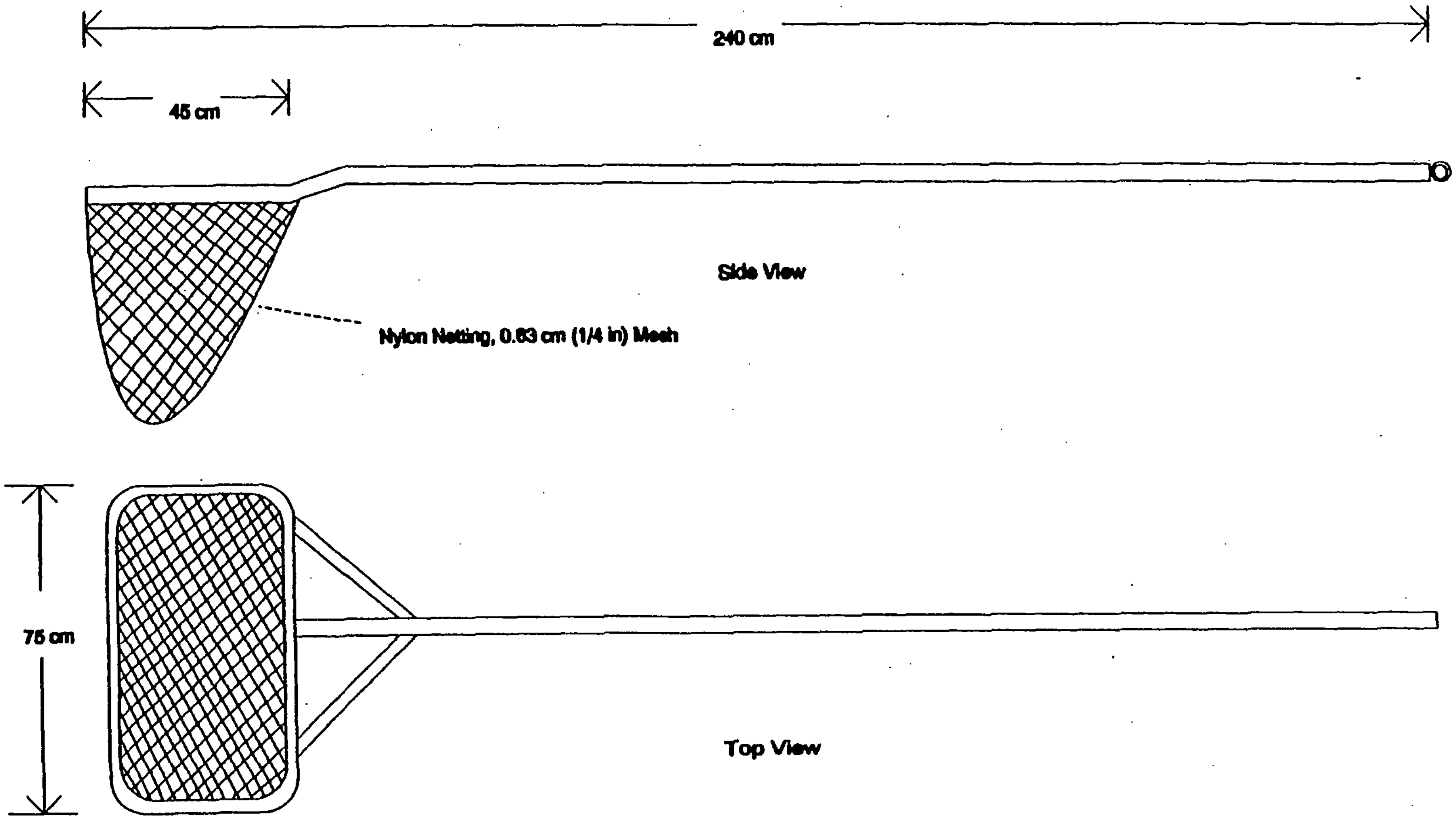


Figure 4-11. Long Handled Dipnet for Sea Turtle Retrieval.

SECTION 5.0
INFORMATION ON SEA TURTLE SPECIES

5.1 GENERAL SEA TURTLE INFORMATION

Living sea turtles are taxonomically represented by two families, five genera, and seven species (Hopkins and Richardson 1984; Carr 1952). The family Cheloniidae is comprised of four genera and six distinct species. These species are Caretta caretta (loggerhead), Chelonia mydas (Atlantic green turtle), Chelonia depressa (flatback), Eretomochelys imbricata (hawksbill), Lepidochelys kempii (Kemp's ridley), and L. olivacea (olive ridley). The family Dermochelyidae is comprised of only one genus and species, Dermochelys coriacea, commonly referred to as the leatherback sea turtle.

Most of these seven sea turtle species are distributed throughout all of the tropical oceans. However, the loggerhead occurs primarily in temperate latitudes, and the leatherback, although nesting in the tropics, frequently migrates into cold waters at higher latitudes because of its unique physiology (Mager 1985).

Sea turtles are believed to be descended from species known from the late Jurassic and Cretaceous periods that were included in the extinct family Thallassemyidae (Carr 1952; Hopkins and Richardson 1984). Modern sea turtles have short, thick, incompletely retractile necks, and legs which have been modified to become flippers (Bustard 1972; Carr 1952). All species, except the leatherback, have a hard, bony carapace modified for marine existence by streamlining and weight reduction (Bustard 1972). Chelonians have only a thin layer of bone covered by overlaying scutes and D. coriacea has a smooth scaleless black skin and soft carapace with seven longitudinal keels (Carr 1952). These differences in structure are the principal reason for their designation as the only species in the monotypic family Dermochelyidae (Carr 1952).

Sea turtles spend most of their lives in an aquatic environment and males of many species may never leave the water (Hopkins and

Richardson 1984; Nelson 1988). The recognized life stages for these turtles are egg, hatchling, juvenile/subadult, and adult (Hirth 1971). A generalized sea turtle life cycle is presented in Figure 5-1.

Reproductive cycles in adults of all species involve some degree of migration in which the animals return to nest at the same beach year after year (Hopkins and Richardson 1984). Nesting generally begins about the middle of April and continues into September (Hopkins and Richardson 1984; Nelson 1988; Carr 1952). Mating and copulation occur just off the nesting beach and it is theorized that sperm from one nesting season may be stored by the female and thus fertilize a later season's eggs (Ehrhart 1980). A nesting female moved shoreward by the surf lands on the beach and crawls to a point above the high water mark (Carr 1952). She then proceeds to excavate a shallow body pit by twisting her body in the sand (Bustard 1972). After digging the body pit she proceeds to excavate an egg chamber using her rear flippers (Carr 1952). Clutch size, egg size, and egg shape are species specific (Bustard 1972). Incubation periods for loggerheads and Atlantic green turtles average 55 days but range from 45 to 65 days depending on local conditions (Nelson 1988).

Hatchlings emerge from the nest at night, breaking the egg shell and digging their way out of the nest (Carr 1952). They find their way across the beach to the surf by orienting to light reflecting off the breaking surf (Hopkins and Richardson 1984). Once in the surf, hatchlings exhibit behavior known as "swim frenzy," during which they swim in a straight line for many hours (Carr 1986). Once into the waters off the nesting beach, hatchlings enter a period known as the "lost year." Researchers are presently trying to determine where young sea turtles spend their earliest years, what habitat(s) they prefer at this age, as well as typical survival rates during the "lost year" (i.e., during their post-hatchling early pelagic stage). It is currently believed the period encompassed by the "lost year" may actually turn out to be several years and various hypotheses have been put forth regarding sea turtle activities during this period. One is that hatchlings may become associated with floating sargassum rafts offshore. These rafts provide shelter and are dispersed randomly by the currents (Carr 1986). Another hypothesis is that the "lost year" of some species may be spent in a salt marsh/estuarine system (Garmon 1981).

The functional ecology of sea turtles in the marine and/or estuarine ecosystem is varied. The loggerhead is primarily carnivorous and has jaws well-adapted to crushing molluscs and crustaceans and grazing on encrusted organisms attached to reefs, pilings and

wrecks; the Kemp's ridley is omnivorous and feeds on swimming crabs and crustaceans; the Atlantic green turtle is a herbivore and grazes on marine grasses and algae; and, the leatherback is a specialized feeder preying primarily upon jellyfish. Until recently, sea turtle populations were relatively large and subsequently played a significant role in the marine ecosystem. This role has been greatly reduced in most locations as a result of declining turtle populations. These population declines were a result of, among other things, natural factors such as disease and predation, habitat loss, commercial overutilization, commercial fishing by-catch mortality and the lack of comprehensive regulatory mechanisms to ensure their protection throughout their geographic range. This has led to several species being threatened with extinction.

Due to changes in habitat use during different life history stages and seasons, sea turtle populations are difficult to census (Meylan 1982).

Because of these problems, estimates of population numbers have been derived from various indices such as numbers of nesting females, numbers of hatchlings per kilometer of nesting beach and number of subadult carcasses (strandings) washed ashore (Hopkins and Richardson 1984). Six of the seven extant species of sea turtles are protected under the Endangered Species Act. Three of the turtles, Kemp's ridley, hawksbill and leatherback, are listed as endangered. The Florida nesting population of Atlantic green turtle and Mexican west coast population of olive ridley are also endangered. All of the remaining populations of Atlantic green turtle, olive ridley and loggerhead are threatened. The only unlisted species is the locally protected Australian flatback turtle (Hopkins and Richardson 1984). Only three species of sea turtles (loggerheads, Kemp's ridleys and occasionally Atlantic greens) occur in Barnegat Bay and coastal waters near OCNGS. Leatherbacks do occur in coastal New Jersey waters but typically are found at considerable distances offshore. Atlantic green turtles have only been sporadically reported from the New Jersey coast. Regional sea turtle distribution will be discussed in more detail later in this section.

5.2 LOGGERHEAD (Caretta caretta)

5.2.1 DESCRIPTION

The adult loggerhead turtle has a slightly elongated, heart-shaped carapace that tapers towards the posterior and has a broad triangular head (Pritchard et al. 1983). Loggerheads normally weigh

up to 200 kg (450 lb) and attain a carapace length (straight line) up to 120 cm (48 in) (Pritchard et al. 1983). Their general coloration is reddish-brown dorsally and cream-yellow ventrally (Hopkins and Richardson 1984). Morphologically, the loggerhead is distinguishable from other sea turtle species by the following characteristics: 1) a hard shell; 2) two pairs of scutes on the front of the head; 3) five pairs of lateral scales on the carapace; 4) plastron with three pairs of enlarged scutes connecting the carapace; 5) two claws on each flipper; and, 6) reddish-brown coloration (Nelson 1988; Dodd 1988; Wolke and George 1981).

Loggerhead hatchlings are brown above with light margins below and have five pairs of lateral scales (Pritchard et al. 1983).

5.2.2 DISTRIBUTION

Loggerhead turtles are circumglobal, inhabiting continental shelves, bays, lagoons, and estuaries in the temperate, subtropical and tropical waters of the Atlantic, Pacific and Indian Oceans (Dodd 1988; Mager 1985).

In the western Atlantic Ocean, loggerhead turtles occur from Argentina northward to Newfoundland including the Gulf of Mexico and the Caribbean Sea (Carr 1952; Dodd 1988; Mager 1985; Nelson 1988; Squires 1954). Sporadic nesting is reported throughout the tropical and warmer temperate range of distribution, but the most important nesting areas are the Atlantic coast of Florida, Georgia and South Carolina (Hopkins and Richardson 1984). The Florida nesting population of loggerheads has been estimated to be the second largest in the world (Ross 1982).

The foraging range of the loggerhead sea turtle extends throughout the warm waters of the U.S. continental shelf (Shoop et al. 1981). On a seasonal basis, loggerhead turtles are common as far north as the Canadian portions of the Gulf of Maine (Lazell 1980), but during cooler months of the year, distributions shift to the south (Shoop et al. 1981). Loggerheads frequently forage around coral reefs, rocky places and old boat wrecks; they commonly enter bays, lagoons and estuaries (Dodd 1988). Aerial surveys of loggerhead turtles at sea indicate that they are most common in waters less than 50 m (164 ft) in depth (Shoop et al. 1981), but they occur pelagically as well (Carr 1986).

5.2.3 FOOD

Loggerheads are primarily carnivorous (Mortimer 1982). They eat a

variety of benthic organisms including molluscs, crabs, shrimp, jellyfish, sea urchins, sponges, squids, and fishes (Nelson 1988). Adult loggerheads have been observed feeding in reef and hard bottom areas (Mortimer 1982). In the seagrass lagoons of Mosquito Lagoon, Florida, subadult loggerheads fed almost exclusively on horseshoe crab (Mendonca and Ehrhart 1982). Loggerheads may also eat animals discarded by commercial trawlers (Shoop and Ruckdeschel 1982). This benthic feeding characteristic may contribute to the capture of these turtles in trawls.

5.2.4 NESTING

The nesting season of the loggerhead is confined to the warmer months of the year in the temperate zones of the northern hemisphere. In south Florida nesting may occur from April through September but usually peaks in late June and July (Dodd 1988; Florida Power & Light Company 1983).

Loggerhead females generally nest every other year or every third year (Hopkins and Richardson 1984) but multi-annual remigration intervals ranging from one to six years have been reported (Bjorndal et al. 1983; Richardson et al. 1978). When a loggerhead nests, it usually will lay 2 to 3 clutches of eggs per season and will lay 35 to 180 eggs per clutch (Hopkins and Richardson 1984). The eggs hatch in 46 to 68 days and hatchlings emerge 2 or 3 days later (Crouse 1985; Hopkins and Richardson 1984; Kraemer 1979).

Hatchling loggerheads are a little less than 5 cm (2 in) in length when they emerge from the nest (Hopkins and Richardson 1984; Florida Power & Light Company 1983). They emerge from the nest as a group at night, orient themselves seaward and rapidly move towards the water (Hopkins and Richardson 1984). Many hatchlings fall prey to sea birds and other predators following emergence. Those hatchlings that reach the water quickly move offshore and exist pelagically (Carr 1986).

Nesting by loggerheads as far north as the New Jersey coast is considered rare. Anecdotal reports of loggerhead nests at Ocean City, NJ and Island Beach State Park during the 1980's are among the few known nesting activities in local waters (Schoelkopf, personal communication, 1993). More recently, a loggerhead nest was found at Holgate, NJ on Long Beach Island during the summer of 1994 (Schoelkopf, personal communication, 1994).

5.2.5 POPULATION SIZE

Loggerhead sea turtles are the most common sea turtle in the coastal waters of the United States. Based on numbers of nesting females, numbers of hatchlings per kilometer of nesting beach and number of subadult carcasses (strandings) washed ashore, the total number of mature loggerhead females in the southeastern United States has been estimated to be from 35,375 to 72,520 (Hopkins and Richardson 1984; Gordon 1983).

Adult and sub-adult (shell length greater than 60 centimeters) population estimates have also been based on aerial surveys of pelagic animals observed by NMFS during 1982 to 1984.

Based on these studies the current estimated number of adult and sub-adult loggerhead sea turtles from Cape Hatteras, North Carolina to Key West, Florida is 387,594 (NMFS 1987). This number was arrived at by taking the number of observed turtles and converting it to a population abundance estimate using information on the amount of time loggerheads typically spend at the surface.

Some sea turtles which die at sea wash ashore and are found stranded. The NMFS Sea Turtle Salvage and Stranding Network collects stranded sea turtles along both the Atlantic and Gulf Coasts (NMFS 1988). Using 1987 data as an example, over 2,300 loggerhead turtles were reported by the network (Figures 5-2 and 5-3). The largest portion was collected from the southeast Atlantic Coast (1,414 turtles) followed by the Gulf Coast (593 turtles) and northeast Atlantic Coast (347 turtles).

One researcher has suggested that loggerhead turtle nesting populations in the U.S. have been declining (Frazer 1986), but positive steps have recently been taken to reverse that trend. In September of 1989, NMFS regulations requiring the use of turtle excluder devices (TED's) on commercial shrimp trawls were implemented. Based upon onboard observations of offshore shrimp trawling in the southeast Atlantic, NMFS estimated that over 43,000 loggerheads are captured in shrimp trawls annually. The number of loggerhead mortalities from this activity was estimated to be 9,874 turtles annually (NMFS 1987). An estimated 5,000 to 50,000 loggerheads were killed annually during commercial shrimp fishing activities prior to regulations requiring the use of TED's (NMFS 1991a). The use of TED's may reduce sea turtle mortality in shrimp trawls by as much as 97% (Crouse et al. 1992). Since the implementation of the TED requirement, strandings of drowned threatened and endangered sea turtle species, in areas where strandings were historically high, have been dramatically lower (Crouse et al. 1992). Sea turtle nesting activity on two key

beaches also increased considerably subsequent to the implementation of the TED regulations (Crouse et al. 1992).
In addition to the apparent success of the TED program, restrictions on development in coastal areas have become more widespread in recent years and may reduce the rate of habitat loss for sea turtles.

Based on these data, it is evident that a large population of loggerhead sea turtles does exist in the southeast Atlantic and Gulf of Mexico and that effective measures have been taken to mitigate a major source of loggerhead mortality. Various populations estimates suggest that the number of adult and subadult turtles is probably in the hundreds of thousands in the southeastern United States alone. In addition, large populations of loggerheads occur in many other parts of the world (Ross and Barwani 1982; NMFS 1991a). These facts suggest that although this species needs to be conserved, it is not in any immediate risk of becoming endangered.

5.3 KEMP'S RIDLEY (Lepidochelys kempii)

5.3.1 DESCRIPTION

The adult Kemp's ridley has a circular-shaped carapace and a medium sized pointed head. Ridleys are the smallest of extant sea turtles. They normally weigh up to 42 kg (90 lb) and attain a carapace length (straight line) up to 70 cm (27 in) (Pritchard et al. 1983). Their general coloration is olive-green dorsally and yellow ventrally (Hopkins and Richardson 1984). Morphologically, the Kemp's ridley is distinguishable from other sea turtle species by the following characteristics: 1) a hard shell; 2) two pairs of scutes on the front of the head; 3) five pairs of lateral scutes on the carapace; 4) plastron with four pairs of scutes, with pores, connecting the carapace; 5) one claw on each front flipper and two on each back flipper; and, 6) olive-green coloration (Pritchard et al. 1983; Pritchard and Marquez 1973).

Kemp's ridley hatchlings are dark grey-black above and white below (Pritchard et al. 1983; Pritchard and Marquez 1973).

5.3.2 DISTRIBUTION

Kemp's ridley turtles inhabit sheltered coastal areas and frequent larger estuaries, bays and lagoons in the temperate, subtropical and tropical waters of the northwestern Atlantic Ocean and Gulf of Mexico (Mager 1985).

The foraging range of adult Kemp's ridley sea turtles appears to be restricted to the Gulf of Mexico. However, juveniles and subadults occur throughout the warm coastal waters of the U.S. Atlantic coast (Hopkins and Richardson 1984; Pritchard and Marquez 1973). Juveniles/subadults travel northward with vernal warming to feed in the productive coastal waters of Georgia through New England, but return southward with the onset of winter to escape the cold (Henwood and Ogren 1987; Lutcavage and Musick 1985; Morreale et al. 1988; Ogren 1989).

5.3.3 FOOD

Kemp's ridleys are omnivorous and feed on crustaceans, swimming crabs, fish, jellyfish and molluscs (Pritchard and Marquez 1973).

5.3.4 NESTING

Nesting of Kemp's ridleys is mainly restricted to a stretch of beach near Rancho Nuevo, Tamaulipas, Mexico (Pritchard and Marquez 1973; Hopkins and Richardson 1984). Occasional nesting has been reported in Padre Island, Texas and Veracruz, Mexico (Mager 1985).

The nesting season of the Kemp's ridley is confined to the warmer months of the year primarily from April through July. Kemp's ridley females generally nest every year to every third year (Márquez et al. 1982; Pritchard et al. 1983). They will lay 2 to 3 clutches of eggs per season and will lay 50 to 185 eggs per clutch. The eggs hatch in 45 to 70 days and hatchlings emerge 2 or 3 days later (Hopkins and Richardson 1984).

Hatchling ridleys are about 4.2 cm (a little less than 2 in) in length when they emerge from the nest (Hopkins and Richardson 1984). They emerge from the nest as a group at night, orient themselves seaward and rapidly move towards the water (Hopkins and Richardson 1984). Following emergence, many hatchlings fall prey to sea birds, raccoons and crabs. Those hatchlings that reach the water quickly move offshore. Their existence after emerging is not well understood but is probably pelagic (Carr 1986). The post-pelagic stages are commonly found dwelling over crab-rich sandy or muddy bottoms. Juveniles frequent bays, coastal lagoons, and river mouths (NMFS 1992b).

5.3.5 POPULATION SIZE

Kemp's ridley sea turtles are the most endangered of the sea turtle species. There is only a single known colony of this species,

almost all of which nest near Rancho Nuevo, Tamaulipas, Mexico. An estimated 40,000 females nested on a single day in 1947, but between 1978 and 1990 there were less than 1,000 nests per season (Figures 5-4 and 5-5). Based on nesting information from Rancho Nuevo, Ross (1989) estimated that the population was declining at a rate of approximately 3 percent per year. In 1994 however, 1,568 nests were observed at Rancho Nuevo, and more Kemp's ridley nests have been laid each year since 1990 than in any previous year on record since 1978 (Byles, 1994). It has been suggested that this recent increase in nesting activity reflects the reduction in shrimp trawl related mortality realized since the implementation of the NMFS TED regulations in September of 1989 (Crouse et al. 1992). The adult Kemp's ridley population has been estimated by Márquez (1989) to be approximately 2,200 adults based on the numbers of nests produced at Rancho Nuevo, this species' nesting cycle, male-female ratios, and fecundity.

Population estimates of immature L. kempii are difficult to develop. Increases have been noted in the number of juvenile captures during the late 1980's and early 1990's in long-term tagging studies in the northeast Gulf of Mexico (Ogren, unpubl. data). If this increase is indicative of an overall increase in the juvenile population, additional recruitment into the adult population should occur in the future (NMFS 1991a).

Kemp's ridleys also die at sea and wash ashore. The NMFS Sea Turtle Salvage and Stranding Network collects stranded sea turtles along both the Atlantic and Gulf Coasts (NMFS 1988). Based on 1987 data, 767 ridleys were reported by the network (Figures 5-2 and 5-3). The largest portion was collected from the Gulf Coast (103 turtles), primarily the western portion of the Gulf. Nearly equal numbers of ridleys were reported from the northeast and southeast Atlantic Coasts (64 and 50, respectively).

Onboard observation of offshore shrimp trawling by NMFS in the southeast Atlantic indicated that over 2,800 ridleys are captured in shrimp trawls annually. The number of ridley mortalities attributable to this activity was estimated to be 767 turtles annually and most of these (65 percent) occurred in the western portion of the Gulf of Mexico (NMFS 1987). Magnuson et al. (1990) estimated the annual shrimp trawl by-catch mortality to be between 500 and 5,000 individuals. As discussed above, significant reductions in this source of mortality, by as much as 97 percent, have been achieved as a result of the implementation of the TED regulations by the NMFS in 1989 (Crouse et al. 1992).

Despite the apparent reduction in mortality afforded by the use of TED's, these data suggest that this population remains at critically low levels. The species was listed as endangered in 1970 and is considered the most endangered of all sea turtles (NMFS 1991a; Burke et al. 1994).

5.4 ATLANTIC GREEN TURTLE (Chelonia mydas)

5.4.1 DESCRIPTION

The Atlantic green turtle is a medium to large sea turtle with a nearly oval carapace and a small rounded head (Pritchard et al. 1983). Its carapace is smooth and olive-brown in color with darker streaks and spots. Its plastron is yellow. Full grown adult Atlantic greens normally weigh 100 to 150 kg (220 to 330 lb) and attain a carapace length (straight line) of 90 to 100 cm (35 to 40 in) (Pritchard et al. 1983; Hopkins and Richardson 1984; Witherington and Ehrhart 1989). Morphologically, this species can be distinguished from the other sea turtles by the following characteristics: 1) a relatively smooth shell with no overlapping scutes; 2) one pair of scutes on the front of the head; 3) four pairs of lateral scutes on the carapace; 4) plastron with four pairs of enlarged scutes connecting the carapace; 5) one claw on each flipper; and, 6) olive, dark-brown mottled coloration (Nelson 1988; Pritchard et al. 1983; Carr 1952).

5.4.2 DISTRIBUTION

Atlantic green turtles are circumglobally distributed mainly in waters between the northern and southern 20°C (68°F) isotherm (Mager 1985). In the western Atlantic, several major assemblages have been identified and studied (Parsons 1962; Pritchard 1966; Schulz 1975; 1982; Carr et al. 1978). In the continental U.S., however, the only known Atlantic green turtle nesting occurs on the Atlantic coast of Florida (Mager 1985). In U.S. Atlantic waters, Atlantic green turtles are found around the U.S. Virgin Islands, Puerto Rico, and the continental United States from Texas to Massachusetts (NMFS, 1991b).

5.4.3 FOOD

Atlantic green sea turtles leave their pelagic habitat phase and enter benthic feeding grounds upon reaching a carapace length of 20 to 25 cm (8-10 in). They are primarily herbivores eating sea grasses and algae (NMFS 1991b). Other organisms living on sea grass blades and algae add to their diet (Mager 1985).

5.4.4 NESTING

Atlantic green turtle nesting occurs on the Atlantic coast of Florida from June to September (Hopkins and Richardson 1984). Mature females may nest one to seven times per season at about 10 to 18 day intervals (Carr et al. 1978). Average clutch sizes vary between 100 and 200 eggs that usually hatch within 45 to 60 days (Hopkins and Richardson 1984). Hatchlings emerge, mostly at night, travel quickly to the water, and swim out to sea. At this point, they enter a period which is poorly understood but is likely spent pelagically in areas where currents concentrate debris and floating vegetation such as sargassum (Carr 1986).

5.4.5 POPULATION SIZE

The number of Atlantic green sea turtles that existed before commercial exploitation and the total number that now exists are not known.
Records show drastic declines in the Florida catch during the 1800's and similar declines occurred in other areas where they were commercially harvested in the past, such as Texas (Hildebrand 1982; Hopkins and Richardson 1984).

The elimination or deterioration of many nesting beaches and less frequent encounters with Atlantic green turtles provide inferential evidence that stocks are generally declining (Mager 1985; Hopkins and Richardson 1984).

5.5 LEATHERBACK TURTLE (Dermochelys coriacea)

5.5.1 DESCRIPTION

The leatherback turtle is the largest of the sea turtles. It has an elongated, somewhat triangularly shaped body with longitudinal ridges or keels. It has a leathery blue-black shell composed of a thick layer of oily, vascularized cartilaginous material, strengthened by a mosaic of thousands of small bones. This blue-black shell may also have variable white spotting (Pritchard et al. 1983). Its plastron is white. Leatherbacks normally weigh up to 300 kg (660 lb) and attain a carapace length (straight line) of 140 cm (55 in) (Pritchard et al. 1983; Hopkins and Richardson 1984). Specimens as large as 910 kg (2,000 lb) have been observed.

Morphologically this species can be easily distinguished from the other sea turtles by the following characteristics: 1) its smooth

unscaled carapace; 2) carapace with seven longitudinal ridges; 3) head and flippers covered with unscaled skin; and, 4) no claws on the flippers (Nelson 1988; Pritchard et al. 1983; Pritchard 1971; Carr 1952).

5.5.2 DISTRIBUTION

Leatherbacks have a circumglobal distribution and occur in the Atlantic, Indian and Pacific Oceans. They range as far north as Labrador and Alaska to as far south as Chile and the Cape of Good Hope. Their occurrence farther north than other sea turtle species is probably related to their ability to maintain a warmer body temperature over a longer period of time (NMFS 1985). Thompson (1984) reported that leatherbacks prefer water temperatures of about $20^{0}C$ ($\pm 5^{0}$) and were likely to be associated with cooler, more productive waters than the Gulf Stream.

Aerial surveys have shown leatherbacks to be present from April to November between North Carolina and Nova Scotia, but most likely to be observed from the Gulf of Maine south to Long Island during summer (Shoop et al. 1981).

5.5.3 FOOD

The diet of the leatherback consists primarily of soft-bodied animals such as jellyfish and tunicates, together with juvenile fishes, amphipods and other organisms (Hopkins and Richardson 1984).

5.5.4 NESTING

Leatherback turtle nesting occurs on the mid-Atlantic coast of Florida from late February or March to September (Hopkins and Richardson 1984; NMFS 1992a). Mature females may nest one to nine times per season at about 9 to 17 day intervals. Average clutch sizes vary between 50 and 170 eggs that hatch usually within 50 to 75 days (Hopkins and Richardson 1984; Tucker 1988). Hatchlings emerge, mostly at night, travel quickly to the water, and swim out to sea. The life history of the leatherback is poorly understood since juvenile turtles are rarely observed.

5.5.5 POPULATION SIZE

The world population estimates for the leatherback have been revised upward to over 100,000 females in recent years due to the discovery of nesting beaches in Mexico (Pritchard 1983).

5.6 SEA TURTLES IN COASTAL WATERS OF NEW JERSEY

Four species of sea turtles are known to occur in the coastal marine and estuarine waters of New Jersey, based on the records of sea turtle strandings compiled by the Marine Mammal Stranding Center (Schoelkopf 1994; Schoelkopf 2000). The Marine Mammal Stranding Center (MMSC) is a member of the Northeast Sea Turtle Salvage and Stranding Network supported by NMFS.

The records of the MMSC include strandings of sea turtles along the seaside beaches of New Jersey as well as New Jersey's coastal embayments and estuaries such as Barnegat Bay and Delaware Bay. The four species of sea turtles reported from these areas include loggerhead, leatherback, Kemp's ridley, as well as Atlantic green sea turtles.

The MMSC has reported 914 sea turtle strandings in coastal New Jersey, from Delaware Bay to Sandy Hook between 1977 and 2000 (Tables 5-1 and 5-2). Only eight of these strandings occurred at OCNGS during 1977-1994 and only six additional strandings have occurred at OCNGS between 1995 and 2000; the details of these strandings are discussed in Section 6.0. Loggerheads were the most commonly stranded turtle, comprising about two-thirds of the strandings in New Jersey between 1977 and 2000. Kemp's ridleys and leatherback were less common (4.6 and 26 percent of the strandings, respectively). Less than one percent of the reported strandings were Atlantic green sea turtles (Schoelkopf 1994;Schoelkopf 2000).

The majority of the strandings and/or sightings reported by MMSC have occurred between June and October (Table 5-2), although leatherbacks can occur virtually all year in New Jersey.

The MMSC (Schoelkopf 1994) reports that the majority of New Jersey sea turtle strandings have occurred in Cape May, Monmouth, Ocean and Salem counties, with fewer occurrences in Atlantic, Cumberland, Middlesex and Burlington counties (Figure 5-6).

Stomach content analyses from dead turtles have shown that primary food items for loggerheads are often blue crab and horseshoe crab. Blue crab occur during most of the year in the OCNGS intake and discharge canals and adjacent areas of Barnegat Bay. Horseshoe crab move into Barnegat Bay to lay eggs in the spring and summer, which coincides with the northward seasonal movement of loggerheads along the coast. Kemp's ridley stomachs which have been examined also often contain primarily blue crab. From a functional ecological viewpoint, loggerhead and Kemp's ridleys would be secondary

consumers. They are not likely to be an important link in the Barnegat Bay food web, however, because of their apparently low abundance.

5.6.1 SEA TURTLES IN BARNEGAT BAY

A considerable body of evidence exists which indicates that sea turtles are not commonly found in Barnegat Bay. From 1975 to 1985, GPUN and its environmental consultants conducted an intensive biological monitoring program designed to qualify and quantify the marine biota of Barnegat Bay. The program included sampling organisms impinged upon the CWS travelling screens and entrained in the cooling water flow of the condenser and dilution pump intakes at the OCNGS. In addition, thousands of trawl, seine and gill-net samples were collected in Barnegat Bay, Forked River and Oyster Creek (Danila et al. 1979; Ecological Analysts, Inc. 1981; EA Engineering, Science and Technology, Inc. 1986; EA Engineering, Science, and Technology, Inc. 1986a; Jersey Central Power and Light Company 1978; Tatham et al. 1977; Tatham et al. 1978).

Impingement and entrainment sampling involved the presence of 2 to 4 biologists at the intake structures during day and night sampling periods. No sea turtles were captured or observed during more than 20,000 hours of sampling.

Nearly 3,000 trawl samples were collected during day and night sampling periods. These samples consisted of 5-minute hauls of a 4.9 meter (16 ft) semiballoon otter trawl. The trawl had a 3.8 cm (1.5 in) stretch mesh body, a 3.2 cm (1.25 in) stretch mesh cod end and a 1.3 cm (0.5 in) stretch mesh inner liner. No sea turtles were found in any of these samples. More than 2,000 seine samples were collected during day and nite periods using 12.2 meter (40 ft) and 45.7 meter (150 ft) seines with 0.6 cm (0.25 in) and 1.3 cm (0.5 in) stretch mesh, respectively. No sea turtles were found in any of these samples.

Gill-net samples were collected using a 91.4 x 1.8 meter (300 x 6 ft) net consisting of three, 30.5 m (100 ft) panels of 38, 70 and 89 mm (1.5, 2.75, and 3.5 in) monofilament stretch mesh or a 61.0 meter (200 ft) net, identical to that described above but without the 70 mm (2.75 in) mesh panel. Several hundred samples were collected during day and night periods but no sea turtles were captured.

The New Jersey Department of Environmental Protection, Division of Fish, Game and Wildlife, has conducted periodic trawl and seine sampling in Barnegat Bay since 1971 (NJDEP 1973; Makai 1993; McLain

1993) and have reported no sea turtle captures. Similarly, Rutgers University reports that only one loggerhead turtle was captured during more than 5 years of periodic trawl sampling in Great Bay and Little Egg Harbor, estuaries located immediately south of Barnegat Bay (Able 1993).

The scarcity of sea turtles in Barnegat Bay is not surprising considering the fact that the only direct access to the bay from the Atlantic Ocean is through a single, narrow inlet, approximately 300 m (1000 ft) wide. By contrast, the inlet to Delaware Bay is over 18 km (11 mi) wide (Figure 5-7), providing unrestricted access from the Atlantic Ocean. Largely as a result of this accessibility, sea turtles have been much more common in Delaware Bay. At the Salem Generating Station located on upper Delaware Bay, Public Service Electric and Gas (1989) has captured sea turtles in the vicinity of their cooling water intakes since 1980, only three years after the first of two generating units began operating. As many as 10 sea turtles have been captured at that facility in a single year.

The location of the generating station relative to the inlet from the ocean, as well as the rate and velocity of the cooling water flows should also be considered when comparing incidental capture rates at the Salem and Oyster Creek generating stations. The OCNGS is located much closer to Barnegat Inlet than Salem Generating Station is to the mouth of Delaware Bay. However, a sea turtle entering Barnegat Bay must travel along several kilometers of narrow, relatively shallow navigation channels, characterized by very heavy boat traffic, and pass through the wooden support structures of 3 bridges, in order to reach the OCNGS (Figure 5-8).

The rate of cooling water withdrawal for either the CWS or the DWS for OCNGS (1740 and 1968 m^3/min respectively) is about 25 percent of that for the cooling water system at Salem (approximately 7565 m^3/min). Similarly, the intake velocity at the OCNGS CWS intake (17-20 cm/sec) is approximately 25% of that at Salem (61-72 cm/sec). The intake velocity at the DWS intake for OCNGS (73 cm/sec) is similar to that at Salem's cooling water intake.

These factors play an important role in minimizing the number of incidental takes, as well as the potential for mortality, at the OCNGS intakes.

The occurrence of fourteen sea turtles at the OCNGS between 1992 and 2000, when none had been observed before despite intensive sampling efforts, may be attributable to recent changes in the accessibility of Barnegat Bay and increases in sea turtle population levels.

The modifications to Barnegat Inlet that were completed in 1991 resulted in a significant increase in the depth of the inlet, and concomitant increase in the volume of water moving through the inlet during each tidal cycle. Recent preliminary data indicate that the average tidal prism after completion of the modifications is approximately 2.5 times greater than during the 1980's prior to the modifications (Gebert 1994). In addition, the removal of shoals near the inlet entrance reduced the amount of turbulence associated with breaking surf. These changes may have made the inlet more accessible to sea turtles migrating along the Atlantic coast.

Dramatically smaller numbers of strandings of drowned sea turtles and increases in sea turtle nesting activity on two key beaches have been attributed to the implementation of the NMFS TED requirements in September of 1989 (Crouse et al. 1992). The use of TED's has apparently resulted in a significant reduction in shrimp trawl by-catch mortality, possibly by as much as 97 percent. According to NMFS estimates (NMFS 1991a), shrimp trawls may have killed as many as 5,000 to 50,000 loggerhead and more than 700 Kemp's ridley turtles each year, prior to the use of TED's. This relatively recent reduction in sea turtle mortality may have resulted in an increase in the number of individuals migrating up the Atlantic coast and moving into the estuaries. This theory is supported by recent trends in incidental sea turtle captures at the Salem Generating Station. From 1980 through 1988, sea turtles were captured at Salem at a rate of approximately 4.2 per year (PSE&G 1989). The rate of capture increased to more than 9 per year during the 1989–1993 period, following implementation of TED's by commercial shrimp trawlers.

It is difficult to predict future trends in the occurrence of sea turtles at the OCNGS. If the number of individuals migrating up and down the Atlantic coast is the major determining factor, incidental captures may continue to occur if the TED regulations are as effective as they seem to be after the first few years of experience. If accessibility to Barnegat Bay is the most important factor, the frequency of incidental captures at OCNGS may decline with time. Barnegat Inlet is notoriously dynamic, the position of the channel shifting frequently and the volume of the tidal prism continuously decreasing due to sedimentation (Table 3-1; Ashley 1988). As a result, accessibility to the bay through the inlet was probably at its maximum following the completion of the inlet modifications in 1991 and subsequent dredging in 1993 and is likely to decrease with time.

TABLE 5-1

SEA TURTLE STRANDINGS IN NEW JERSEY COASTAL AND ESTUARINE WATERS REPORTED BY MARINE MAMMAL STRANDING CENTER, 1977-2000. (SCHOELKOPF 1993; SCHOELKOPF 2000)

ANNUAL DISTRIBUTION					
YEAR	LOGGERHEAD	KEMP'S RIDLEY	LEATHERBACK	GREEN	UNKNOWN
1977	1	0	1	0	0
1978	4	0	2	0	0
1979	11	0	10	0	0
1980	9	0	2	0	0
1981	4	0	13	0	0
1982	2	0	13	0	0
1983	8	4	9	0	0
1984	8	0	2	0	0
1985	22	1	7	0	0
1986	15	0	2	0	0
1987	37	1	33	0	0
1988	13	0	6	0	0
1989	17	7	3	0	0
1990	26	0	9	1	0
1991	55	4	13	2	0
1992	39	5	5	1	0
1993	17	6	28	2	1
1994	33	4	9	1	1
1995	74	1	40	1	8
1996	51	2	5	0	0
1997	35	1	14	0	0
1998	47	1	4	0	1
1999	79	4	9	1	1
2000*	2	1	0	0	0
TOTALS	609	42	239	9	12

*Note: Partial year data for 2000

TABLE 5-2

SEASONAL OCCURRENCE OF SEA TURTLE STRANDINGS IN NEW JERSEY COASTAL AND ESTUARINE WATERS REPORTED BY MARINE MAMMAL STRANDING CENTER AND PUBLIC SERVICE ELECTRIC AND GAS, 1977-1994.
(PSE&G 1989; SCHOELKOPF 1994)

MONTHLY DISTRIBUTION (*)					
MONTH	LOGGERHEAD	RIDLEY	LEATHERBACK	GREEN	UNKNOWN
JAN	1(0)	1(0)	3(0)	0	0
FEB	0	0	3(0)	0	0
MAR	0	0	1(0)	0	1(0)
APR	0	0	1(0)	0	0
MAY	0	0	2(0)	0	0
JUNE	37(2)	4(0)	4(0)	0	0
JULY	108(1)	10(2)	10(0)	1(0)	0
AUG	77(0)	9(0)	30(0)	2(0)	1(0)
SEP	84(1)	13(0)	56(0)	1(0)	0
OCT	40(0)	4(2)	44(0)	1(0)	0
NOV	5(0)	1(0)	8(0)	2(0)	0
DEC	0	0	2(0)	0	0
TOTALS	352(4)	42(4)	164(0)	7(0)	2(0)

Note:
* Number of incidental captures at OCNGS in parentheses.
** Data for 1994 includes all standings through mid-September

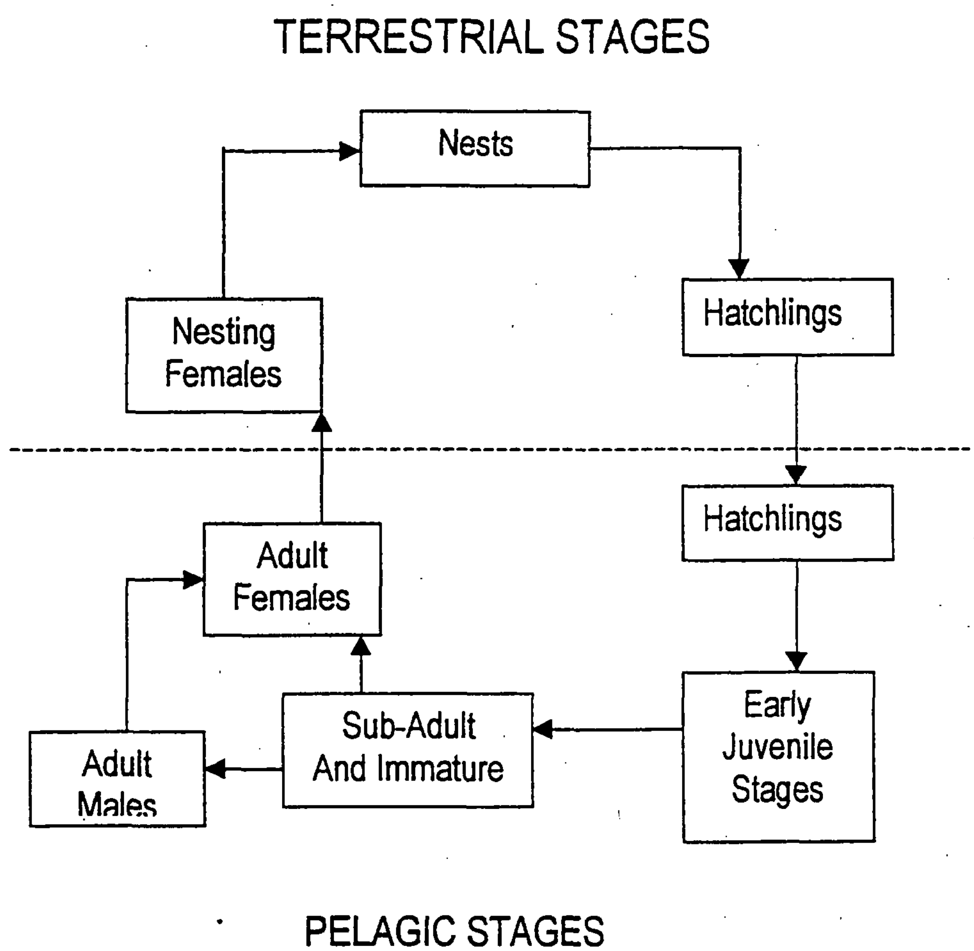


Figure 5-1. Generalized sea turtle life cycle (After PSE&G 1989).

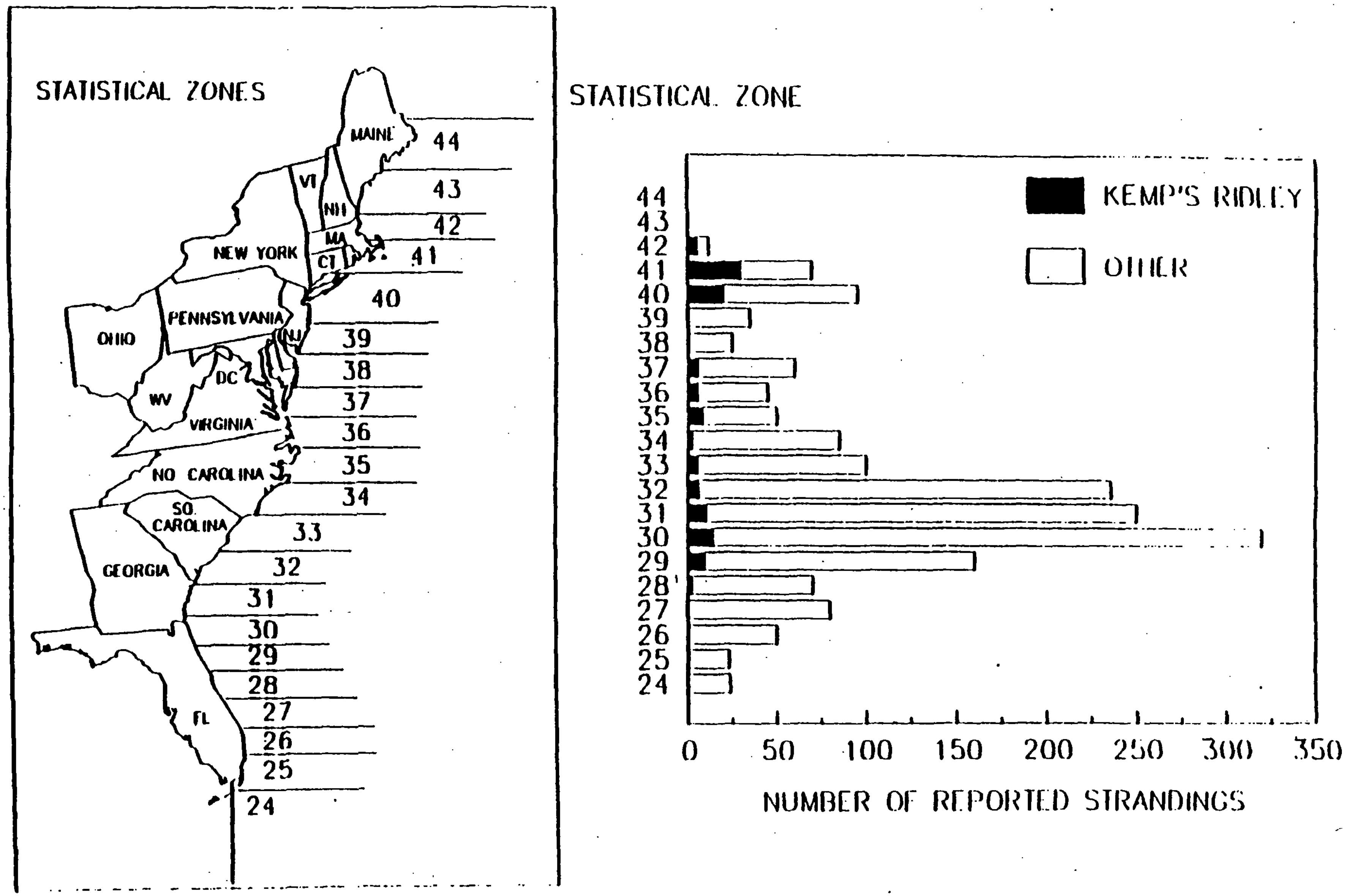
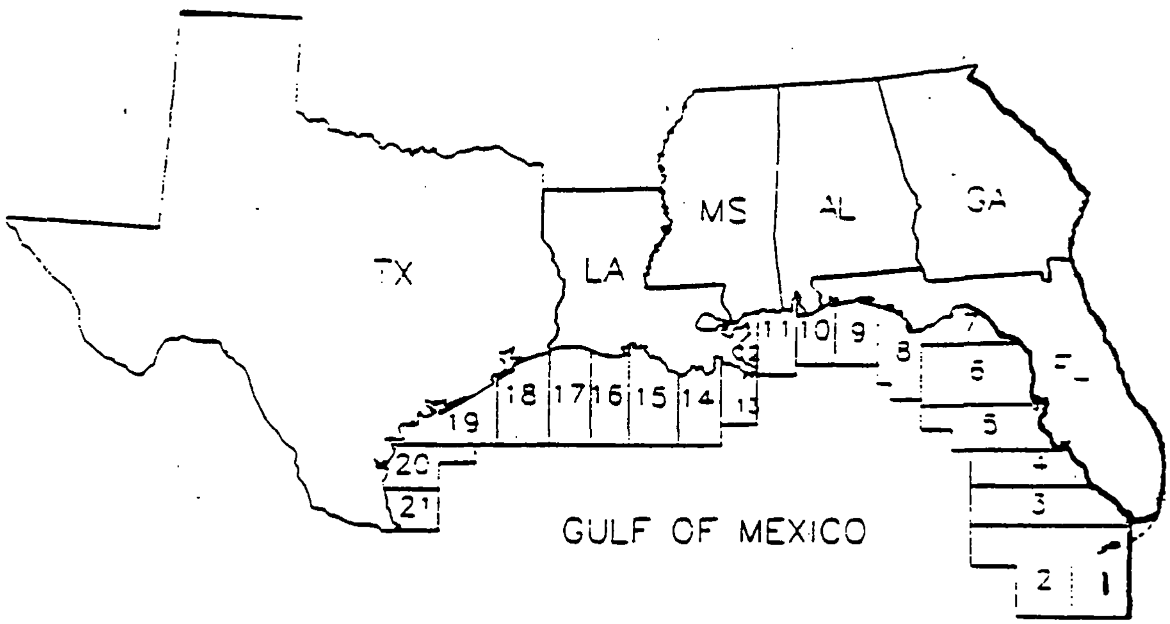


Figure 5-2. Sea Turtle Strandings, U.S. Atlantic Coast 1987 (After NMFS 1988).



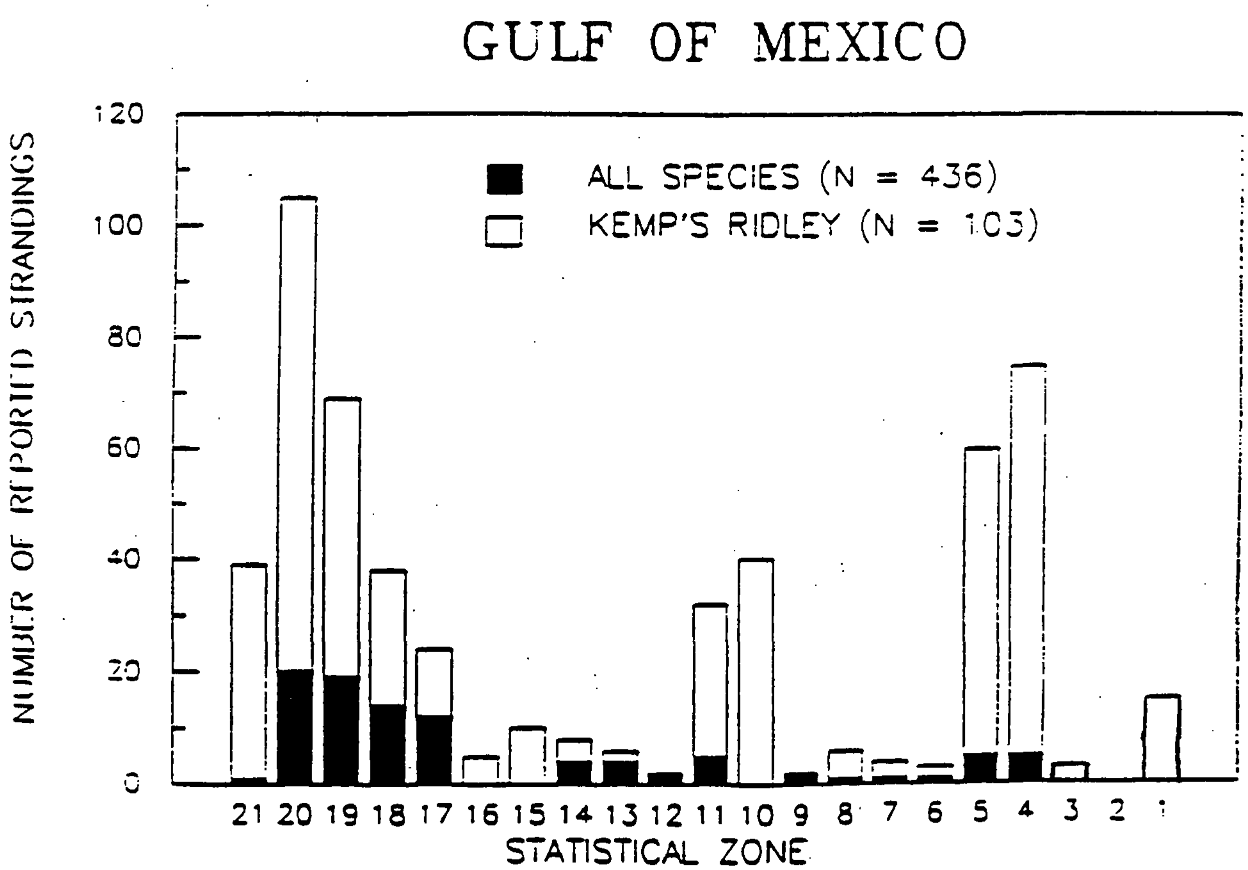


Figure 5-3. Sea Turtle Strandings, U.S. Gulf of Mexico 1987 (After NMFS 1988).

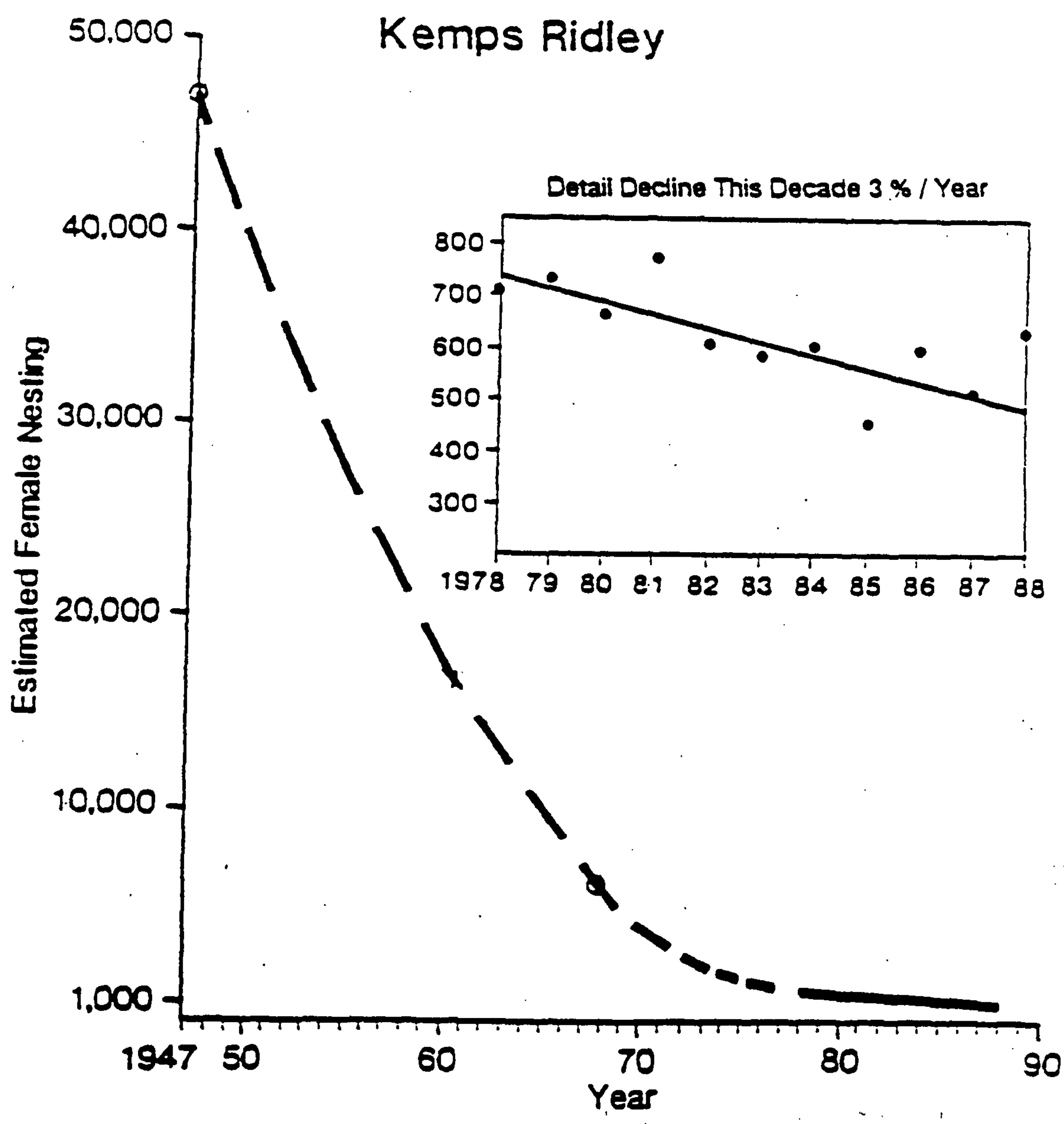


Figure 5-4. Estimated Annual Number of Nesting Female Kemp's Ridley Sea Turtles (After Ross 1989).

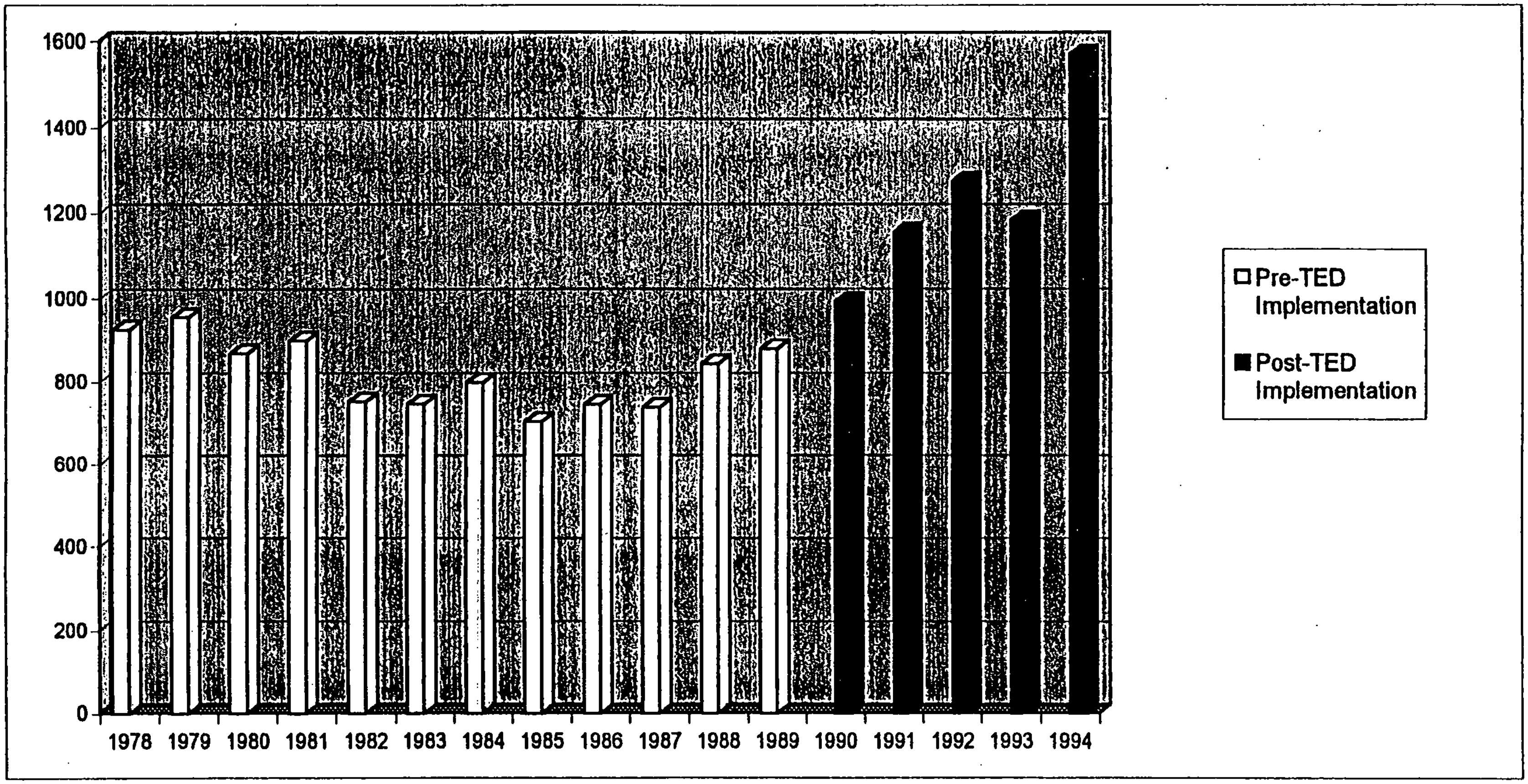


Figure 5-5. Number of Kemp's Ridley Nests at Rancho Nuevo Before and After Implementation of TED Regulations in 1989 (After Crouse et al. 1992).

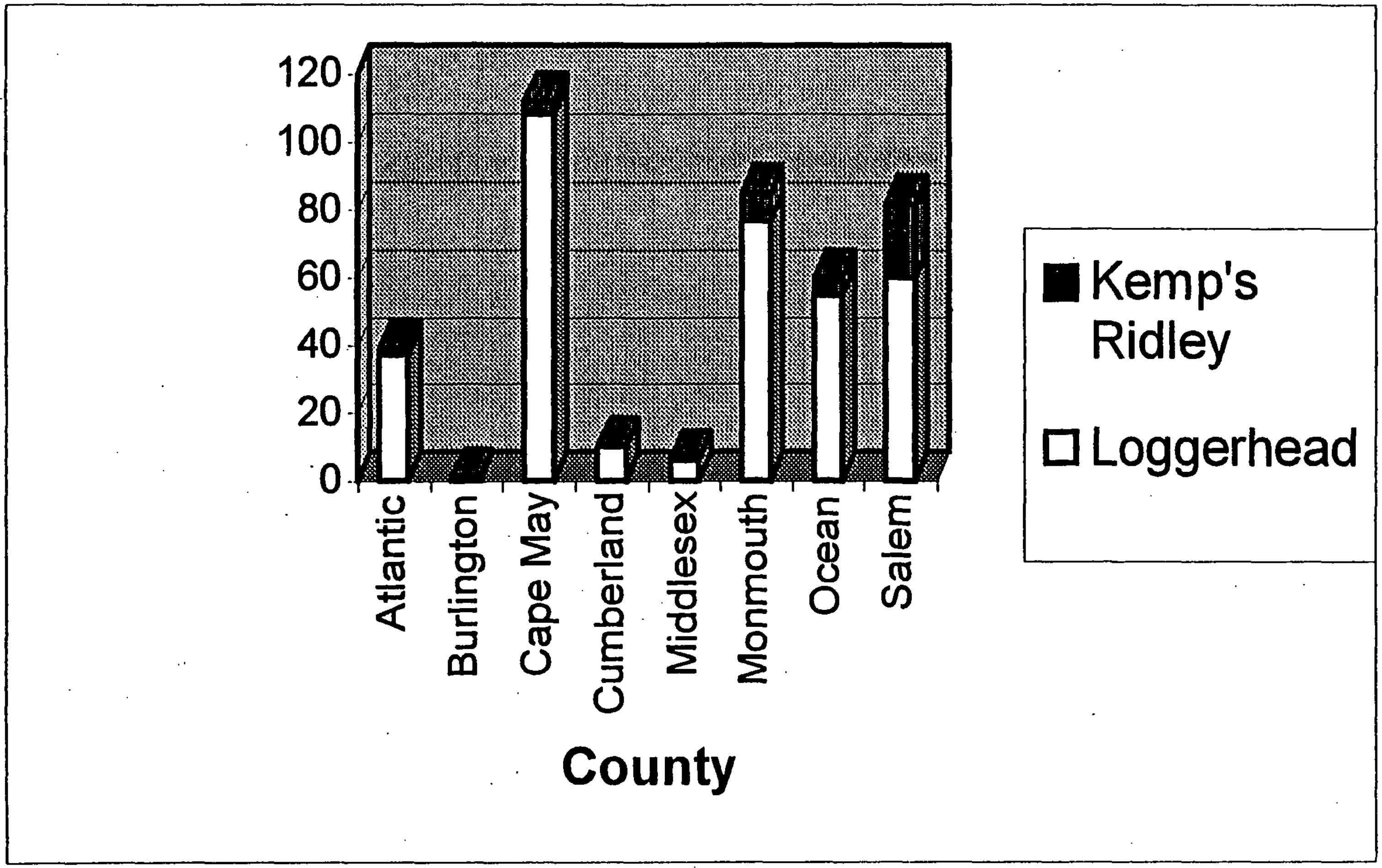


Figure 5-6. New Jersey Sea Turtle Strandings by County, as Reported by Marine Mammal Stranding Center, 1977-1984 (Schoelkopf, 1994)

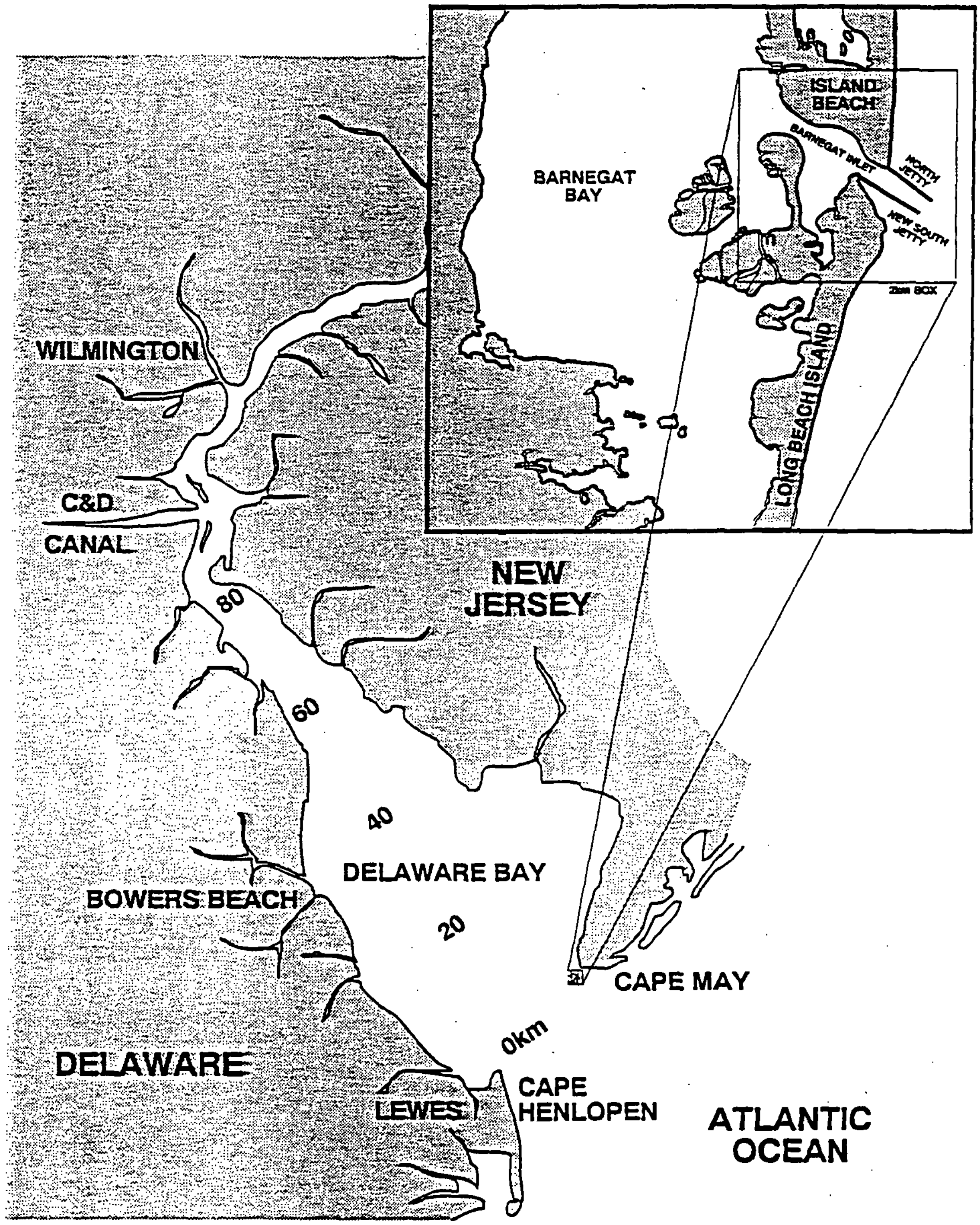


Figure 5-7. Relative widths of the mouth of Delaware Bay and Barnegat Inlet. Inset shows Barnegat Inlet vicinity in greater detail.

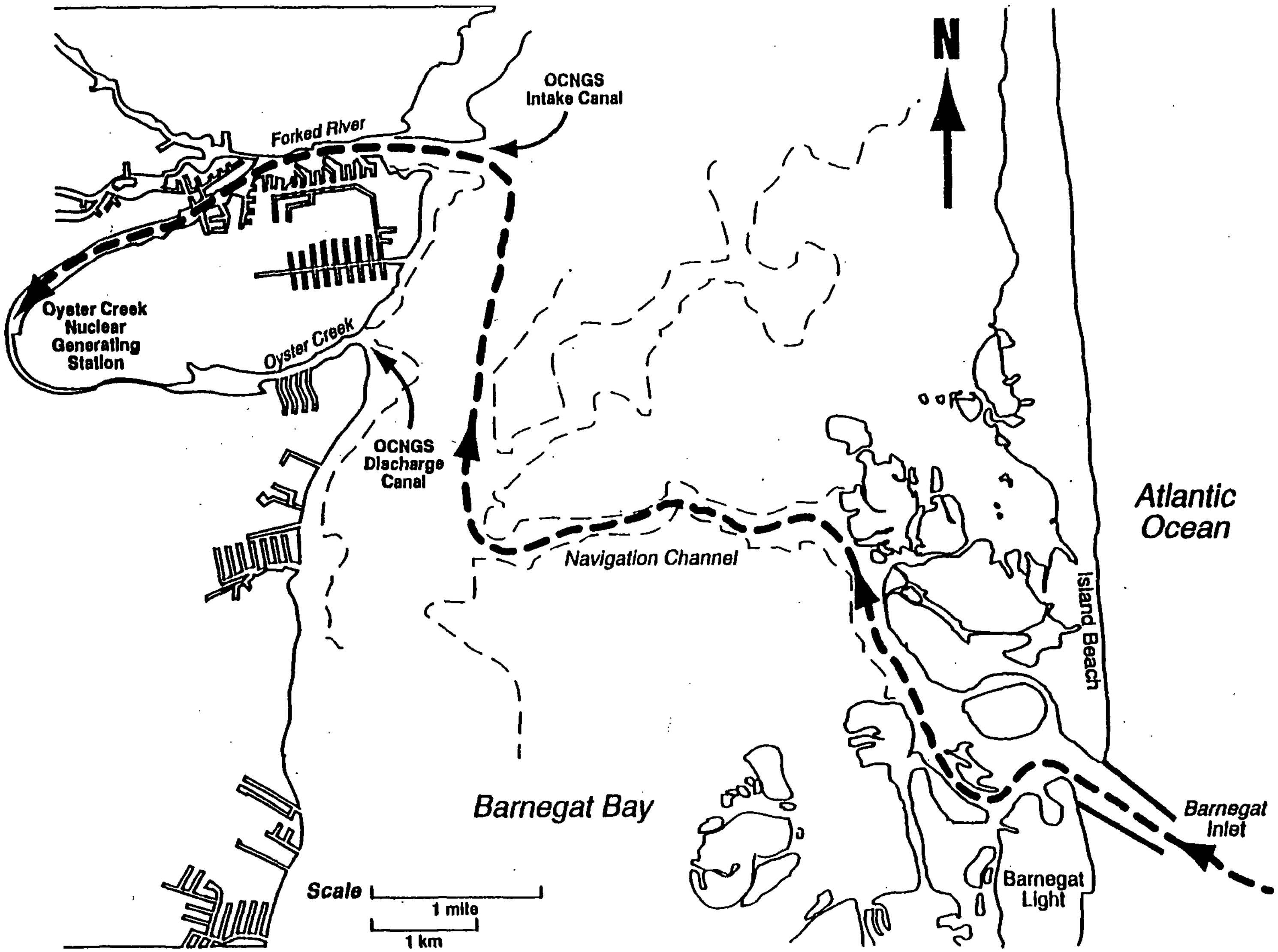


Figure 5-8 Probable pathway of sea turtles moving from the Atlantic Ocean to OCNGS via Barnegat Inlet.

SECTION 6.0
ONSITE INFORMATION

6.1 OCCURRENCE OF SEA TURTLES AT OYSTER CREEK NUCLEAR GENERATING STATION

As discussed in Section 5.0, despite intensive sampling efforts, no sea turtles were observed during the 23 years of OCNGS operation prior to 1992; fourteen sea turtles have been captured since 1992 (Tables 5-2 and 6-1). Three sea turtles were taken in 1992: a dead loggerhead with deep boat propeller wounds was impinged on June 25, 1992; a live loggerhead taken twice in September 1992; and a live Kemp's ridley turtle was taken October 26, 1992. During 1993, the only sea turtle observed at OCNGS was a dead juvenile Kemp's ridley turtle taken on October 17, 1993.

Four sea turtles were taken in 1994: a live juvenile loggerhead in June, a dead loggerhead subadult taken during July (and for which the necropsy showed that death due to infections and boat propeller wounds had occurred prior to capture at OCNGS), and two dead Kemp's ridley juveniles taken during July (Table 6-1).

No sea turtles were observed or taken at the OCNGS during the three-year period from August of 1994 through August of 1997.

One sea turtle was taken each year in 1997 and 1998: a dead Kemp's ridley subadult taken during September 1997, and a live loggerhead subadult taken during August 1998 which was transported to Florida and subsequently released into the Atlantic Ocean.

Two sea turtles were taken in 1999: a live Kemp's ridley subadult taken during September 1999 which was transported to Virginia and subsequently released into the Atlantic Ocean, and a dead juvenile green sea turtle taken during October 1999.

Two sea turtles were taken in 2000: a live loggerhead subadult was taken during June 2000 which was transported to the Marine Mammal Stranding Center in Brigantine, NJ, then tagged and subsequently released into the Atlantic Ocean, and a dead juvenile Kemp's ridley taken during early July 2000.

6.1.1 DETAILS OF INCIDENTAL CAPTURES AT OCNGS

Descriptions of the circumstances surrounding each of the incidental captures at OCNGS based on available information are provided in Sections 6.1.1.1 through 6.1.1.14. This information is also summarized in Table 6-1. In some cases, observations or inferences about the turtles' behavior or orientation could be made. However, when turtles were removed from more than about 1 m (3 ft) below the surface, or if they were obscured by debris near the surface, detailed information on their exact location and orientation was not always available. The OCNGS Sea Turtle Sighting/Capture Report Form, an attachment to the Sea Turtle Surveillance, Handling and Reporting Instructions (Appendix I), was developed in order to standardize the gathering of data related to future incidental captures.

6.1.1.1 INCIDENTAL CAPTURE OF JUNE 25, 1992

A dead sea turtle was removed from the dilution water system intake trash bars at approximately 12:50 PM on June 25, 1992. Members of the OCNGS Environmental Affairs Department identified it as a juvenile loggerhead measuring 35.5 cm (14 in) carapace length and noted that this turtle had several deep gashes on its side which appeared to be boat propeller wounds. The Marine Mammal Stranding Center (MMSC) of Brigantine, NJ was notified and requested to perform a necropsy. MMSC confirmed that the specimen was a juvenile Caretta caretta. The MMSC necropsy determined that the cause of death was from boat propeller wounds and that the specimen had died prior to becoming impinged on OCNGS.

6.1.1.2 INCIDENTAL CAPTURES OF SEPTEMBER 9 AND 11, 1992

During the early evening (approx. 6:00 PM) of September 9, 1992 a live sea turtle was noticed by OCNGS Operations personnel during a routine inspection of the circulating water system (CWS) intake trash bars. The turtle was carefully removed by several plant personnel, tentatively identified as a juvenile loggerhead, and released alive into the OCNGS discharge canal. Although this individual was alive and healthy when released, it was noted that it had a small wound surrounded by scar tissue just behind its head. The turtles carapace length was 46.7 cm (18.4 in).

During a mid-afternoon (approx. 2:00 PM) tour of the circulating water system intake structure on September 11, 1992, an OCNGS security officer noticed a live sea turtle impinged on the CWS trash bars. When the turtle was removed from the intake structure, it was identified as a juvenile loggerhead with a neck

wound identical to that noted on the loggerhead released at OCNGS on September 9, 1992. The Marine Mammal Stranding Center was notified and the turtle was released in healthy condition to MMSC personnel who took it their Brigantine facility for examination, holding, tagging and subsequent release. MMSC personnel confirmed the turtle to be a juvenile loggerhead and observed that it had a small (0.6 cm; 0.25 in) wound with scar tissue on the dorsal midline just behind the head. MMSC Director Robert Schoelkopf stated that he believed it to be the same juvenile loggerhead which was collected and released at OCNGS on September 9, 1992. The turtle was tagged by MMSC personnel and released in the Atlantic Ocean near Brigantine in healthy condition.

6.1.1.3 INCIDENTAL CAPTURE OF OCTOBER 26, 1992

During an early morning routine inspection of the CWS intake, an OCNGS Operations department representative noticed a live sea turtle impinged against the trash bars. The turtle was initially found at about 3:00 AM with its head out of the water and pointing upward. The turtle was carefully retrieved as quickly as possible and found to be in good condition. Environmental Affairs department personnel who took custody of the turtle identified it as a subadult Kemp's ridley and made arrangements for its immediate transfer to the MMSC. Although it was impossible to say precisely how long the turtle had been on the intake structure prior to removal, it may have been there between three and eight hours.

MMSC personnel who examined the turtle found that it was very healthy, swam freely, and required no direct care. However, two scars from slash-like wounds were apparent on the plastron, indicating that the turtle had been wounded at some time prior to its incidental capture at OCNGS. The turtle measured 32 cm (12.6 in) carapace length.

The water temperature in the OCNGS intake canal at the time of the impingement was 11.1^{0}C (51^{0}F). Because of concerns that the turtle may be subject to cold stunning if released into New Jersey coastal waters, MMSC personnel made arrangements for the turtle to be transported to North Carolina prior to being released to ensure that cold stunning would not occur. The turtle was tagged and released on October 31, 1992 at Kure Beach, North Carolina.

6.1.1.4 INCIDENTAL CAPTURE OF OCTOBER 17, 1993

OCNGS Operations department personnel conducting a routine morning (approx. 12 noon) inspection of the dilution water system intake

on October 17, 1993 noticed a sea turtle impinged against the trash bars. The turtle was found to be limp, immobile and with no apparent breathing when retrieved. OCNGS Environmental Affairs personnel who examined the turtle identified it as a juvenile Kemp's ridley. No tags, prominent scars or slash-like propeller wounds were apparent on the turtle. Minor scrape marks which were observed on the plastron may have occurred during removal of the turtle from the dilution intake area. The turtle measured 26 cm (10.25 in) carapace length.

The water temperature in the intake canal at the time of the impingement was approximately 14.4^{0}C (58^{0}F). Although it was impossible to say precisely how long the turtle had been on the intake structure prior to removal, it may have been between four and eight hours. Within three to four hours after its capture, the turtle was placed in a freezer for temporary storage at an on-site OCNGS biological laboratory. At the suggestion of the National Marine Fisheries Service, arrangements were made to have a necropsy of the turtle performed by sea turtle expert Dr. Steven Morreale of Cornell University and his associates at the New York State College of Veterinary Medicine. The following is an excerpt from Dr. Morreale's necropsy:

> "... The overall condition of this turtle was one of an otherwise healthy young Kemp's ridley, typical of the many that I have examined in northeastern waters. The lack of food in the gut is typical of the sea turtles that I have seen at this time of year and is indicative of a behavioral change prior to migrating southward. The lack of any obvious trauma would tend to implicate drowning as the cause of death to this animal. The lack of fluid in the lungs is not necessarily contradictory to this conclusion. It is my opinion that sea turtles suffocate underwater rather than inhaling water. The superficial scrapes on the plastron and neck were very fresh and probably occurred on the intake (trash racks). However, I could not tell whether these occurred prior to or after death. The only potentially contradictory evidence of this turtle having died as a result of impingement, was the condition of the specimen. From the information given to me about the timing of death, the water temperature, and the subsequent handling of the carcass, I expected to observe slightly less decomposition. The moderate levels of decomposition of liver and gonad tissues are usually more representative of a turtle that has been dead for one to two days at those temperatures."

6.1.1.5 INCIDENTAL CAPTURE OF JUNE 19, 1994

During the early afternoon (approx. 1:30 PM) of June 19, 1994, OCNGS Operations personnel conducting a routine inspection of the circulating water system intake area observed a sea turtle in the #4 CWS intake bay (CWS and DWS intake bays are sequentially numbered from 1 through 6, north to south). The turtle was swimming freely a few feet upstream of the face of the CWS intake trash bars. The turtle was removed carefully and as quickly as possible and found to be active, healthy and with no apparent wounds. OCNGS Environmental Affairs department personnel identified it as a juvenile loggerhead turtle and immediately notified the Marine Mammal Stranding Center of the capture. The turtle measured 36.8 cm (14.5 in) carapace length.

Although it was impossible to determine precisely how long the turtle had been near the intake structure prior to retrieval, it is believed to have been in the vicinity for a relatively short period of time. Within three to four hours of the time of its capture, the turtle was taken to MMSC. Personnel at MMSC examined and tagged it, and subsequently released it offshore of Brigantine, NJ.

6.1.1.6 INCIDENTAL CAPTURE OF JULY 1, 1994

During a routine mid-morning (approx. 10:00 AM) cleaning of the dilution water system intake trash bars on July 1, 1994, a dead sea turtle was retrieved from the trash bars in front of DWS bay #5. The turtle was removed as quickly as possible by OCNGS Operations personnel. It was found to be inactive and exhibited a strong odor of decomposition. Environmental Affairs personnel identified it as a juvenile Kemp's ridley turtle and tried unsuccessfully to resuscitate it. The turtle measured 27.7 cm (10.9 in) carapace length.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it is known that the intake bay in which the turtle was found had been cleaned during the previous afternoon. No prominent scars or slash-like propeller wounds were apparent on the turtle. The turtle has been sent to marine turtle experts at the Center for the Environment, Cornell University, who will perform a thorough necropsy. As of this writing, the results of the necropsy are not yet available.

6.1.1.7 INCIDENTAL CAPTURE OF JULY 6, 1994

At approximately 6:15 AM on July 6, 1994, OCNGS Operations personnel conducting routine cleaning of the dilution water system intake area removed a sea turtle from the DWS trash bars in bay #4. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a subadult loggerhead (carapace length 61.4 cm or 24.5 in) and tried unsuccessfully to resuscitate it. Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, the trash bars at the DWS intake had previously been cleaned 6-8 hours earlier.

At least three deep scars or slash-like propeller wounds were apparent on the turtle. These scars were not fresh because blue mussels were attached and growing within the scars.

Several hours after its capture, the turtle was taken to the Marine Mammal Stranding Center (MMSC) in Brigantine, NJ. MMSC Director Robert Schoelkopf performed a necropsy of the carcass. Mr. Schoelkopf reported that the turtle did not die at the intake nor did it suffocate. The lungs were found to be in good condition. The turtle was believed to have died one to two days prior to arriving at OCNGS, probably due to a long term illness. Decomposition of all four appendages, as well as a large notch along the turtle's marginal scutes, were attributed by Schoelkopf to bacterial or fungal infections.

6.1.1.8 INCIDENTAL CAPTURE OF JULY 12, 1994

At approximately 10:40 PM on July 12, 1994, OCNGS Operations personnel conducting routine cleaning of the dilution water system intakes removed a sea turtle from the trash bars at bay #4. The turtle was found to be inactive, but had no apparent wounds. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a juvenile Kemp's ridley turtle (26.7 cm or 10.5 in carapace length) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle.

This turtle was sent to marine turtle experts at the Center for the Environment, Cornell University, who performed a thorough necropsy.

6.1.1.9 INCIDENTAL CAPTURE OF SEPTEMBER 4, 1997

During the early morning (approx. 3:00 AM) of September 4, 1997,

Operations personnel conducting routine cleaning of the dilution water system intakes noticed a sea turtle among the eelgrass on the trash bars at bay #6 of the DWS. The turtle, which was carefully removed as quickly as possible, was limp, immobile and had no apparent breathing. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a subadult Kemp's ridley turtle (48.8 cm or 19 in carapace length) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle. Damage to two dorsal scutes, which may have occurred either during removal of the turtle from the DWS or prior to its capture, was noted. Because this turtle was collected immediately after the Labor Day weekend, which is one of the periods of busiest Barnegat Bay boat traffic, the damage to the turtle may have resulted from a collision with a boat.

6.1.1.10 INCIDENTAL CAPTURE OF AUGUST 18, 1998

During the morning(approx. 10:00 AM) of August 18, 1998, OCNGS Operations personnel conducting a routine inspection of the circulating water system intake area observed a sea turtle in the #4 CWS intake bay. The turtle was swimming freely a few feet upstream of the face of the CWS intake trash bars. The turtle was removed carefully and as quickly as possible using a sea turtle dipnet and found to be alive and moving about actively. However, a twelve foot length of 1/4" polypropylene rope with a bucket attached to one end was tightly wrapped around the base of the right front flipper of the turtle, causing restricted circulation and movement of that limb. It was apparent from the atrophied and partially decayed condition of the right front flipper that the turtle had been injured by becoming entangled in the rope long before its incidental capture. OCNGS Environmental Affairs department personnel identified it as a subadult loggerhead turtle and notified the Marine Mammal Stranding Center of the capture.

The water temperature at the time of the incidental capture was 80.5^0 F (26.9 ^{0} C) and OCNGS was in operation at full power with four circulating water pumps and two dilution pumps in operation. The turtle measured 50.8 cm (20.0 in) carapace length and weighed 53.9 lb (24.4 kg).

After the turtle was examined by Environmental Affairs personnel,

it was transferred to the Marine Mammal Stranding Center (MMSC) in Brigantine, NJ. MMSC personnel attempted to locate a facility where the turtle could receive appropriate medical treatment and rehabilitation prior to releasing it. The turtle was transported to Sea World in Orlando, FL, which provided specialized surgery and rehabilitation and eventually released the turtle in the ocean.

6.1.1.11 INCIDENTAL CAPTURE OF SEPTEMBER 23, 1999

During an early morning routine inspection of the CWS intake, an OCNGS Operations department representative noticed a live sea turtle impinged against the trash bars. The turtle was initially found at about 3:00 AM. The turtle was carefully retrieved as quickly as possible and found to be in good condition. Environmental Affairs department personnel who took custody of the turtle identified it as a subadult Kemp's ridley and made arrangements for its immediate transfer to the MMSC. The turtle measured 26.4 cm (10.3 in) carapace length and weighed 2.9 kg (6.3 lb).

The water temperature at the time of the capture was approximately 67.2^{0}F (19.6^{0}C) and OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating.

After the turtle was examined by Environmental Affairs personnel, it was transferred to the Marine Mammal Stranding Center (MMSC) in Brigantine, NJ. MMSC personnel attempted to locate a facility in a warmer climate where the turtle could be transferred for eventual release in the ocean. The turtle was transported to the Virginia State Aquarium, which tagged and eventually released the turtle in the ocean off of Virginia Beach, VA.

6.1.1.12 INCIDENTAL CAPTURE OF OCTOBER 23, 1999

During an early morning routine inspection of the DWS intake, an OCNGS Operations department representative noticed a sea turtle among materials removed from the trash bars in DWS Bay #4. The turtle was initially found to be either dead or comatose at about 2:00 AM. Attempts were made to resuscitate the turtle for several hours after the incidental capture, but the attempts were unsuccessful. Environmental Affairs department personnel who took custody of the turtle identified it as a juvenile Atlantic green sea turtle (Chelonia mydas). The turtle measured 27.0 cm (10.6 in) carapace length and weighed 2.8 kg (6.1 lb).

The water temperature at the time of the capture was approximately

62.8°F (17.1°C) and OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating. Although it was impossible to say precisely how long the turtle had been near the intake structure prior to removal, the intake trash bars had been mechanically cleaned the previous day.

The cause of death was not immediately apparent. There were no obvious boat propeller wounds and no open wounds that would have been life threatening. After the turtle was examined by Environmental Affairs personnel, arrangements were made for it to be examined further by Dr. Steven Morreale, a Cornell University sea turtle expert who has conducted numerous necropsies on sea turtles in the past.

6.1.1.13 INCIDENTAL CAPTURE OF JUNE 23, 2000

During an early morning routine inspection of the DWS intake, an OCNGS Operations department representative noticed a sea turtle in front of the trash bars in DWS Bay #1. The turtle was carefully dipnetted from the trash bars and found to be very active and with no visible wounds or signs of injury. OCNGS Environmental Affairs personnel who took custody of the turtle confirmed it to be a juvenile loggerhead. The turtle measured 47.8m cm (18.8 in) carapace length and weighed approximately 17.2 kg (38 lb). The water temperature at the time of the incidental capture was approximately 77.5°F (25.3°C) and OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating.

After the turtle was examined by Environmental Affairs personnel, arrangements were made for it to be transferred to the Marine Mammal Stranding Center (MMSC). At the MMSC, the turtle was examined, fed and eventually released to safety in the Atlantic Ocean off Brigantine, NJ.

6.1.1.14 INCIDENTAL CAPTURE OF JULY 2, 2000

During the afternoon (approx. 3:00 PM) of July 2, 2000, Operations personnel conducting routine cleaning of the dilution water system intakes noticed a sea turtle approach the trash bars at bay #1 of the DWS. The turtle, which was carefully removed as quickly as possible, was limp, immobile and had no apparent breathing. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a juvenile Kemp's ridley turtle (27.3 cm or 10.8 in carapace length) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle

had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle. Minor scrapes to two dorsal scutes, which may have occurred either during removal of the turtle from the DWS or prior to its capture, were noted. Because this turtle was collected during the Independence Day weekend, which is one of the periods of busiest Barnegat Bay boat traffic, the damage to the turtle may have resulted from a collision with a boat.

6.1.2 ANNUAL COMPARISON

During any particular year the number of sea turtles collected at the Oyster Creek CWS and DWS intakes ranged from zero (in all years from 1970 to 1991, as well as 1995 and 1996) to four during 1994 (Table 6-2). The actual number of loggerheads incidentally captured on the intake ranged between zero and two animals annually. The actual number of Kemp's ridleys incidentally captured on the intake ranged between zero and two animals annually. The actual number of Atlantic green sea turtles incidentally captured on the intake ranged between zero and one animal annually.

Given the very small number of sea turtles captured at OCNGS and the fact that they have only occurred during some of the years between 1992 and 2000, it is difficult to predict how many may be captured in the future. However, based on the levels of incidental capture observed at the intake to date, it is estimated that zero to three loggerheads, zero to three Kemp's ridleys and zero to one Atlantic green sea turtles could be expected to be taken from the OCNGS intake during any given year.

6.1.3 SPECIES COMPOSITION

Six loggerhead sea turtles (*Caretta caretta*), seven Kemp's ridleys (*Lepidochelys kempii*) and one Atlantic green sea turtle (*Chelonia mydas*) have been captured at the circulating and dilution water intakes between 1992 and 2000.

The loggerheads were all juveniles or subadults. Carapace lengths (straight length) ranged from 35.5 to 61.4 cm (14 to 24 in) with a mean of 46.5 cm (18.3 in) (Figure 6-1). The ridleys were also juveniles or subadults. Their carapace lengths (straight length) ranged from 26 to 48.8 cm (10 to 19.2 in) with a mean of 30.7 cm (12.1 in) (Figure 6-1). The only Atlantic green sea turtle captured was a juvenile which measured 27 cm (10.6 in) carapace

6.1.4 SEASONAL DISTRIBUTION OF OCCURRENCES

Three out of fourteen sea turtle strandings at the OCNGS were reported during June, four during July, one during August, three during September, and three during October. No turtles were collected during the winter months (Table 6-3).

The timing of sea turtle occurrences at OCNGS corresponds well with the available information on the seasonal movements of these animals. Based on aerial surveys of pelagic turtles (Shoop et al. 1981), sea turtles, loggerheads in particular, migrate up the coast from the southeast in the spring and summer months. They move into the bays and coastal waters as water temperatures reach suitable levels and forage on crabs and other preferred foods (Keinath et al. 1987; Morreale and Standora 1989). As the temperatures of the bays and coastal waters start to decline, these animals move southward to the warmer water of the southeast Atlantic Coast. Recapture information from tagged animals provides evidence for such movements in loggerheads and ridleys (Shoop et al. 1981; Henwood 1987; PSE&G 1989).

6.1.5 CONDITION OF TURTLES CAPTURED AT INTAKE STRUCTURES

Of the fourteen turtles captured at the OCNGS intakes, eight were dead and six were alive and subsequently released (Tables 6-1 and 6-2).

The two dead loggerheads captured in 1994 both had boat propeller wounds and were partially decomposed when impinged at the dilution water system intake structure at OCNGS. One of the live loggerheads taken at OCNGS, a juvenile, was removed alive from the CWS intake and released in good condition on September 9, 1992. The same individual was subsequently recaptured at the CWS intake on September 11, 1992, delivered to the Marine Mammal Stranding Center where it was examined, found to be healthy and released into the Atlantic Ocean. Another live loggerhead juvenile was removed from the CWS intake in good condition on June 19, 1994, delivered to the Marine Mammal Stranding Center, and also subsequently released into the ocean. Two additional live loggerheads which were captured in August 1998 and June 2000 were subsequently released into the ocean in Florida and New Jersey, respectively.

One of the Kemp's ridleys was alive when captured in October 1992 and was successfully transported and released into the Atlantic Ocean in North Carolina by the Marine Mammal Stranding Center after observing its behavior for several days. An additional live Kemp's ridley was captured in September 1999 and was eventually released into the Atlantic Ocean in Virginia. The five dead ridleys, all juveniles, appeared to be fresh dead. The specimens were sent to Dr. Steven Morreale of the Center for the Environment, Cornell University, to perform necropsies on them. Dr. Morreale reported that the most likely cause of death of the Kemp's ridley captured on October 17, 1993 was drowning at the OCNGS DWS intake (see Section 6.1.1.4). Similarly, the cause of death of the other Kemp's ridleys remains uncertain but may be attributable to drowning.

The only green sea turtle captured at OCNGS was dead when captured in October 1999. It appeared fresh when captured. Its cause of death is uncertain pending completion of its necropsy, but may be attributable to drowning or natural causes.

Information collected at Salem Generating Station has shown that both anthropogenic and natural causes of death contribute to sea turtle mortalities in local estuaries (PSE&G 1989). Furthermore, based on other necropsy information available from the Marine Mammal Stranding Center, boat-related injuries appear to be common occurrences in both stranded loggerheads and ridleys in Delaware Bay and coastal New Jersey (Schoelkopf 1994). This is consistent with NMFS findings which show boat-related injuries as a common carcass anomaly (NMFS 1988).

TABLE 6-1. OYSTER CREEK NUCLEAR GENERATING STATION SEA TURTLE INCIDENTAL CAPTURES

DATE OF COLLECTION	TIME OF CAPTURE	SPECIES AND LIFE STAGE	CARAPACE LENGTH (cm) & WEIGHT (kg)	CAPTURED AT CWS OR DWS/# PUMPS OPERATING	INTAKE TEMP. deg. F (deg C)	ALIVE WHEN CAPTURED?	FRESH DEAD?	BOAT PROP WOUNDS?	RELEASE SITE
6/25/92	10:00 PM	Loggerhead juvenile	35.5 cm/9.6 kg	DWS/2 pumps	70.8 F(21.6 C)	No	No	Yes	N/A
9/9/92	6:00 PM	Loggerhead juvenile	46.7 cm/19.1 kg	CWS/4 pumps	78.2 F(25.6 C)	Yes	N/A	No	NJ
9/11/92*	2:00 PM	Loggerhead juvenile	46.7 cm/19.1 kg	CWS/4 pumps	79.2 F(26.2 C)	Yes	N/A	No	NJ
10/26/92	3:00 AM	Kemp's ridley subadult	32.0 cm/5.7 kg	CWS/4 pumps	52.4 F(11.3 C)	Yes	N/A	No	NC
10/17/93	12:00 Noon	Kemp's ridley juvenile	26.0 cm/3.0 kg	CWS/4 pumps	62.0 F(16.7 C)	No	Yes	No	N/A
6/19/94	1:30 PM	Loggerhead juvenile	36.8 cm/9.8 kg	CWS/4 pumps	81.1 F(27.3 C)	Yes	N/A	No	NJ
7/1/94	10:00 AM	Kemp's ridley juvenile	27.7 cm/3.6 kg	DWS/2 pumps	78.3 F(25.7 C)	No	Yes	No	N/A
7/6/94	6:40 AM	Loggerhead subadult	61.4 cm/40.4 kg	DWS/2 pumps	80.5 F(26.9 C)	No	No	Yes	N/A
7/12/94	10:40 PM	Kemp's ridley juvenile	26.7 cm/3.3 kg	DWS/2 pumps	83.2 F(28.4 C)	No	Yes	No	N/A
9/4/97	3:18 AM	Kemp's ridley subadult	48.8 cm/18.1 kg	DWS/2 pumps	73.2 F(22.9 C)	No	Yes	No	N/A
8/18/98	9:59 AM	Loggerhead subadult	50.8 cm/22.4 kg	CWS/4 pumps	80.5 F(26.9 C)	Yes	N/A	No	FL
9/23/99	3:10 AM	Kemp's ridley subadult	26.4 cm/2.9 kg	DWS/2 pumps	67.2 F(19.6 C)	Yes	N/A	No	VA
10/23/99	2:00 AM	Green sea turtle juvenile	27.0 cm/2.8 kg	DWS/2 pumps	62.8 F(17.1 C)	No	**	No	N/A
6/23/00	1:00 AM	Loggerhead juvenile	47.8 cm/17.2 kg	DWS/2 pumps	77.5 F(25.3 C)	Yes	N/A	No	NJ
7/2/00	3:00 PM	Kemp's ridley juvenile	27.3 cm/3.2 kg	DWS/2 pumps	78.1F(25.6C)	No	**	No	N/A

NOTE: No sea turtles were captured during the first 22 full years of OCNGS operation, 1970-1991.

* Loggerhead captured on 9/11/92 was the same turtle that was captured on 9/9/92.

** To be determined by necropsy.

TABLE 6-2

MORTALITY OF SEA TURTLES CAPTURED FROM INTAKE TRASH BARS AT OYSTER CREEK NUCLEAR GENERATING STATION (LIVE/DEAD)

YEAR	LOGGERHEAD	KEMP'S RIDLEY	GREEN	TOTALS
1969	0/0	0/0	0/0	0/0
1970	0/0	0/0	0/0	0/0
1971	0/0	0/0	0/0	0/0
1972	0/0	0/0	0/0	0/0
1973	0/0	0/0	0/0	0/0
1974	0/0	0/0	0/0	0/0
1975	0/0	0/0	0/0	0/0
1976	0/0	0/0	0/0	0/0
1977	0/0	0/0	0/0	0/0
1978	0/0	0/0	0/0	0/0
1979	0/0	0/0	0/0	0/0
1980	0/0	0/0	0/0	0/0
1981	0/0	0/0	0/0	0/0
1982	0/0	0/0	0/0	0/0
1983	0/0	0/0	0/0	0/0
1984	0/0	0/0	0/0	0/0
1985	0/0	0/0	0/0	0/0
1986	0/0	0/0	0/0	0/0
1987	0/0	0/0	0/0	0/0
1988	0/0	0/0	0/0	0/0
1989	0/0	0/0	0/0	0/0
1990	0/0	0/0	0/0	0/0
1991	0/0	0/0	0/0	0/0
1992	1/1	1/0	0/0	2/1
1993	0/0	0/1	0/0	0/1
1994	1/1	0/2	0/0	1/3
1995	0/0	0/0	0/0	0/0
1996	0/0	0/0	0/0	0/0
1997	0/0	0/0	0/1	0/1
1998	1/0	0/0	0/0	1/0
1999	0/0	1/0	0/1	1/1
2000	1/0	0/1	0/0	1/1
TOTALS	4/2	2/5	0/1	6/8

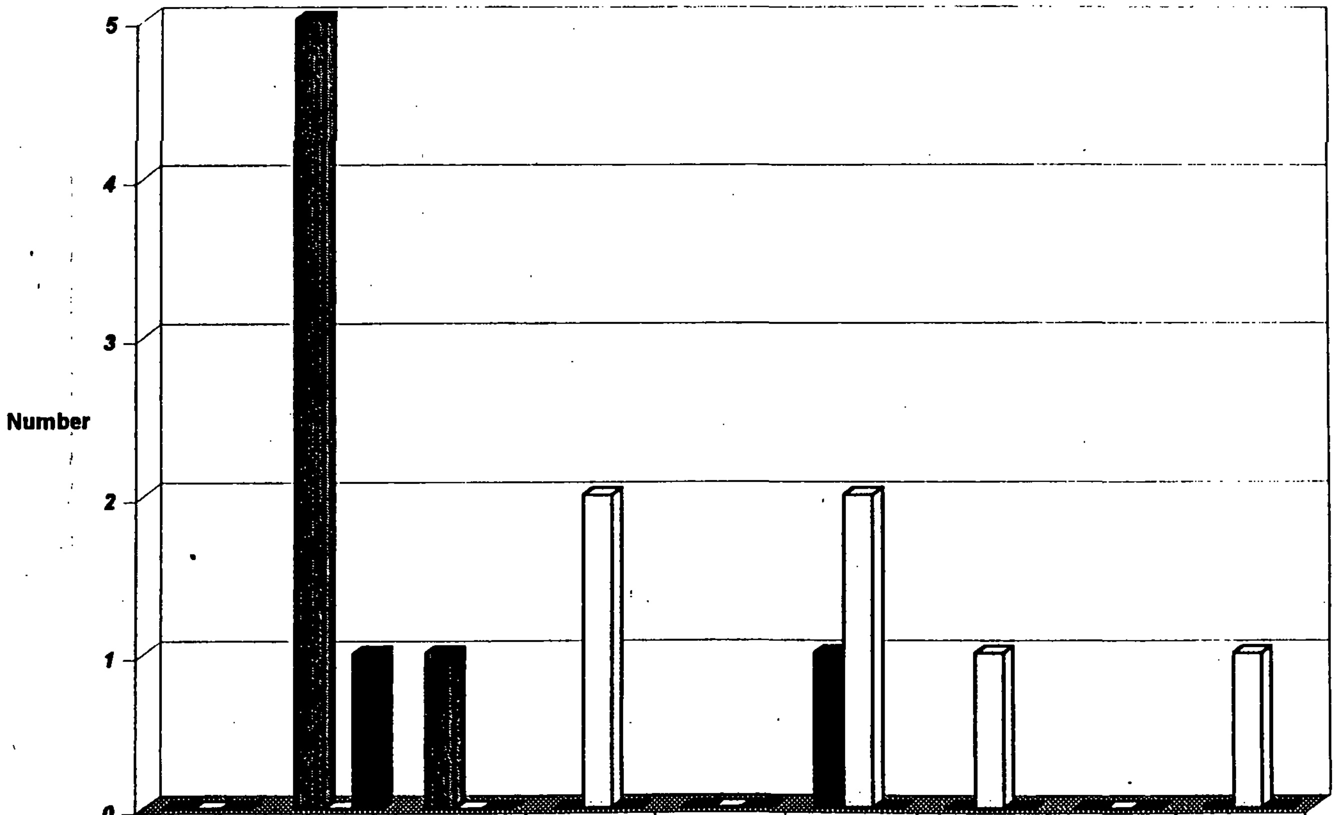
TABLE 6-3

SEASONAL OCCURRENCE OF SEA TURTLES AT OYSTER CREEK NUCLEAR GENERATING STATION INTAKES

MONTHLY DISTRIBUTION

MONTH	LOGGERHEAD	KEMP'S RIDLEY	GREEN	TOTALS
JAN	0	0	0	0
FEB	0	0	0	0
MAR	0	0	0	0
APR	0	0	0	0
MAY	0	0	0	0
JUN	3	0	0	3
JUL	1	3	0	4
AUG	1	0	0	1
SEP	1	2	0	3
OCT	0	2	1	3
NOV	0	0	0	0
DEC	0	0	0	0
TOTALS	6	7	1	14

SEA TURTLE LENGTH FREQUENCY DISTRIBUTION
Standard carapace length (cm)



	21-25 cm	26-30 cm	31-35 cm	36-40 cm	41-45 cm	46-50 cm	51-55 cm	56-60 cm	61-65 cm
■ *L. kempii*	0	5	1	0	0	1	0	0	0
□ *C. caretta*	0	0	0	2	0	2	1	0	1
■ *C. mydas*	0	1	0	0	0	0	0	0	0

Figure 6-1. Frequency Distribution of Carapace Lengths for Kemp's Ridley, Loggerhead and Green Sea Turtles Captured from Intake Structures at OCNGS.

SECTION 7.0
ASSESSMENT OF PRESENT OPERATIONS

The primary concern with sea turtles at OCNGS is whether or not any station related losses of these endangered or threatened sea turtle species "jeopardizes their continued existence." Federal regulation (50 CFR 402) defines "jeopardizes the continued existence" as "engaging in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of that species." Therefore, the question relative to OCNGS is: Do the activities associated with the operation of Oyster Creek Nuclear Generating Station "appreciably reduce" the reproduction, numbers or distribution of either the loggerhead, Kemp's ridley or Atlantic green sea turtles?

7.1 IMPACTS OF CONTINUED OPERATION OF OYSTER CREEK NUCLEAR GENERATING STATION ON SEA TURTLE POPULATIONS

7.1.1 IMPACTS DUE TO INCIDENTAL CAPTURE (IMPINGEMENT) OF TURTLES ON CWS AND DWS INTAKE TRASH RACKS

Fourteen sea turtles have been retrieved from either the circulating water or dilution water system intake at OCNGS during the period 1992 through 2000. Six of these turtles were alive and returned to the Atlantic Ocean by Marine Mammal Stranding Center (MMSC) personnel. Typically the live sea turtles were released near the MMSC in Brigantine, New Jersey. However, one Kemp's ridley was transported by MMSC personnel to warmer Atlantic Ocean waters for release near Kure Beach, North Carolina due to the cold and falling ocean water temperatures in New Jersey at the time. Additionally, a live loggerhead retrieved from the CWS intake in 1998 and a live Kemp's ridley retrieved from the DSW intake in 1999 were transported to Florida and Virginia, respectively for release.

Eight of the turtles removed from the intake were dead. Of these, two loggerheads exhibited severe boat prop wounds and were moderately decomposed indicating that death occurred prior to encountering the intake. The intake trash bars routinely capture floating debris during normal operation; dead and injured turtles which wash ashore, buoyed by the gases of decomposition, would be expected to be part of the debris load in the intake canal removed by the station. One of the dead sea turtles was a juvenile green sea turtle captured during late October 1999. The remaining five sea turtles found dead at the OCNGS intake structures were all Kemp's ridleys. The most likely cause of death of one of these individuals was determined by necropsy to be drowning at the DWS intake. The deaths of the other impinged turtles may also be attributable to drowning at either the DWS or CWS intake, although

death could also be due to natural causes such as cold shock resulting from rapid seasonal water temperature changes of offshore or estuarine waters. Therefore, it is apparent that there have been only six or less dead turtles removed from the intake since the plant began operation in 1969 whose cause of death may have been attributable to OCNGS operations.

Based on these levels of incidental capture at the intake, it is estimated that zero to three loggerheads, zero to three Kemp's ridleys and zero to one green sea turtle would be expected to be taken from the intake during any given year.

7.1.1.1 ASSESSMENT OF IMPACT ON LOGGERHEAD SEA TURTLE POPULATIONS

The annual number of loggerheads incidentally captured at OCNGS has ranged from zero to two turtles. Four of the six loggerheads captured were alive and released back into the wild. The two dead loggerheads taken were moderately decomposed when collected, suggesting death prior to involvement with the station. Carapace wounds suggested that the damage from boat propellers caused the death of one of these loggerheads, and the effects of a variety of diseases had resulted in the death of the other. Therefore, if live and long dead animals are removed from the assessment of impact, the OCNGS has had no impact on loggerhead sea turtle populations to date.

Adult and subadult loggerhead sea turtle populations have been recently estimated to be approximately 387,000 in the southeast United States (see Section 5.0). The estimated number of mature females in this same area has been estimated to range between 35,000 and 72,000 turtles. (Gordon 1983; Hopkins and Richardson 1984; NMFS 1987).

In order to determine if any future losses attributable to OCNGS "appreciably reduce" the reproduction, numbers or distribution of loggerheads, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species.

Although three loggerhead nests were reported from New Jersey in the 1980's and 1990's (Schoelkopf 1994), loggerhead nesting in the United States primarily occurs along coastal beaches in Florida, Georgia, South Carolina and North Carolina. Also, all loggerheads incidentally captured at the CWS and DWS intakes were juveniles or subadults too young to reproduce which are more prevalent along the mid-Atlantic coast than adults (Van Buskirk and Crowder, 1994).

Therefore, based on the immaturity of the specimens captured and the fact that loggerhead nesting does not typically occur in New Jersey, the only loss to loggerhead reproduction would be from production foregone due to the loss of juvenile/subadult animals on the intake which could potentially be recruited into the breeding female population at some time in the future.

The observed worst case incidental catch level for loggerheads at OCNGS has been two turtles during any given year, with no mortality attributable to the OCNGS. However, for the purposes of this assessment we will assume that three deaths per year is a worst case estimate of loggerhead mortality associated with the OCNGS.

If we compare this with the estimated population size of 387,000 animals, this mortality would represent 0.0008 percent of the population in the southeast U.S. It should be kept in mind that the population estimate on which this percentage is based does not include juveniles or subadults in the region or populations from areas other than the U.S. This means that the population size is probably underestimated and the worst case estimate of losses attributable to OCNGS is overestimated. Mortality at this level will not "appreciably reduce" the distribution or numbers of loggerhead sea turtles along the Atlantic Coast of the United States.

7.1.1.2 ASSESSMENT OF IMPACT ON KEMP'S RIDLEY SEA TURTLE POPULATIONS

The number of Kemp's ridleys incidentally captured at OCNGS has been one each year during 1992, 1993, 1997, 1999 and 2000, and two during 1994. Two of the ridleys captured were alive and were successfully released back into the wild. The Kemp's ridleys found dead at the OCNGS appeared to be fresh dead. The observed worst case incidental catch level was in 1994 when two dead Kemp's ridleys were taken at the DWS intake.

In order to determine if OCNGS "appreciably reduces" the reproduction, numbers or distribution of ridley sea turtles, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species. The adult Kemp's ridley sea turtle population has recently been estimated to be approximately 2,200 turtles based on breeding females observed in Mexico (see Section 5.0). Since this breeding colony is the only known colony in the world, this estimate apparently represents the worldwide breeding population for Kemp's ridleys. All specimens captured at OCNGS were juveniles or subadults not yet capable of reproducing (Van Buskirk and Crowder, 1994). Therefore, based on the immaturity of the specimens captured and the fact that ridley nesting does not occur in New Jersey, the only loss to ridley reproduction would be from production foregone due to the mortality of juvenile/subadult animals on the intake which could potentially be recruited into the breeding female population at some time in the future.

If we assume a worst case incidental mortality rate at OCNGS of three Kemp's ridley sea turtles during any given year and compare it with the estimated population size of 2,200, they would represent 0.14 percent of the population. This population estimate does not include juveniles and subadults and therefore underestimates the actual population size. It is unlikely that losses at this level would "appreciably reduce" the distribution or numbers of Kemp's ridley sea turtles along the Atlantic Coast of

the United States.

7.1.1.3 ASSESSMENT OF IMPACT ON ATLANTIC GREEN SEA TURTLE POPULATIONS

The only incidental capture of an Atlantic green turtle at OCNGS occurred during October 1999. The specimen captured was a juvenile which was found dead at OCNGS and appeared to be fresh dead. Although it has been sent to Cornell University in order for a necropsy to be performed on it, the results of the necropsy are not yet available.

In order to determine if OCNGS "appreciably reduces" the reproduction, numbers or distribution of Atlantic green sea turtles, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species. Although the green turtle occurs worldwide in tropical and semitropical waters, they are found in U.S. Atlantic waters around the Virgin Islands, Puerto Rico, and continental United States from Texas to Massachusetts (NMFS and USFWS, 1991b). In U.S. Atlantic waters, green turtles nest in small numbers in the United States Virgin Islands and Puerto Rico, and in larger numbers along the east coast of Florida. As many as 477 Atlantic green turtle nests per year have been documented to occur along a 21 km stretch of beach in Melbourne Beach, Florida. The Florida Department of Natural Resources (FDNR) has found up to 2288 clutches of Atlantic green turtle eggs per year in nests on Florida beaches (FDNR, unpubl. data). However, more information is needed before detailed maps or estimates of population number and structure can be made for green turtle populations in U.S. territorial waters (NMFS and USFWS, 1991b).

Based on the immaturity of the lone Atlantic green turtle specimen captured at OCNGS and the fact that nesting of Atlantic green turtles is not known to occur as far north as New Jersey, the only loss to green turtle reproduction would be from production foregone due to the mortality of juvenile/subadult animals on the intake which could potentially be recruited into the breeding female population at some time in the future.

If we assume a worst case incidental mortality rate at OCNGS of one Atlantic green sea turtle during any given year and compare it with the estimated population size of several thousand, they would represent only a very small fraction of one percent of the population. It is unlikely that losses at this level would "appreciably reduce" the distribution or numbers of Atlantic green sea turtles along the Atlantic Coast of the United States.

7.2 OTHER POTENTIAL STATION IMPACTS ON SEA TURTLES

7.2.1 ACUTE THERMAL EFFECTS

The discharges from the circulating water and dilution water systems of OCNGS are located 45 and 105 m (150 and 450 ft) west of the reactor building, respectively (Figure 4-2). As discussed in

Section 4.0, the temperature rise of the CWS discharge is typically about 11°C (20°F) above ambient intake canal temperatures. Because of the relatively high discharge velocities (65-95 cm/sec; 2.1-3.1 ft/sec), a sea turtle is not likely to remain in the immediate vicinity of the condenser discharge for any length of time. Furthermore, turtles in the area would easily be able to avoid entrainment in the thermal discharge flow by swimming away. Downstream of the condenser discharge, complete mixing with ambient temperature water from the DWS occurs, reducing the discharge canal water temperatures by approximately 5.6°C (10°F) when two dilution pumps are operating. The resulting water temperature of approximately 5.6°C (10°F) above ambient should not be stressful for any sea turtle species. Therefore, it is concluded that no adverse acute thermally-related impacts will be sustained by any of the sea turtle species.

7.2.2 CHRONIC THERMAL EFFECTS

The thermal discharge from Oyster Creek Nuclear Generating Station will not adversely impact the reproduction or migratory behavior of sea turtles inhabiting Barnegat Bay or coastal oceanic waters in the vicinity of OCNGS.

Because the vast majority of reproduction occurs in the southeastern United States in the case of the loggerhead and Mexico in the case of the Kemp's ridley, no reproductive impacts are expected.

The New Jersey Department of Environmental Protection evaluation of the impact of the OCNGS thermal plume on Barnegat Bay concluded that the effects on fish distribution and abundance were small and localized with few or no regional consequences (Summers et al. 1989). Similarly, due to the shallow nature of the plume, the relatively small area affected, and the small temperature increases within Barnegat Bay, the movements of sea turtles in the bay should not be adversely impacted. The areal extent of the thermal plume, as measured by the 1.1°C excess temperature isotherm, depends upon prevailing wind conditions and tidal stage but has been estimated to be less than 1.6 km (5,300 ft) in an east-west direction by 5.6 km (18,500 ft) in a north-south direction, under all conditions (Starosta et al. 1979, JCP&L 1986). More importantly, as discussed in Section 4.1.3, outside of the immediate vicinity of the mouth of Oyster Creek, the plume is primarily a surface phenomenon. As such, it is easily avoidable by sea turtles which move freely about in the water column, spending a large portion of their time foraging on the bottom.

7.2.3 COLD SHOCK

Cold shock mortalities of fishes have occurred at the OCNGS in the past. These events occurred when migratory species, attracted to the heated condenser discharge, remained in the discharge canal after they would normally have migrated out of Barnegat Bay in response to falling autumn water temperatures. Subsequent station outages, after ambient water temperatures had fallen below 10°C

(50^{0}F), resulted in cold-shock fishkills. The number and severity of these events has been reduced as a result of the operation of two dilution pumps in the fall, when ambient water temperatures began to drop, to decrease the attractiveness of the discharge canal as overwintering habitat (Summers et al. 1989).

Cold-shock mortality of sea turtles has not been observed and is not expected to occur at the OCNGS for a number of reasons. The area where sea turtles could overwinter is extremely limited, including only the immediate vicinity of the condenser discharge, prior to any mixing with the DWS flow. Winter water temperatures in the discharge canal, downstream of the area where CWS and DWS flows mix, routinely fall below 7.2^{0}C (45^{0}F).

The small area where winter water temperatures would be suitable for overwintering sea turtles is characterized by a relatively high discharge velocity of 65-95 cm/sec (2.1-3.1 ft/sec). This would require continuous swimming activity, 24 hours per day, in order for a sea turtle to maintain its position in the heated discharge flow.

Food availability in the potential overwintering area would be extremely limited and probably insufficient to support the amount of swimming activity required to maintain a turtle in the heated discharge flow throughout the winter. Their preferred food, blue crabs and horseshoe crabs, would not be found in this area during the winter months. In addition, the canal bottom has a very hard substrate in the vicinity of the condenser discharge, and does not support a wide variety of benthic organisms that might serve as sea turtle forage.

7.2.4 BIOCIDES

Low level, intermittent chlorination is used to control biofouling in the OCNGS service water system and circulating water systems. New Jersey Pollutant Discharge Elimination System (NJPDES) permit conditions limit chlorine discharge levels to a maximum daily concentration of 0.2 mg/l or a maximum daily chlorine usage of 41.7 kg/day. The main condenser cooling water is chlorinated for approximately 2 hours per day. The chlorine demand in the main condenser discharge consumes almost all remaining free chlorine and results in essentially no chlorine being released to the discharge canal.

Given the very small quantities of chlorine applied, the short duration of the application periods, the fact that residual chlorine levels in the condenser discharge are at or near zero, and the fact that the condenser discharge is combined with unchlorinated DWS flow, the use of this biocide will not have any impact on sea turtles that may occur in the discharge canal or Barnegat Bay.

7.3 MITIGATING MEASURES

In order to minimize the potential impact of station operations on threatened or endangered sea turtles, a variety of mitigating

measures have been instituted at OCNGS. These measures include all of the "reasonable and prudent measures necessary to minimize the impact on listed species" specified in the Incidental Take Statement dated September 21, 1995, and are described in this section.

7.3.1 SEA TURTLE SURVEILLANCE AND HANDLING

The surveillance and handling requirements necessary to minimize the impact of OCNGS operations on sea turtles are defined in the Sea Turtle Surveillance, Handling, and Reporting Instructions Procedure for Operations personnel (Appendix I) and associated Operations Department tour sheets. These instructions apply to all Operations Department personnel responsible for conducting surveillances of the intake structures, cleaning trash bars, and making notifications. This includes Equipment Operators, Group Operating Supervisors, and Group Shift Supervisors.

7.3.1.1 SURVEILLANCE OF CIRCULATING WATER SYSTEM AND DILUTION WATER SYSTEM INTAKES

The CWS and DWS intake trash bars, and the area immediately upstream of the trash bars, are inspected for the presence of sea turtles at least twice per 8-hour shift during the June 1 - October 31 period. This represents a doubling of the frequency of intake structure inspections previously specified, and is a response to the incidental capture of two Kemp's ridley sea turtles during July of 1994. Prior to 1994, only two individuals of this species had been observed at the OCNGS, both during the month of October. The first inspection will normally be conducted one to two hours into the work-shift; the second inspection will normally be performed five to six hours into the work-shift. Although emergencies or other responsibilities may periodically prohibit strict adherence to this schedule, the intent of the schedule is to prevent the individual inspections from being clustered together in a relatively short time period. The time that each inspection is completed will be recorded on intake area supplemental tour sheets.

Because the sea turtle season typically coincides with the period of greatest debris loading at the intakes, additional inspections of the intakes are often made during this period to ensure that they are sufficiently clean of debris. The cleaning of all of the CWS and DWS intake trash bars may take several hours when debris levels are high. These additional activities at the intake structures provide further opportunities for plant personnel to observe sea turtles.

The Sea Turtle Surveillance, Handling, and Reporting Instructions for Operations personnel (Appendix I) provides guidance on how to distinguish sea turtles from Diamondback Terrapins. In addition, large color posters which illustrate the distinguishing features of sea turtles have been placed in prominent locations at both the CWS and DWS intake structures (Fig. 7-1). This information is also published in the OCNGS employee newspaper each spring in order to

increase the level of awareness of station personnel just prior to the period when sea turtles are likely to occur in the vicinity of the station.

Station personnel conducting sea turtle surveillances will use portable spot lights during night inspections in order to assist them in spotting turtles. It should be noted, however, that visibility is limited to approximately 1 m (3 ft) below the waters surface.

7.3.1.2 SPECIAL PRECAUTIONS DURING TRASH RACK CLEANING

Personnel cleaning the CWS and DWS intake trash racks during the June 1 - October 31 period observe the trash rake while cleaning operations are underway so that the rake may be stopped if a sea turtle is sighted. The debris gathered from the trash racks is hand raked into the trash car hopper. Personnel performing this task are instructed to look for sea turtles and to take particular care to ensure that sea turtles are not mistaken for horseshoe crabs. The floodlights attached to the trash rake unit (Figs. 4-5 and 4-8) are utilized during the evening hours to aid station personnel in spotting sea turtles. Note, however, that organisms are only visible in the upper few feet of water at the intakes because water transparency is typically about 1 m (3 ft).

7.3.1.3 ACTIONS TAKEN IF A SEA TURTLE IS OBSERVED

Sea turtles observed on the trash racks or in the vicinity of the intake structures are recovered as soon as possible, taking care to prevent injury to the animal. The method of recovery depends upon the size and location of the turtle. A rescue sling suitable for larger turtles (in excess of 40 pounds), is kept in the fish sampling pool at the CWS intake structure. This device consists of large-mesh netting on a rigid metal frame with ropes attached to each corner (Fig. 4-10). Long handled dip nets suitable for the smaller turtles most commonly encountered have also been fabricated (Fig. 4-11). These dip nets will be stored within easy reach, attached to fences, railings, or buildings at the CWS and DWS intake structures during the sea turtle season (June 1 - October 31).

Both the rescue sling and the long handled dip nets are adequate for retrieving turtles from the surface to approximately 1 m (3 ft) below the surface. The use of either device requires that the sea turtles be visible from the surface. The retrieval of sea turtles from the trash bars, more than 1 m (3 ft) below the waters surface, requires the use of the trash rake alone or in combination with the dip nets or rescue sling.

7.3.1.4 SEA TURTLE HANDLING AND RESUSCITATION

In accordance with the Sea Turtle Surveillance, Handling and Reporting Instructions for Operations personnel (Appendix I), sea turtles removed from the intake structures, regardless of their condition, are kept moist and out of direct sunlight. Fiberglass tubs suitable for holding sea turtles are stored in the fish

sampling pool building at the CWS intake structure. Station personnel are cautioned not to assume that an inactive turtle is dead and that they should attempt to revive inactive animals immediately after they are retrieved. Specific guidance on handling and resuscitation is provided in the written instructions and on large color posters placed in prominent locations at both the CWS and DWS intake structures (Fig. 7-2). Special instructions are also provided for cold-stunned turtles (Appendix I).

Live sea turtles are delivered to the local affiliate of the Sea Turtle Salvage and Stranding Network (Marine Mammal Stranding Center in Brigantine, New Jersey) for examination and subsequent release into the ocean. Dead sea turtles have been sent to Cornell University for necropsy.

7.4 NOTIFICATION AND REPORTING OF INCIDENTAL CAPTURES

Section 9 of OCNGS Procedure 126, entitled Notification of Station Events, directs station personnel to report all sightings or captures of sea turtles to the NRC and the NMFS. The Sea Turtle Surveillance, Handling, and Reporting Instructions for Operations personnel (Appendix I) call for the Group Shift Supervisor (GSS) to be notified immediately of any sea turtle observations or captures. The GSS or his designee is required to notify Environmental Affairs personnel as soon as possible and to complete the Sea Turtle Sighting/Capture Report form, an attachment to Appendix I. Environmental Affairs personnel are required to provide oral notification to the NRC and NMFS within 24 hours of the event. In addition, a written report is prepared by the Environmental Affairs Department and submitted to both regulatory agencies within 30 days of the event. The written report provides the details of the capture or sighting including the time and place of capture; the length, weight and condition of the turtle; the disposition of the turtle, and any other pertinent information. Annual reports of sea turtle captures have been provided as part of the Annual Environmental Operating Report for the OCNGS.

7.5 DISCUSSION OF GENERAL IMPACTS ON SEA TURTLE POPULATIONS

Five factors have been listed by the federal government as factors contributing to the decline in sea turtle populations (43 FR 146:32800-32811):

1. Destruction or modification of habitat;
2. Overutilization for commercial, scientific or educational purposes;
3. Inadequate regulatory mechanisms;
4. Disease and/or predation; and,
5. Other natural or man-made sources.

The destruction and/or modification of habitat from coastal

development and losses due to incidental capture during commercial fishing are likely the two major factors impacting sea turtle populations along the Atlantic Coast of the United States. The continued development of beachfront and estuarine shoreline areas is likely to be impacting foraging and nesting grounds for several sea turtle species. Incidental capture (take) is defined as the capture of species other than those towards which a particular fishery is directed. As implied by this definition, the commercial fishing industry has been implicated in many of the turtle carcass strandings on southeast U.S. beaches. The annual by-catch of sea turtles by shrimp trawlers in the southeast alone has been estimated by Henwood and Stuntz (1987) to be nearly 48,000 turtles (primarily loggerheads), resulting in over 11,000 turtle deaths per year. In a study conducted for Congress, the National Academy of Sciences concluded that incidental drowning in shrimp trawls "kills more sea turtles than all other human activities combined...", and may result in as many as 55,000 sea turtle drownings annually in U.S. waters (Magnuson et al. 1990).

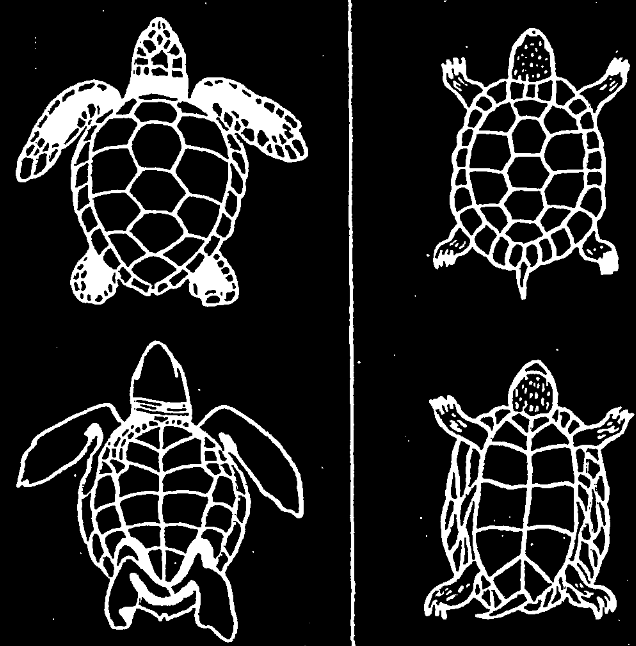
The drowning of sea turtles in commercial fishing nets is not the only anthropogenic source of mortality. Other human-related causes include injuries from encounters with boats, plastic ingestion, and entanglement in trash. In New Jersey and New York, boat related damage is a commonly observed injury in stranded turtles. The loggerhead, because it is the most abundant sea turtle in U.S. coastal waters, is the species most frequently encountered by fishermen and other boat operators. More research needs to be conducted to identify all of the sources of sea turtle mortality and to develop methods of mitigating those losses.

The unintentional entrapment of sea turtles during non-fishery related industrial processes, such as the generation of electricity, is another source of incidental capture and mortality. We have documented the capture of fourteen sea turtles at the OCNGS during more than 30 years of operation. Only six of these turtles may have died as a result of their encounter with the station's intakes. Relative to losses from other sources, such as commercial fishery by-catch, this loss is extremely small. Even though any loss of any individual of an endangered or threatened species is important, the magnitude of the potential losses of loggerhead, Kemp's ridley and Atlantic green sea turtles associated with the operation of the Oyster Creek Nuclear Generating Station would not be expected to significantly impact the U.S. Atlantic coast populations of these sea turtle species.

Figure 7-1. Sea Turtle Identification Poster Placed at OCNGS Intake Structures.

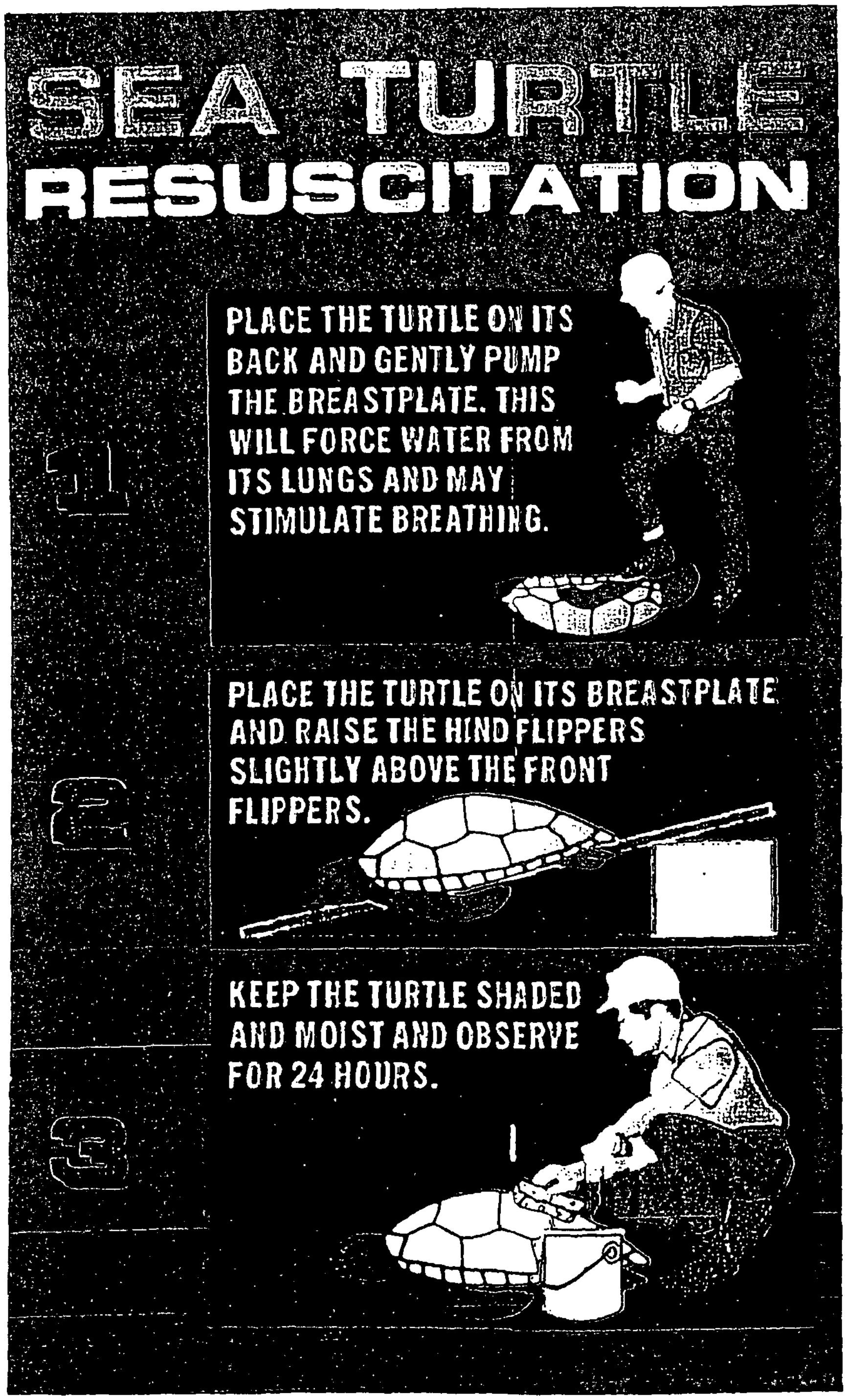
HOW TO DISTINGUISH SEA TURTLES FROM TERRAPINS

Distinguishing Features	Sea Turtles	Terrapins
Limbs	Has swimming fins or flippers.	Lacks flippers, but has walking feet with 4 or 5 claws at the end.
Head	Unable to fully withdraw head inside of shell.	Can withdraw head inside of shell.
Maximum Size	Adult can grow to over three feet in length.	Does not exceed 10 inches in length.
Top View		
Bottom View		



	Sea Turtles	Terrapins
Actions Required	Notify Group Shift Supervisor (x4667) and Environmental Controls (x4022) immediately.	None required. May be gently removed from intake and returned to discharge canal.

Figure 7-2. Sea Turtle Resuscitation Poster Placed at OCNGS Intake Structures.



SECTION 8.0

REFERENCES

50 CFR 17.11; Endangered and Threatened Wildlife

50 CFR 222.23(a); Endangered Fish or Wildlife Permits, (Under National Marine Fisheries Service jurisdiction)

50 CFR 227.4(b); Threatened Fish and Wildlife, Enumeration of Threatened Species

50 CFR 402; Interagency cooperation - Endangered Species Act of 1973, as amended (Joint regulations of U.S. Fish and Wildlife Service and National Marine Fisheries Service).

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APPENDIX I

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title: Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0
Applicability/Scope: Applies to work at Oyster Creek		Responsible Office: Plant Operations 2100
This document is within QA plan scope _X_Yes___No Safety Reviews Required _X_Yes___No		Effective Date: (06/01/95) 06/11/95

Prior Revision N/A incorporated the following Temporary Changes:

N/A

This Revision 0 incorporates the following Temporary Changes:

N/A

List of Effective Pages

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2.0	0
3.0	0
4.0	0
5.0	0
6.0	0
E1-1	0
E1-2	0

	Signature	Concurring Organization Element	Date
Originator	[signature]	Plant Operations Engineer	24MAY95
Concurred By	[signature]	Manager, Plant Operations	5-24-95
	[signature]	Manager Environmental Affairs	5/25/95
Approved By	[signature]	Director, Ops/Mtce, O.C.	5-30-95

(10612)

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

1.0 PURPOSE

1.1 To establish the tour, handling, and reporting requirements necessary to minimize the impact of station operation on sea turtles.

1.2 Document the sighting or capture of sea turtles in the vicinity of the station intake structures.

2.0 APPLICABILITY/SCOPE

To all Operations Department personnel responsible for conducting tours of the intake area, cleaning trash racks and making notifications.

3.0 DEFINITIONS

3.1 Cold-Stunned Turtle - a comatose turtle found in water less than 10°C (50°F). Most common in the fall and early winter.

3.2 Sea Turtle - a turtle characterized by the following distinguishing features:

- Possessing swimming fins or flippers.
- Unable to fully withdraw head inside of shell.
- Able to grow to over 3 feet in length.

4.0 PROCEDURE

4.1 During the period June 1 to October 31, the Circulating Water Pump and Dilution Pump intake trash racks and the area immediately upstream of the trash racks shall be inspected for the presence of sea turtles in accordance with the Intake Area Tour Sheet.

NOTE

Information on how to identify a sea turtle and differentiate a sea turtle from a terrapin is posted at the Circulating Water and Dilution Pump intake structures.

4.2 IF a sea turtle is sighted,

THEN complete the following:

4.2.1 IF the sea turtle is observed on a trash rack while the rack is being cleaned,

THEN immediately stop cleaning the rack.

4.2.2 Report the sighting to the Control Room and the GSS.

4.2.3 The GSS shall complete the following:

- Attachment 106.12-1, Sea Turtle Sighting/Capture Report.
- Notification in accordance with Procedure 126, Category V Reportable Event (Environmental Related).

4.3 IF the turtle is observed on the trash rack,

THEN recover the animal as follows:

4.3.1 For smaller turtles, use a long handled dip net, located at each intake structure.

4.3.2 For larger turtles, use the rescue sling, stored in the fish sampling pool at the Circulating Water Intake.

4.3.3 IF the recovered turtle is NOT a sea turtle,

THEN release the turtle to the discharge canal. No additional actions or notifications are required.

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

CAUTION

Keep clear of the head and front flippers which have claws.

4.4 Pickup the sea turtle by the front and back of the top shell and place the sea turtle in a fiberglass tub. The tubs are stored in the fish sampling pool building.

4.5 Maintain the captured sea turtle moist and out of direct sunlight until Environmental Affairs personnel arrive. Add a small amount of intake water to the tub but do not cover the mouth or nostrils of the turtle with water.

NOTE 1

Do not assume an inactive turtle is dead. The onset of rigor mortis is often the only definite indication that a turtle is dead.

NOTE 2

Normally, the activities described in Steps 4.6 and 4.7, would be performed by Environmental Affairs personnel, but if not available in a few minutes, the efforts should be initiated by station personnel.

4.6 IF a turtle appears to be comatose (unconscious),

AND

intake water temperature is less than 10°C (50°F),

THEN assume the turtle to be cold-stunned and perform the following:

1. Increase blood flow in the turtle by flapping the flippers and rubbing the skin,
2. If possible, place the turtle in a few inches of water that is warmer than the water it was removed from. Do not cover the mouth or nostrils with water.
3. Gradually, over a period of six hours, move the turtle to a warmer area.

APPENDIX I

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12

Title Sea Turtle Surveillance, Handling, and Reporting Instructions	Revision No. 0
Applicability/Scope Applies to work at Oyster Creek	Responsible Office Plant Operations 2100
This document is within QA plan scope _X_Yes___No Safety Reviews Required _X_Yes___No	Effective Date (06/01/95) 06/11/95

Prior Revision N/A incorporated the following Temporary Changes:

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This Revision 0 incorporates the following Temporary Changes:

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List of Effective Pages

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	Signature	Concurring Organization Element	Date
Originator	Thomas [signature]	Plant Operations Engineer	24MAY95
Concurred By	[signature]	Manager, Plant Operations	5-24-95
	James J. Vaughton	Manager Environmental Affairs	5/25/95
Approved By	[signature]	Director, Ops/Mtce, O.C.	5-30-95

(10612)

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

1.0 PURPOSE

1.1 To establish the tour, handling, and reporting requirements necessary to minimize the impact of station operation on sea turtles.

1.2 Document the sighting or capture of sea turtles in the vicinity of the station intake structures.

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To all Operations Department personnel responsible for conducting tours of the intake area, cleaning trash racks and making notifications.

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3.2 Sea Turtle - a turtle characterized by the following distinguishing features:

- Possessing swimming fins or flippers.
- Unable to fully withdraw head inside of shell.
- Able to grow to over 3 feet in length.

4.0 PROCEDURE

4.1 During the period June 1 to October 31, the Circulating Water Pump and Dilution Pump intake trash racks and the area immediately upstream of the trash racks shall be inspected for the presence of sea turtles in accordance with the Intake Area Tour Sheet.

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

NOTE

Information on how to identify a sea turtle and differentiate a sea turtle from a terrapin is posted at the Circulating Water and Dilution Pump intake structures.

4.2 IF a sea turtle is sighted,

THEN complete the following:

4.2.1 IF the sea turtle is observed on a trash rack while the rack is being cleaned,

THEN immediately stop cleaning the rack.

4.2.2 Report the sighting to the Control Room and the GSS.

4.2.3 The GSS shall complete the following:

- Attachment 106.12-1, Sea Turtle Sighting/Capture Report.
- Notification in accordance with Procedure 126, Category V Reportable Event (Environmental Related).

4.3 IF the turtle is observed on the trash rack,

THEN recover the animal as follows:

4.3.1 For smaller turtles, use a long handled dip net, located at each intake structure.

4.3.2 For larger turtles, use the rescue sling, stored in the fish sampling pool at the Circulating Water Intake.

4.3.3 IF the recovered turtle is NOT a sea turtle,

THEN release the turtle to the discharge canal. No additional actions or notifications are required.

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

CAUTION

Keep clear of the head and front flippers which have claws.

4.4 Pickup the sea turtle by the front and back of the top shell and place the sea turtle in a fiberglass tub. The tubs are stored in the fish sampling pool building.

4.5 Maintain the captured sea turtle moist and out of direct sunlight until Environmental Affairs personnel arrive. Add a small amount of intake water to the tub but do not cover the mouth or nostrils of the turtle with water.

NOTE 1

Do not assume an inactive turtle is dead. The onset of rigor mortis is often the only definite indication that a turtle is dead.

NOTE 2

Normally, the activities described in Steps 4.6 and 4.7, would be performed by Environmental Affairs personnel, but if not available in a few minutes, the efforts should be initiated by station personnel.

4.6 IF a turtle appears to be comatose (unconscious),

AND

intake water temperature is less than 10°C (50°F),

THEN assume the turtle to be cold-stunned and perform the following:

1. Increase blood flow in the turtle by flapping the flippers and rubbing the skin,
2. If possible, place the turtle in a few inches of water that is warmer than the water it was removed from. Do not cover the mouth or nostrils with water.
3. Gradually, over a period of six hours, move the turtle to a warmer area.

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

4.7 IF a turtle appears to be comatose (unconscious),

THEN revive the turtle by performing the following:

> **NOTE**
>
> This procedure is designed to void the turtle's lungs of water by active pumping and passive draining. Sea turtles have been known to revive up to 24 hours after this procedure has been complete.

4.7.1 Place the turtle on its back and gently pump the breastplate.

4.7.2 Place the turtle on its breastplate and raise its hindquarters. The degree of elevation depends on the size of the turtle; greater elevations are required for larger turtles.

4.7.3 Keep the turtle shaded and moist and observe for 24 hours.

4.8 Complete Attachment 106.12-1 with all required information and send to Environmental Affairs.

5.0 RESPONSIBILITIES

5.1 The Group Shift Supervisor is responsible for:

5.1.1 The implementation of this procedure on their respective shift.

5.1.2 The completion of notifications in accordance with Procedure 126 for the sighting or capture of sea turtles.

5.1.3 The completion of Attachment 106.12-1 for the sighting or capture of sea turtles.

5.2 The Nuclear Plant Operators (assigned to the Intake Area Tour) are responsible for:

5.2.1 Inspecting the intake area (dilution and circulating water) trash racks and area immediately upstream of the trash racks for the presence of sea turtles.

5.2.2 Reporting all sightings and captures of sea turtles to the Control Room.

5.2.3 Recovering sea turtles observed on the trash racks.

5.2.4 Maintaining captured sea turtles moist and out of direct sunlight and if required, reviving inactive sea turtles immediately after they are retrieved.

6.0 REFERENCES

6.1 Procedures

- 106, Conduct of Operations
- 126, Procedure for Notification of Station Events
- 344, Screen Wash System
- 6635-ABN-4511.02, OC Environmental Technical Specifications

6.2 Assessment of Impact of Oyster Creek Nuclear Generating Station on Kemp's Ridley (Lepidochelys Kempii) and Loggerhead (Caretta Caretta) Sea Turtles.

6.3 Plant Operations Intake Area Tour Sheet

7.0 ATTACHMENTS

- 106.12-1, Sea Turtle Sighting/Capture Report

GPU Nuclear	OYSTER CREEK NUCLEAR GENERATING STATION PROCEDURE	Number 106.12
Title: Sea Turtle Surveillance, Handling, and Reporting Instructions		Revision No. 0

ATTACHMENT 106.12-1

Sea Turtle Sighting/Capture Report

Date: ____________________ Sighting / Capture (circle one)

Time: ____________________

Location of Sighting/Capture:

Circ Water Intake ________ (Initials) Dilution Intake ________ (Initials)

Intake Bay (number/designation): ______________________________

Plant Conditions:

Number of Circulating Water Pumps On: __________

Number of Dilution Pumps On: __________

Grass Conditions (circle): Heavy Medium Light

Intake bay where turtle was sighted/captured last cleaned ____________________ Date / Time

Intake Temperature ____________

Turtle Condition:

Turtle's head below surface when first sighted (circle): YES NO

Condition (circle): ALIVE DEAD NOT SURE

Notifications:

Notification completed in accordance with Procedure 126, Category V Reportable Events (Environmental Related).

____________________ Group Shift Supervisor ____________________ Date / Time

ATTACHMENT 106.12-1
(continued)

Sea Turtle Sighting/Capture Report

Personnel Involved:

Name	Department

Comments:

Submit report to Environmental Affairs

Biological Assessment

Oyster Creek Nuclear Generating Station

Sea Turtle Impact Assessment

Ocean County, New Jersey

March 2005

Docket No. 50-219

U.S. Nuclear Regulatory Commission
Rockville, Maryland

1.0 Summary and Conclusions

This Biological Assessment (BA) was prepared in support of reinitiating a formal consultation between the United States (U.S.) Nuclear Regulatory Commission (NRC) and National Oceanic and Atmospheric Administration (NOAA) Fisheries in compliance with Section 7 of the Endangered Species Act (ESA). The purpose of this BA is to examine the potential impacts associated with the continued operation of the Oyster Creek Nuclear Generating Station (OCNGS) on protected sea turtle species, and to support the NRC's August 26, 2004 request to NOAA Fisheries for reinitiation of formal Section 7 consultation on sea turtle takes at the OCNGS. The fifth incidental take of a Kemp's ridley turtle (*Lepidochelys kempii*) at the OCNGS on August 7, 2004 prompted the reinitiation. As a result of that event, the OCNGS exceeded the Incidental Take Statement (ITS) annual limit for that species.

The OCNGS is located along the western shore of Barnegat Bay between the South Branch of Forked River and Oyster Creek, in Ocean County, New Jersey. Monthly mean salinity values observed in western Barnegat Bay near the OCNGS vary seasonally from approximately 18.5 parts per thousand (ppt) to over 28 ppt. Monthly mean ambient water temperatures in this portion of the Bay range from a winter mean of 1°C (33.8°F) to approximately 28°C (82.4°F) during the summer (Kennish and Lutz, 1984).

The OCNGS consists of a single boiling water nuclear reactor with an electrical capacity of approximately 650 megawatts. When the OCNGS is in operation, water flows from Barnegat Bay into Forked River and the OCNGS, where the flow is used to cool the power plant. Heated water discharged from the OCNGS site flows eastward in Oyster Creek back into Barnegat Bay.

The OCNGS has two water intake structures, the circulating water system (CWS) intake and the dilution water system (DWS) intake. During normal operation, the circulating water system moves approximately 1,740 cubic meters per minute (m^3/min) (0.46 million gallons per minute [gpm]) of water through the main condensers for cooling purposes. Additionally, up to two dilution pumps (each with a 984-m^3/min or 0.26-million gpm capacity) divert water from the intake canal to the discharge canal to reduce the temperature of the circulating water discharge (Kennish, 1978). Both intakes utilize trash bars to remove debris from the water. The CWS intake also has vertical traveling screens which have been modified with Ristroph fish buckets and a fish return system to minimize the effects of impingement.

Five species of sea turtles have been reported from coastal New Jersey waters. These sea turtle species are loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle, Atlantic green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), and hawksbill turtle (*Eretmochelys imbricata*). Three of these sea turtles species, Kemp's ridley, leatherback, and hawksbill, are listed as endangered. The loggerhead is listed as threatened. Atlantic green turtles in U.S. waters are listed as threatened except for the Florida breeding population that is listed as endangered. Due to the inability to distinguish between the two Atlantic green turtle populations away from the nesting beaches, Atlantic green turtles are considered endangered wherever they occur in U.S. waters (NOAA Fisheries 2004). Only the loggerhead, Kemp's ridley, and Atlantic green turtles have been captured at the OCNGS.

The loggerhead turtle is the most common sea turtle in the coastal waters of the U.S. and occurs in many other locations throughout the world. The adult female population in the Atlantic is estimated to be 44,780 (Turtle Expert Working Group 2000). The loggerhead population in the southeast is threatened by reductions in nesting and foraging habitats due to the continued development of coastal areas and losses resulting from incidental capture in shrimp trawls. An estimated 5,000 to 50,000 turtles have been lost annually from trawling without the use of turtle excluder devices (TEDs) (NMFS 1991a). As a result of the implementation of NOAA Fisheries regulations requiring the use of TEDs, and efforts to protect nesting beaches, the U.S. loggerhead population is widely believed to be increasing (Turtle Expert Working Group 2000).

The Kemp's ridley is the most endangered sea turtle species worldwide. A single colony, with almost all members nesting near Rancho Nuevo, Mexico, essentially represents the world population for this species. The population was estimated at less than 1,000 nesting females based on data from the early to mid 1990s (Caribbean Conservation Organization 2003b). The Kemp's ridley population is also impacted by coastal development, poaching, and shrimp trawling. Incidental take by the shrimp industry has been identified as the largest source of mortality (between 500 and 5,000 killed annually) for *Lepidochelys kempii* (Magnuson et al. 1990). However, subsequent to nest protection efforts and the implementation of the NOAA Fisheries TED regulations in 1989, significant increases in nesting activity have been observed, and the population appears to be increasing rapidly (Crouse et al. 1992; Turtle Expert Working Group 1998; Turtle Expert Working Group 2000; Marquez et al. 2001). More than 6,436 and 8,288 nests were laid in Mexico in 2002 and 2003, respectively, representing a significant increase from the 1985 low of only 702 nests (USFWS 2003).

For green turtles, the breeding populations off Florida and Mexico's Pacific coast are endangered while all other populations are threatened. Although population data are scarce, the best available abundance estimates indicate that there are 200 to 1100 nesting females on U.S. beaches (NOAA Fisheries 2005a). The biggest threats to green turtle populations are incidental catch in shrimp trawls as well as commercial harvests for eggs and meat. In the 1990s, increasing trends have been observed in the nesting populations in Florida and Costa Rica (NOAA Fisheries 2003).

Leatherback turtles have been endangered for about 35 years. Current estimates indicate there are 20,000 to 30,000 nesting female leatherbacks worldwide (NOAA Fisheries 2005c). While the status of the entire Atlantic population is unknown, it appears that the nesting population in the Atlantic and Caribbean is stable. Commercial fisheries, habitat destruction, egg and meat harvest, boat collisions, and marine pollution appear to be the biggest threats to leatherback populations in the U.S. Unfortunately, the TED regulations do not protect many leatherbacks; due to their large size, leatherbacks cannot fit through the openings of most TEDs.

Like the leatherback, the hawksbill turtle has been listed as endangered for about 25 years as well. While hawksbills are most common in Puerto Rico and the U.S. Virgin Islands, sightings have been reported in all east coast states, except Connecticut, as far north as Maine (NOAA Fisheries 2005b). Because hawksbills are solitary nesters, population estimates are unreliable, but based on nesting data from the 1990s, Meylan (1999) calculated an order-of-magnitude population estimate for the Caribbean region to be 5000 adult females. Available trends indicate that hawksbill populations are declining in most areas of the Caribbean, with the

exceptions of increasing populations that nest on Mona Island, Puerto Rico and in parts of Mexico (Meylan, 1999). Commercial exploitation, especially for the shell and eggs, is a major cause, in addition to marine debris, of decline for hawksbill populations.

Sea turtles have been observed and incidentally captured at the OCNGS from 1992 through 2004, but were never captured during more than 10 years of field sampling associated with the station, which began sampling in 1975. Their scarcity in Barnegat Bay is largely attributable to the fact that access to the bay is extremely limited. The only direct access to Barnegat Bay from the Atlantic Ocean is via Barnegat Inlet, narrow inlet approximately 300 meters (m) (1,000 feet [ft]) wide.

Only 32 sea turtles have been captured at the OCNGS during more than 35 years of operation. Nineteen turtles were alive at the time of capture (5 of 7 loggerheads; 11 of 21 Kemp's ridleys; 3 of 4 Atlantic greens) and safely returned to the wild.

Since 1992, a total of 13 turtles removed from the OCNGS intake were dead at the time of capture. Of these, two loggerheads exhibited severe boat prop wounds and were moderately decomposed indicating that death probably occurred prior to encountering the intake. One of the dead sea turtles was a juvenile green turtle captured during late October 1999. This individual exhibited no significant wounds, but given the time of year, its death may have been related to cold stunning. The remaining ten sea turtles found dead at the OCNGS intake structures were all Kemp's ridleys. The condition of four dead Kemp's ridleys at the time of capture suggests that their deaths may have been attributable to factors other than interaction with the OCNGS intake. One of the two dead Kemp's ridleys taken in 1994 exhibited a strong odor of decomposition, suggesting that it may have died prior to becoming impinged on the DWS intake. A Kemp's ridley taken in July 2001 had a deep slice wound on its neck that could have been caused by an encounter with a boat. Two of the three dead Kemp's ridleys taken during 2004 had puncture wounds on the carapace or neck that could have resulted from collisions with boats. The most likely cause of death of one individual taken in 1993 was determined by necropsy to be drowning at the DWS intake. The deaths of the remaining five Kemp's ridleys may also be attributable to drowning at either the DWS or CWS intake, although the cause of death was not definitively determined. In summary, a maximum of 11 and as few as 6 sea turtles have died as a result of OCNGS operations during the past 35 years. All sea turtles captured at the OCNGS were subadults or juveniles.

The occurrence of 32 sea turtles at the OCNGS between 1992 and 2004 is probably attributable to at least two factors. Modifications to Barnegat Inlet, completed in 1991 by the U.S. Army Corps of Engineers, and subsequent maintenance dredging of the inlet have resulted in significant increases in the depth of the inlet and the volume of water passing through the inlet during each tidal exchange. These changes may have made Barnegat Bay more accessible to sea turtles migrating along the Atlantic coast. In addition, there is a significant body of evidence indicating that sea turtle population levels, particularly the Kemp's ridley population, have been increasing rapidly during the past several years (Crouse et al. 1992; Turtle Expert Working Group 1998; Marquez et al. 1999; Turtle Expert Working Group 2000; Marquez et al. 2001). These increases in abundance are probably a result of decreased mortality associated with the implementation of the NOAA Fisheries TED regulations in 1989 as well as ongoing efforts to protect nesting beaches.

It is unknown whether the changes to Barnegat Inlet would be permanent or, as has happened in the past, shoaling would occur over time, reducing access to Barnegat Bay via the inlet. Similarly, additional data on sea turtle populations and commercial fishing bycatch must be gathered to fully evaluate the effectiveness of the TED regulations at reducing sea turtle mortality.

No changes in the design or the mode of operation of the OCNGS could explain the incidental take of eight Kemp's ridley turtles at the facility during 2004, when the previous annual maximum had been two individuals. This phenomenon was most likely ascribable to the combined effects of the rapidly-increasing Kemp's ridley population and the unusually-warm ocean water temperatures along the New Jersey coast during the summer of 2004. Water temperatures during June through September 2004 were the third warmest since record keeping began in 1912 (National Weather Service 2004). These abnormally-high ocean water temperatures, along with the abundant food supply in the form of blue crabs found in Barnegat Bay (MacKenzie 2003), provided excellent conditions to attract the increasing numbers of juvenile and subadult Kemp's ridleys migrating along the Atlantic coast in search of productive foraging grounds during 2004.

Of the eight Kemp's ridley takes in 2004, five were alive and released into the ocean. The causes of death for the remaining three turtles were indeterminate; the turtles may have died before impingement, or their deaths could have been causally-related to OCNGS operations. The dead turtles were all found on the trash bars on an intake structure–two on the DWS intake structure and one on the CWS intake structure.

The primary concern with sea turtles at the OCNGS is whether any station-related losses of these endangered or threatened species "jeopardizes their continued existence." Federal regulation defines this term as "engaging in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of that species." A comparison was made of sea turtle losses caused by OCNGS operations, assuming losses equivalent to the current ITS lethal take limit, with conservative population estimates for each species. The maximum estimated annual loss of loggerheads at the station is two turtles, which represents approximately 0.004 percent of the adult female population in the Atlantic. The estimated worst-case annual loss of Kemp's ridleys at the OCNGS is three turtles, which would represent 0.14 percent of the adult population using the 1989 estimate of 2,200 (Márquez 1989). The estimated worst-case annual loss of Atlantic green turtles at the OCNGS is one turtle, which would represent 0.1 percent of the estimated population size of nesting females. It is unlikely that losses at these levels would "appreciably reduce" the distribution or numbers of any of these species. Losses to reproduction would be restricted to "production foregone" due to the loss of juvenile/subadult animals that could potentially be recruited into the breeding population at some time in the future.

Thermal impacts from the operation of the OCNGS, such as acute and chronic thermal impacts and cold shock, are not a concern. The thermal effluent from the station forms only a shallow thermal plume within Barnegat Bay. All sea turtle species found in Barnegat Bay have strong swimming ability and can easily avoid thermally-affected areas where water temperatures exceed their preferences. In addition, no sea turtles have ever been observed within the discharge canal of the OCNGS.

To minimize the impact of OCNGS operations on threatened or endangered sea turtles, a variety of measures has been instituted, including all of the "reasonable and prudent measures necessary to minimize the impact on listed species" specified in the ITS dated July 18, 2001. To ensure the timely removal of sea turtles from the both the CWS and DWS intake structures and optimize chances for turtle survival, a formal procedure has been developed for station personnel that defines the surveillance, handling and reporting requirements necessary to minimize the impact on sea turtles incidentally captured at the OCNGS. The procedure requires inspections of the CWS and DWS intake structures for the presence of sea turtles at least twice per eight-hour shift, and the cleaning of the intake trash bars on at least a daily basis, throughout the sea turtle season, which is June 1 to October 31. This represents a doubling of the frequency of intake structure inspections specified prior to 1994. The intake structures are provided with high-intensity lamps and floodlighting to facilitate inspection and removal efforts. Guidance on the identification, handling, and resuscitation of sea turtles is also included in the procedure. In addition, large color posters, which illustrate the distinguishing features of sea turtles, resuscitation techniques, and reporting requirements, are prominently posted at the intake structures. Custom-made dipnets and a sling designed to facilitate the gentle removal of sea turtles from the intake are stored at the intake structures during the sea turtle season. OCNGS procedures also includes precautions to be taken during routine cleaning of the intake trash bars to ensure that any sea turtles mixed in with the accumulated debris are removed and properly handled.

In accordance with the requirements of the ITS, the licensee has notified NOAA Fisheries and the NRC of all sea turtle captures at the OCNGS, by facsimile within two business days. All live sea turtles have been taken to the Marine Mammal Stranding Center, in Brigantine, NJ, an authorized agent of the Sea Turtle Stranding and Salvage Network. Dead sea turtles were submitted to Cornell University or the University of Pennsylvania for necropsy. Annual reports of sea turtle captures have been provided as part of the Annual Environmental Operating Report for the OCNGS.

In summary, the continued operation of OCNGS is not likely to jeopardize the continued existence of the loggerhead, Kemp's ridley or Atlantic green turtles. In light of the 2004 takes, the NRC suggests a change in the incidental take level at OCNGS for sea turtles; the suggestion is to have no limit on live takes but to retain the current limits on lethal takes caused by station operations. The estimated losses of these species attributable to the operation of the station, particularly the water intakes, would not "appreciably reduce" the distribution or numbers of these species. Losses to reproduction would be restricted to "production foregone" due to the loss of juvenile or subadult animals, which could potentially be recruited into the female breeding population in the future.

2.0 Introduction

2.1 Purpose

This Biological Assessment (BA) is submitted to National Oceanic and Atmospheric Administration (NOAA) Fisheries in compliance with Section 7 of the Endangered Species Act of 1973 (as amended) (ESA), and in support of the United States (U.S.) Nuclear Regulatory Commission's (NRC's) August 26, 2004 request to NOAA Fisheries for reinitiation of formal Section 7 consultation on sea turtles at the Oyster Creek Nuclear Generating Station (OCNGS), which is licensed to and owned by AmerGen Energy Company, LLC.

The purpose of this BA is to examine the potential impacts associated with the continued operation of the OCNGS on sea turtle species protected under the ESA. The primary species of concern are the loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), and green turtle (*Chelonia mydas*), all of which have been captured on the circulating water or dilution intake trash bars at the OCNGS. The Kemp's ridley turtle is listed as endangered, and the loggerhead turtle is listed as threatened (50 CFR 17.11). Atlantic green turtles in U.S. waters are listed as threatened except for the Florida breeding population, which is listed as endangered. Due to the inability to distinguish between these populations away from the nesting beach, these sea turtles are considered endangered wherever they occur in U.S. waters (NOAA Fisheries 2001). The leatherback turtle (*Dermochelys coriacea*) and the hawksbill turtle (*Eretmochelys imbricata*) are also listed as endangered in U.S. waters and are known to occur in New Jersey waters, but have not been observed at the OCNGS. NOAA Fisheries has jurisdiction for these species at sea (50 CFR 222.23(a) and 50 CFR 227.4(b)). The olive ridley turtle (*L. oliveacea*) is listed as threatened in U.S. waters but does not occur in New Jersey waters.

2.2 Endangered Species Act

This BA is part of the formal consultation process provided under Section 7 of the ESA. Detailed procedures for this consultation process are defined in 50 CFR 402.

2.3 Chronology of Events Leading up to This Assessment

A review of the sea turtle strandings at the OCNGS was requested in a letter from NOAA Fisheries to the NRC in November 1993 (Mantzaris 1993). This letter followed communications among OCNGS, NRC, and NOAA Fisheries regarding the capture of sea turtles at the OCNGS during 1992 in spite of the OCNGS having operated for many years (1969 to 1991) prior to any being taken.

The issue of sea turtles at the OCNGS was initially addressed in 1992 when sea turtles were first observed at the station's circulating water and dilution structure intake trash bars. The matter was discussed jointly by OCNGS, NRC, and NOAA Fisheries (informal Section 7 consultation). Subsequent to an additional sea turtle being captured in 1993, NOAA Fisheries advised the NRC that a formal consultation process including preparation of a BA would be

required (Mantzaris 1993). The BA was completed in 1994, and NOAA Fisheries issued a Biological Opinion (BO)/ITS on September 21, 1995.

The BA was updated in 2000 to include information on sea turtle incidental captures that occurred at the OCNGS between 1994 and July 2, 2000, in support of the renewal of the BO/ITS originally issued in September of 1995. NOAA Fisheries subsequently issued a new BO/ITS on July 18, 2001.

On August 7, 2004, the OCNGS recorded the fifth incidental take of a Kemp's ridley turtle since the beginning of the year, thereby exceeding the ITS limits for the facility. As a result, the NRC formally requested reinitiation of Section 7 consultation on sea turtles at the OCNGS (Kuo 2004). This update of the BA, issued in support of that request, includes detailed discussions of the incidental captures of sea turtles at the OCNGS that have occurred since the current BO/ITS was issued on July 18, 2001, and addresses "reasonable and prudent measures necessary to minimize impacts" on listed sea turtles taken by AmerGen Energy Company, LLC at the OCNGS.

3.0 Site Description

3.1 Location

The Oyster Creek Nuclear Generating Station (OCNGS) is located along the eastern edge of the coastal pine barrens of New Jersey in Lacey and Ocean Townships, Ocean County (Figure 3-1). The station site is approximately 55 kilometers (km) (34 miles [mi]) north of Atlantic City, New Jersey and 70 km (44 mi) east of Philadelphia, Pennsylvania. Approximately 15 km (9 mi) north of the site are several small residential communities: Toms River, South Toms River, Beachwood, Pine Beach, Ocean Gate, Island Heights, and Gilford Park. West of the Garden State Parkway the land is primarily undeveloped woodland, and wooded wetlands are found along the banks of small creeks to the north, south, and west of the site. East of the station along the shoreline of Barnegat Bay, the land is characterized by alternating sections of residential development and undeveloped coastal wetlands and adjacent uplands. The terrain surrounding the site is relatively flat along the shoreline to gently rolling inland.

The OCNGS site is located to the west of U.S. Route 9, and is bounded on the north, south and west by the South Branch of Forked River, Oyster Creek, and the man-made intake and discharge canals, respectively. Barnegat Bay forms the site's eastern boundary (Figure 3-2). The power plant structures are situated approximately midway between Oyster Creek and the South Branch of Forked River and about 425 meters (m) (1,394 feet [ft]) west of Route 9.

3.2 Barnegat Bay Morphology and Bathymetry

The OCNGS utilizes Barnegat Bay as a source of cooling water, via the South Branch of Forked River, and the bay serves as the receiving water body for thermal discharges via Oyster Creek (Figure 3-2). Barnegat Bay is a shallow, lagoon-type estuary typical of the back bay systems of barrier island coastlines. The long axis of Barnegat Bay extends approximately 50 km (31 mi) in roughly a north-south direction and parallels the mainland, forming an irregular tidal basin ranging from 1 to 6 km (0.6 to 3.7 mi) in width and 0.3 to 6 m (1 to 20 ft) in depth (Kennish and Olsson 1975; Kennish 1978). The bay is bordered on the west by the New Jersey mainland, on the north by Point Pleasant and Bay Head, on the east by Island Beach and Long Beach Island, and on the south by Manahawkin Causeway. Island Beach and Long Beach Island comprise a barrier island complex breached only at Barnegat Inlet, which is located 10.5 km (6.5 mi) southeast of the OCNGS. This single, relatively narrow inlet provides the only direct access to the bay from the Atlantic Ocean (Figure 3-1).

The estimated surface area of Barnegat Bay is 124 square kilometers (km^2) (47.9 square miles [mi2]) (Seabergh et al. 2003a). About 73 percent of the estuary is less than 2 m (6.6 ft) deep at mean low water, which is characteristic of lagoon-barrier island systems (Barnes 1980). The bay's eastern perimeter is shallower (less than 0.9 m or 3.0 ft) than the central and western sectors which are 0.9 to 4.0 m (3.0 to 13.0 ft) deep, with extensive shoal areas exposed at low tide (Chizmadia et al. 1984). The greatest depths of 3 to 4 m (10 to 13 ft) occur along the Intracoastal Waterway, a narrow channel traversing the length of the bay. The Intracoastal Waterway is heavily utilized by both recreational boaters and commercial fishing boats, and is maintained at a depth of approximately 2 m (6.6 ft) for navigation purposes by the U.S. Army Corps of Engineers (Marcellus 1972).

3.3 Hydrology of Barnegat Bay

Barnegat Bay communicates with Manahawkin Bay to the south and, via the Bay Head-Manasquan Canal, with the Manasquan River to the north (Chizmadia et al. 1984). The primary exchange of ocean and bay water occurs through Barnegat Inlet, where Carpenter (1963) estimated an exchange rate of 7 percent per tide and a net discharge rate of 56.7 m^3/sec (2,002 ft^3/sec).

The salinity regime and circulation patterns within the bay are affected by the inflow of relatively high-salinity waters originating in the Atlantic Ocean and entering the northern and central bay via the Bay Head-Manasquan Canal and Barnegat Inlet, respectively. Because the proportion of bay water that escapes seaward each tidal cycle is relatively small, Chizmadia et al. (1984) estimate that 96 tidal cycles are required for complete turnover of estuarine water to take place. Marcellus (1972) reported a mean tidal current through Barnegat Inlet of 1.1 meters per second (m/sec) (3.6 feet per second [ft/sec]) during flood tide and 1.3 m/sec (4.3 ft/sec) during ebb tide. Ashley (1987) measured peak flood-tide-flow velocities of 1.1 m/sec (3.6 ft/sec) and peak ebb velocities of 1.0 m/sec (3.3 ft/sec).

3.3.1 Influence of Barnegat Inlet Modifications on Barnegat Bay Hydrology

Beginning in 1988, a multi-year project by the U.S. Army Corps of Engineers was undertaken to realign the south jetty at Barnegat Inlet and to dredge accumulated sediments from within the inlet. The new alignment of the inlet's south jetty so that it is nearly parallel to the north jetty was completed in 1991. The new jetty configuration has not changed the effective width of the inlet, which remains approximately 300 m (1000 ft) wide, through which Atlantic Ocean waters can enter Barnegat Bay. The mean tidal range at Barnegat Inlet was reported by Ashley (1987) to be approximately 0.6 m (2 ft) prior to the jetty modifications, and the tide range became progressively damped in a landward direction. The small size of Barnegat Inlet and the shallowness of the bay both restrict tidal flow and attenuate tidal energy, thereby minimizing tidal fluctuations. The depth of the inlet was significantly increased via dredging during the 1991-1993 period, and the realignment of the south jetty straightened the channel flow, which permits a freer interchange of ocean and bay waters. The less-restricted tidal flow due to the dredging and jetty modifications has resulted in a significantly-greater volume of water passing through Barnegat Inlet during a given tidal cycle (Table 3-1). U.S. Army Corps of Engineers data indicate that the average tidal prism has more than doubled since completion of the modifications, and the mean tide range at Barnegat Inlet has increased by over 30 percent (Ashley 1987; Seabergh et al. 2003b). The Waretown gauge, the one closest to OCNGS, showed a 33 percent increase in tide range from 1978 to 1993 (Seabergh et al., 2003a).

3.4 Barnegat Bay Salinity

Maximum Barnegat Bay salinities of over 30 ppt are found near Barnegat Inlet due to the input of Atlantic Ocean water. Most freshwater, however, enters the estuary from surface runoff and groundwater seepage along the western shore of the bay (Chizmadia et al. 1984). Several tributaries that drain the New Jersey Pine Barrens provide a mean surface runoff of 10.2 m^3/sec (360 ft^3/sec). Toms River provides the greatest freshwater input (5.7 m^3/sec; 201 ft^3/sec) to the

estuary, and Cedar Creek provides an additional 3.1 m^3/sec (110 ft^3/sec) (U.S. Atomic Energy Commission 1974). Other significant tributaries of the bay include Metedeconk River, Kettle Creek, Forked River, Oyster Creek, and Manahawkin Creek (Figure 3-1). The freshwater input from these tributaries creates a slight salinity gradient from west to east. The salinity of the central bay, in the vicinity of the OCNGS, is typically about 25 ppt (Chizmadia et al. 1984).

A relatively-pronounced salinity gradient occurs along the north-south axis of the bay due to the freshwater input of Pine Barrens streams in the northwestern portion of the bay and the location of Barnegat Inlet in the southern portion (Figure 3-3). Relatively-high-salinity waters entering the northernmost section of the bay through the Bay Head-Manasquan Canal result in elevated salinities in that portion of the bay (Chizmadia et al. 1984).

3.5 Water Temperature in Barnegat Bay

Barnegat Bay is a meteorological transition zone between the continent and the ocean. The temperature extremes of both the summer and winter seasons are moderated within the bay by the proximity of the ocean. On an average annual basis, the warmest months of the year are July and August, and the coldest months are January and February. Tatham et al. (1977) reported winter water temperatures in western Barnegat Bay as low as -1.5°C (29.3°F) and summer temperatures approaching 30°C (86°F). Periods of relatively-rapid temperature change occur in spring and fall.

Atlantic Ocean water that enters the estuary typically exhibits a somewhat narrower annual range of temperature; however, year-to-year variations can be considerable. According to the National Weather Service (2004), ocean water temperatures along the southern New Jersey coast during the summer (June-September) of 2004 were the third warmest since record keeping began more than 90 years ago in 1912. The average ocean water temperature during the summer of 2004 (measured at Atlantic City, NJ) was 21.7°C (71.1°F), or 1.4°C (2.5°F) above normal and 3.0°C (5.4°F) warmer than the previous year. Ocean water temperatures during the summer of 2003 were among the coolest on record, averaging 18.7°C (65.7°F).

Ice typically forms each winter adjacent to the shoreline of Barnegat Bay, but more extensive ice covering across a major portion of the bay has occurred only during the coldest of recent winters. Periodically, during winter or early spring, ice from Barnegat Bay is drawn into the OCNGS intake canal.

3.6 Water Transparency in Barnegat Bay

Water transparency in Barnegat Bay, as measured by Secchi depth, ranges from 0.2 to 2.5 m (0.7 to 8.2 ft). The annual average Secchi depth in the vicinity of Oyster Creek is 1.1 m (3.6 ft) (Vouglitois 1983).

Table 3-1
Barnegat Inlet average tidal prisms, adjusted to mean tidal conditions

DATE	AVERAGE TIDAL PRISM (x 10^7 m^3)
June 1932	2.29
December 1940	3.21
April 1941	3.45
November 1941	3.31
September 1943	2.12
June 1945	2.01
May 1968	1.39
March 1980	1.17
September 1987	1.17
June 1993	2.55
Note: New south jetty constructed 1981-1991. Sources: Ashley 1988; Seabergh et al. 2003b.	

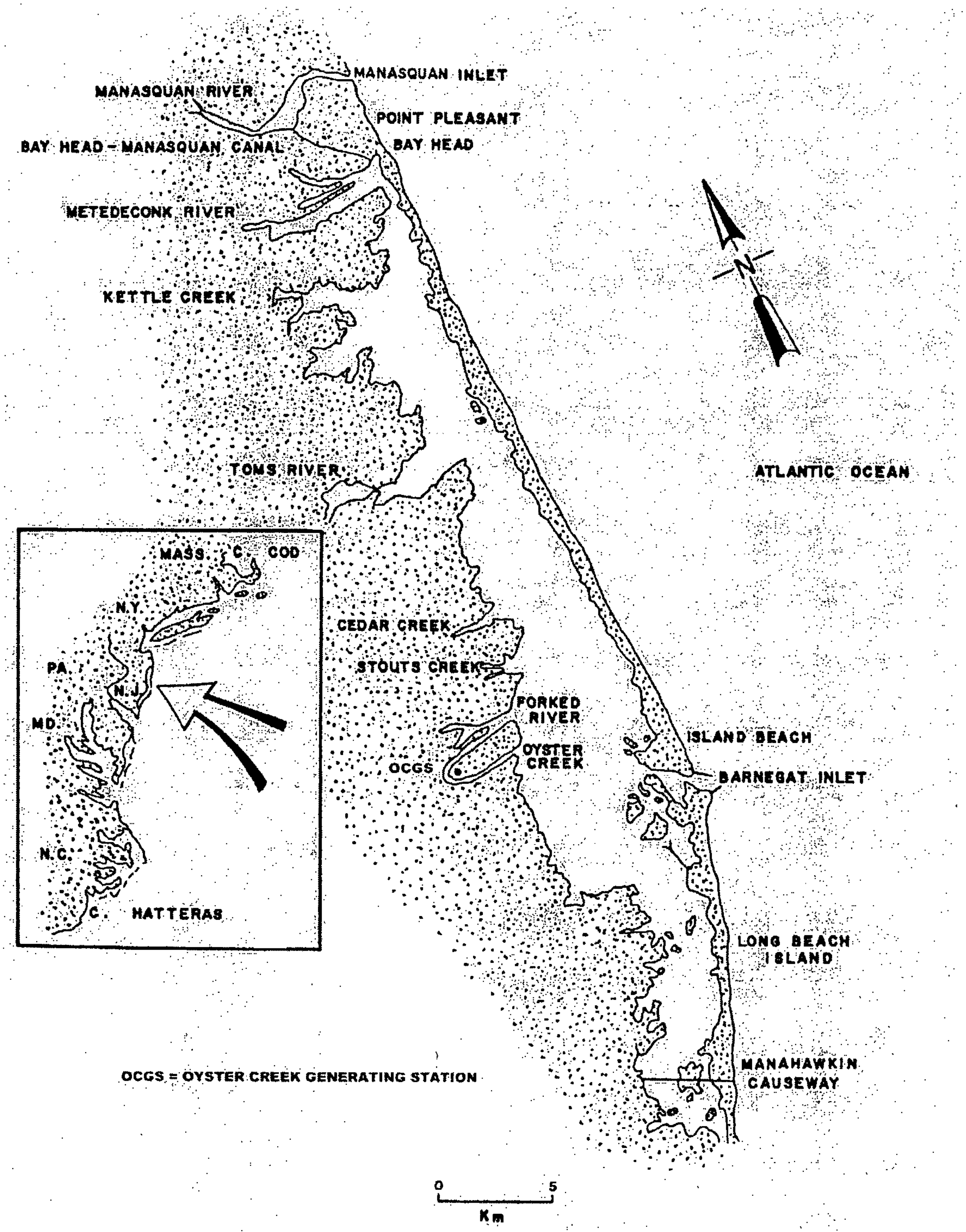


Figure 3-1
Map of Barnegat Bay, New Jersey showing the location of the Oyster Creek Nuclear Generating Station. Inset shows Barnegat Bay in relationship to the Mid-Atlantic Bight (after Kennish and Lutz 1984). Note: OCGS in this figure is OCNGS.

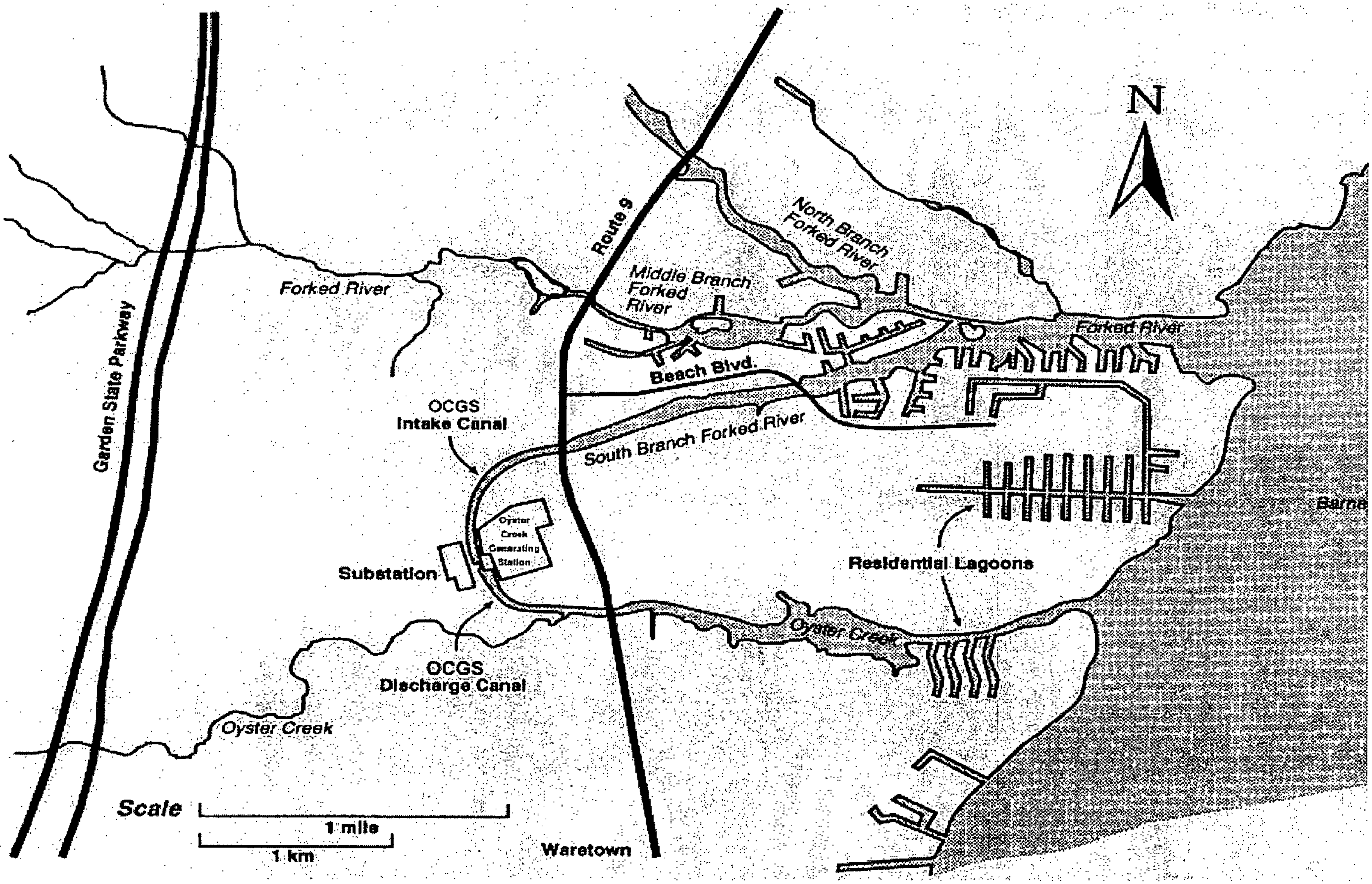


Figure 3-2
Location map of the Oyster Creek Nuclear Generating Station and vicinity. Note: OCGS in this figure is OCNGS.

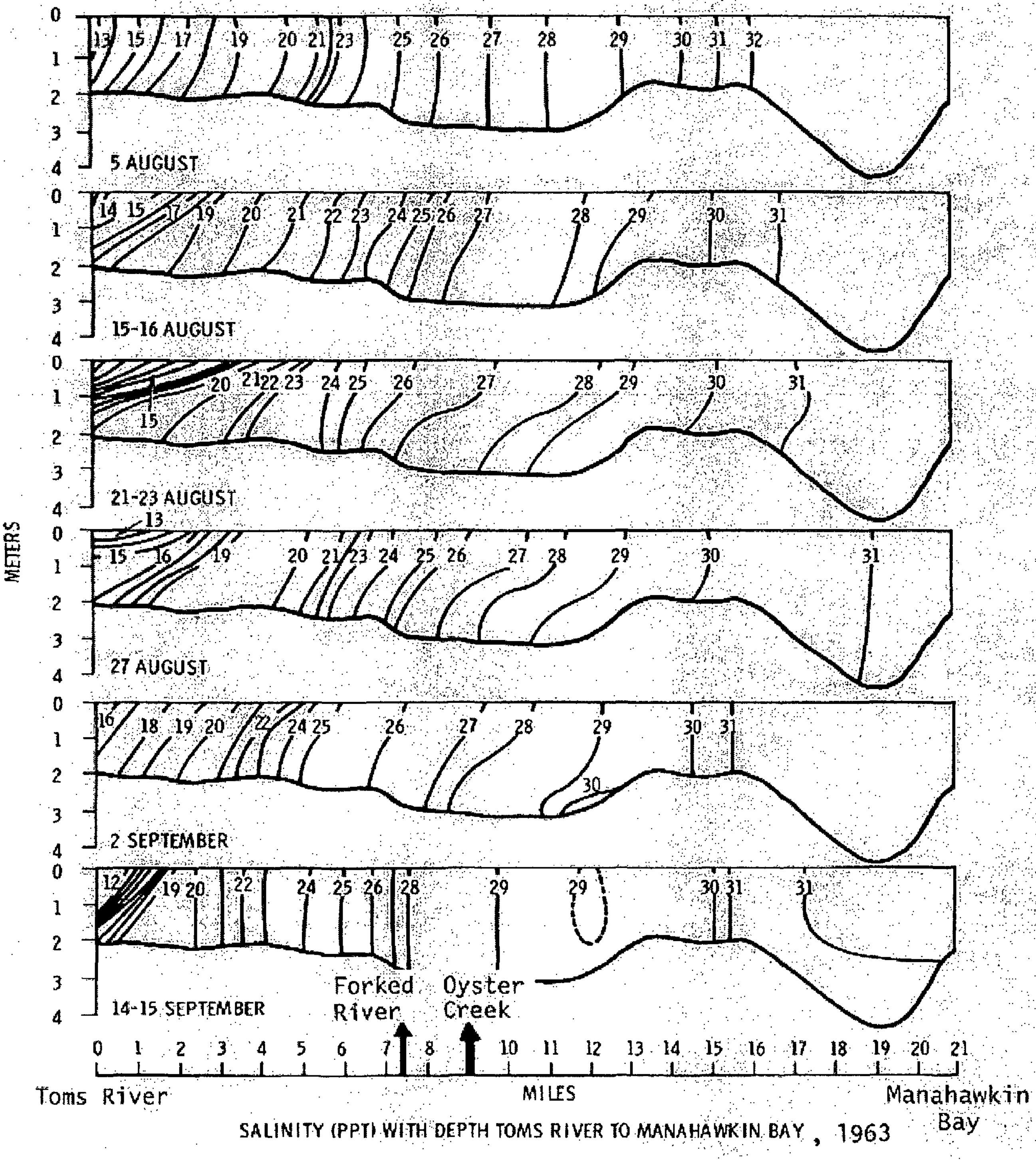


Figure 3-3
Salinity profile of Barnegat Bay from Toms River to Manahawkin Bay for August and September 1963 (after Carpenter 1963).

4.0 Oyster Creek Nuclear Generating Station Description

4.1 Oyster Creek Nuclear Generating Station

The Oyster Creek Nuclear Generating Station (OCNGS) consists of a boiling water nuclear reactor with an electrical capability of approximately 650 megawatts. The OCNGS began commercial operation late in 1969. The facility was owned and operated by Jersey Central Power & Light Company/GPU Nuclear until August 2000 when it was sold to the current owner/operator, AmerGen Energy Company, LLC.

The containment structure housing the reactor and the turbine, and auxiliary and service buildings for the OCNGS are located on a semicircular plot of land bounded by the intake and discharge canals and by U.S. Route 9 (Figure 4-1). Water is withdrawn from Barnegat Bay via the Forked River through an intake canal to two separate intake structures (Figures 4-2 through 4-9). The circulating water system (CWS) intake provides cooling water for the main condensers and also provides cooling water for safety-related heat exchangers and other equipment within the station. The dilution water system (DWS) minimizes the thermal effects on the discharge canal and Barnegat Bay by "thermally diluting" the circulating water from the condenser with colder water drawn from the intake canal. Water from both systems is discharged via discharge tunnels to the head of the discharge canal, located immediately west of the plant (Figure 4-2). The discharge canal debouches into Oyster Creek, which flows into Barnegat Bay.

4.1.1 Circulating Water System

The once-through CWS is designed to remove waste heat from the stations main condensers. The CWS withdraws cooling water from the intake canal, routes it to the condensers, and returns warmed water to the discharge canal (Figure 4-2). During normal plant operation, four 435-m^3/min (0.115-million-gallons-per-minute [gpm]) circulating water pumps (Figures 4-3 and 4-4) withdraw a total of 1740 m^3/min (0.46 million gpm). The typical temperature rise across the condensers in this operating mode is 11 to 12.8 °C (20 to 23 °F). Measurements of the intake velocity of water approaching the CWS intake ports show flows of 17-20 centimeters per second (cm/sec) (0.56-0.66 ft/sec) with four circulating water pumps operating and all six intake bays open.

The station's New Jersey Pollutant Discharge Elimination System (NJPDES) Discharge to Surface Water Permit regulates the intake velocity as well as the effluent characteristics of the CWS. The maximum permissible average intake velocity for water approaching the CWS intake ports is 30 cm/sec (1 ft/sec). The maximum temperature difference between the intake and discharge water is 12.8°C (23°F); the maximum effluent temperature is 41.1°C (106°F). Both temperature limits apply during normal operating conditions (i.e.; when four circulating water pumps are operating and condenser backwashing is not underway.)

When fewer than four circulating water pumps are operating, or during condenser backwashing, alternate temperature limitations apply. The maximum temperature difference between the intake and discharge water under those conditions is 18.3°C (33°F); the alternate maximum effluent temperature is 43.3°C (110°F). The operation of dilution pumps (see Section 4.1.2) reduces the

water temperature in the discharge canal by approximately 2.8°C (5°F) for each pump operated. Two dilution pumps are typically operated during the summer months, thereby providing a 5.6°C (10°F) reduction in discharge canal temperature.

4.1.1.1 Circulating Water System Intake Structure

The CWS intake consists of six separate, independent intake bays or port cells (Figures 4-3 and 4-4). Each intake bay is equipped with its own trash bars and traveling screens. Provisions for stop logs are made within each port to facilitate dewatering the intake bays for maintenance.

Originally, the circulating water intake structure consisted of trash bars followed by conventional traveling screens whose primary purpose was to collect and remove debris from intake water. Traveling screens were intermittently cleaned via a front wash, high-pressure spray system activated by differential pressure, a timer, or manual intervention.

To mitigate fish impingement losses, modifications have been made to the original installation by adding horizontal, water-filled fish survival buckets on the traveling screen baskets (Ristroph modification); a low pressure rear spray wash fish removal system; and a modified fish and trash sluiceway system specifically designed to gently return fish to the discharge canal.

4.1.1.1.1 Trash Bars and Trash Rake Assembly

Six sets of trash bars protect each of the six port cells from large debris, mats of eel grass, marine algae, or detritus entrained in the intake water flow (Figure 4-5). The trash bar assemblies, sometimes referred to as trash racks, are 7.3 m (24 ft) high and extend from the deck of the CWS intake structure at elevation +6.0 ft MSL (mean sea level) to the bottom of each CWS intake port, elevation -18.0 MSL, and are approximately 3.3 m (11 ft) wide. Constructed of 0.95 cm (3/8 inches [in]) wide steel bars on 7.5 cm (3.0 in) centers, the trash bars have openings between them that are 6.6 cm (2.6 in) wide.

The trash bars are inspected at least twice during each eight-hour work shift, throughout the sea turtle season (see Section 7 and Appendix A), and debris is removed as needed by a mobile mechanical trash rake. The trash rake/trash cart assembly is a self-contained unit that traverses the entire width of the intake on rails; it contains a trash hopper that transports the material removed from the bars to a debris container at the south end of the intake. Figures 4-5 through 4-8 illustrate the trash rake/trash cart assembly at the CWS and DWS intake structures.

The trash rake is 1.8 m (6.0 ft) wide and is controlled by a single operator from a manual pushbutton control panel that is mounted on the unit's frame assembly. The trash rake unit consists of an integral frame assembly that houses the traversing drive, hoisting machinery, hopper, and hydraulic control assemblies. The hoisting machinery includes a cable-operated raking device that is designed to remove large, floating or submerged objects that may accumulate on the trash bars. Wide-flanged wheels permit the raking device to travel along the face of the inclined trash bars and guide the cleaning device vertically over the bars. The curved tines of the trash rake extend approximately 2.5 cm (1.0 in) beyond the plane of the trash bars to ensure effective cleaning of the trash bars.

Lighting the intake bays and trash bars is provided by nearby high-intensity lamps, as well as downward-facing floodlights mounted on each corner of the trash cart (Figures 4-5 and 4-8). The floodlights attached to the trash rake unit are utilized during the evening hours to aid station personnel in spotting sea turtles. Personnel cleaning the CWS and DWS intake trash racks during the period from June 1 to October 31 observe the trash rake during the cleaning operation so the rake may be stopped if a sea turtle is sighted. The debris gathered from the trash racks is hand raked into the trash car hopper. Personnel performing this task are instructed to look for sea turtles and to take particular care to ensure that sea turtles are not mistaken for horseshoe crabs.

4.1.1.1.2 Traveling Screens

Each CWS intake cell is equipped with a vertical traveling screen. Each traveling screen unit contains thirty-five, stainless steel mesh (0.95 cm [3/8 in]), fish-removal screen panels. Each screen panel has a 5.1-cm (2-in) -wide lip, which creates a water-filled bucket. As the screen is raised through and out of the water, most impinged organisms such as small fish or invertebrates drop off the screen into the bucket, which prevents them from falling back into the screen well and becoming re-impinged. These organisms are subsequently washed into a fish-return system that gently returns them to the discharge canal.

For maximum fish survival, the screen wash operates with both low-pressure and high-pressure spray headers. As the screen basket travels over the head sprocket, organisms slide onto the screen face and are washed by one low-pressure spray header located outside the screen unit, and two low-pressure spray headers located inside the screen unit, into an upper sluice. This spray wash is designed to minimize de-scaling and other injuries that would occur with conventional high-pressure spray headers. Subsequently, heavier debris is washed into a lower sluice by two high-pressure spray headers.

Normally the screens operate at a speed of 75 cm/sec (2.5 ft/sec). They can also be operated at an alternate speed of 300 cm/sec (10 ft/sec) to accommodate large debris loads.

Because all sea turtles captured at the OCNGS have measured at least 18.3 cm (7.2 in) in straight carapace length (SCL), it is not anticipated that a sea turtle small enough to pass through the 6.6-cm (2.6-in) openings of the trash racks would ever occur at the OCNGS. However, in the unlikely event that such a small sea turtle occurs at the OCNGS, the fish return system would gently return it to the discharge canal automatically (i.e., without the need for manual intervention by OCNGS personnel).

4.1.1.1.3 Circulating Water Pumps

There are four circulating water pumps located on the CWS intake structure (Figure 4-4). They are vertical wet-pit-type pumps rated at 435 m^3/min (0.115 million gpm), which discharge through lines 1.7 m (6.0 ft) long to the main condensers and ultimately to a square concrete discharge tunnel 3.2 m (10.5 ft) in length. The once-through cooling system piping running from the intake to the discharge is approximately 200 m (650 ft) in length. A 1.5 m (5 ft) concrete recirculation pipe for ice control runs below the water level from the discharge tunnel back to the intake structure. The area in close proximity to the CWS intake is kept from freezing by the intake deicing system and the turbulence induced by the circulating water and dilution pumps.

4.1.1.1.4 Sea Turtle Retrieval/Rescue Equipment

As indicated in Section 4.3.2 of Procedure 106.12, "Sea Turtle Surveillance, Handling, and Reporting Instructions" (Appendix A), a rescue sling suitable for lifting large sea turtles (in excess of 20 kilograms [kg] or 44 pounds [lbs]) is kept at the CWS intake structure. The sea turtle rescue sling (Figure 4-10) consists of a weighted tubular metal frame of 2.5-cm (1-in) outer diameter stainless steel measuring 120 cm (48 in) on a side from which 6.4-cm (2.5-in) mesh nylon netting is suspended. Ropes attached at each corner of the rescue sling are joined into a bridle and single lift rope, which are designed to allow the user to drop the sling below a turtle at the trash bars, then lift it out of the water to the intake structure deck.

Custom-made long-handled dipnets suitable for retrieving the smaller turtles most commonly encountered at the OCNGS have also been fabricated for use at the CWS and DWS intake structures (Figure 4-11). The turtle dipnets are constructed of 3.3-cm (1.3-in) outer diameter aluminum tubing and consist of a 240-cm (8-ft) handle attached to a rounded rectangular net frame measuring 75 by 45 cm (2.5 by 1.5 ft). Nylon netting of 0.63-cm (0.25-in) mesh is suspended from the dipnet frame. These dipnets are stored within easy reach, attached to fences, railings, or buildings at the CWS and DWS intake structures during the sea turtle season (June 1 to October 31).

Both the rescue sling and the long-handled dipnets are only adequate for retrieving turtles from the water surface or within about 1 m (3.3 ft) of the surface because the use of either device requires that the sea turtle be visible from the surface.

4.1.1.2 Condensers

There are three sections to the main condenser, one located immediately below each low-pressure turbine (Figure 4-9). There are 14,560 tubes in each main condenser section carrying circulating water from the intake canal. This provides approximately 13,000 m^2 (139,880 ft^2) of cooling surface area. Each section is 12.2 m (40 ft) long, almost 6.1 m (20 ft) wide, and 9.9 m (32.5 ft) high. Two 1.8-m (6-ft) diameter pipes deliver circulating water to each section of the main condensers.

The discharge piping from the main condenser is joined through 1.8-m (6-ft) lines into a common 3.2-m (10.5-ft) square concrete discharge tunnel. The discharge tunnel transports the condenser cooling water across the site to the discharge canal (Figures 4-2 and 4-9).

4.1.2 Dilution Water System

The DWS is designed to minimize thermal effects on the environment by withdrawing ambient temperature water from the intake canal and routing it to the discharge canal where it mixes with the main condenser discharge flows (Figure 4-2). The dilution flow is provided by three low-speed, 984-m^3/min (0.26-million-gpm) axial flow dilution pumps, with 2.1-m (7-ft) diameter impellers (Figure 4-6). The number of dilution pumps operated is governed by the station's NJPDES Discharge to Surface Water Permit and a maximum of two pumps (1,968 m^3/min; 0.52 million gpm) are operated at one time.

To reduce the attraction of migratory fish to the station's discharge canal in the fall, when these species would normally leave Barnegat Bay, two dilution pumps are put into operation when the

ambient (intake) water temperature is less than 15.5 °C (60 °F). To reduce the temperature of the discharge canal during the summer months, when the water temperature as measured at the U.S. Route 9 Bridge over Oyster Creek (Figure 4-1) exceeds 30.5 °C (87 °F), one dilution pump is put into operation. If, after one dilution pump has been in operation for at least two hours, the water temperature at the U.S. Route 9 Bridge continues to exceed 30.5 °C (87 °F), a second dilution pump is put into operation. The station's third dilution pump is held in reserve to be put into operation within 40 minutes of such time as an insufficient number of dilution pumps are operable to meet the intent of the permit requirements.

The operation of two dilution pumps during the seasonal periods required by the NJPDES permit reduces the discharge canal temperature by approximately 5.6 °C (10 °F). During the remainder of the year, one dilution pump is typically operated, providing a temperature reduction of approximately 2.8 °C (5 °F). Following this seasonal operational regime results in the operation of two dilution pumps during about 70 percent of the June-to-October sea turtle season.

The average intake velocity in front of the DWS intake, with two pumps in operation, is approximately 73 cm/sec (2.4 ft/sec).

4.1.2.1 Dilution Water System Intake Structure

The DWS intake is a reinforced concrete structure located on the west side of the intake canal (Figures 4-2 and 4-6). It consists of six intake bays. Each intake bay is fitted with trash bars identical to those employed at the CWS intake (Figures 4-5 and 4-6). Unlike the CWS, the DWS intake structure has no traveling screens or fish-return system.

4.1.2.1.1 Trash Bars

The DWS trash bars are 0.95-cm (3/8-in) steel bars set on 7.5-cm (3.0-in) centers. There are six DWS trash bar assemblies, each 3.3 m (11 ft) wide. The DWS is fitted with a mobile mechanical trash rake similar in design and operation to the trash rake used at the CWS intake (Figures 4-5 through 4-8). The process of inspecting and cleaning the trash bars at the DWS is identical to that described for the CWS in Section 4.1.1.1.1, Section 7.3, and Appendix A.

4.1.2.1.2 Floating Debris/Ice Barrier

A floating barrier has been designed and installed upstream of the CWS and DWS intake structures to divert floating debris such as wood, eelgrass or ice away from the CWS intake and towards the DWS intake. The barrier is intended to prevent excessive amounts of debris or ice from accumulating on the CWS traveling screens or trash bars. The floating barrier is of wooden construction and extends approximately 60 cm (2 ft) below the surface from just upstream of the CWS intake to just upstream of the DWS intake (Figure 4-2).

4.1.3 Thermal Plume Studies

Heated condenser cooling water discharged from the CWS and ambient temperature intake canal water discharged from the DWS meet and mix in the discharge canal and ultimately are returned to Barnegat Bay via the discharge canal (Figures 4-1 and 4-2).

The cooling water discharged from the OCNGS has been studied on several occasions to determine the distribution, geometry, and dynamic behavior of the thermal plume. Dye studies as well as real-time mobile mapping of the plume track have been performed (Carpenter 1963; Starosta et al. 1981; JCP&L 1986).

Three rather different thermal regimes can be observed in Oyster Creek and Barnegat Bay. In Oyster Creek, initial mixing of the condenser discharge with dilution water produces a reduction in discharge temperature of between 2.8 to 5.6 °C (5 to 10 °F) depending upon whether one or two dilution pumps are operating. Little temperature decay is observable east of U.S. Route 9 until the discharge reaches Barnegat Bay. Minimal horizontal or vertical temperature change occurs in Oyster Creek between U.S. Route 9 and the bay because of the relatively-short residence time and the lack of turbulence or additional dilution. In Barnegat Bay, temperatures are rapidly reduced as substantial mixing with ambient temperature bay water and heat rejection to the atmosphere occurs. In the bay, the plume spreads on the surface, thereby facilitating heat rejection by direct radiation and evaporation to the atmosphere. Thus, there is a very small area near the OCNGS condenser discharge of relatively-high excess temperature in which turbulent dilution mixing produces rapid temperature reductions; a somewhat larger area in Oyster Creek between the OCNGS and Barnegat Bay in which little further temperature reduction occurs; and a still larger area in the bay in which the plume spreads on the surface.

About 150 m (492 ft) east of the mouth of Oyster Creek the water depth decreases from approximately 3.4 m (11 ft) to 1.5 m (5 ft), causing turbulence and mixing and directing the plume toward the surface. In general, excess temperatures do not remain on the bottom of the bay except in the area immediately adjacent to the mouth of Oyster Creek. Shoreline plumes may extend from the surface to the bottom since the water depths are usually less than 1.5 m (5 ft). In Barnegat Bay, the plume occupies a relatively large surface area with low excess temperatures where the balance of the heat discharged by the OCNGS is dissipated to the atmosphere or diluted by entrained bay water. The surface excess temperature isotherm of 2.2 °C (4 °F) under all operating conditions is contained in a rectangle approximately 1.6 km (1 mi) along the east-west axis by 5.6 km (3.5 mi) along the north-south axis bounding the mouth of Oyster Creek. For the 0.8 °C (1.5 °F) isotherm, the rectangle is 2.4 km (1.5 mi) by 7.2 km (4.5 mi). All measured plumes exhibited a plume length of approximately two to three times their width (JCP&L 1986).

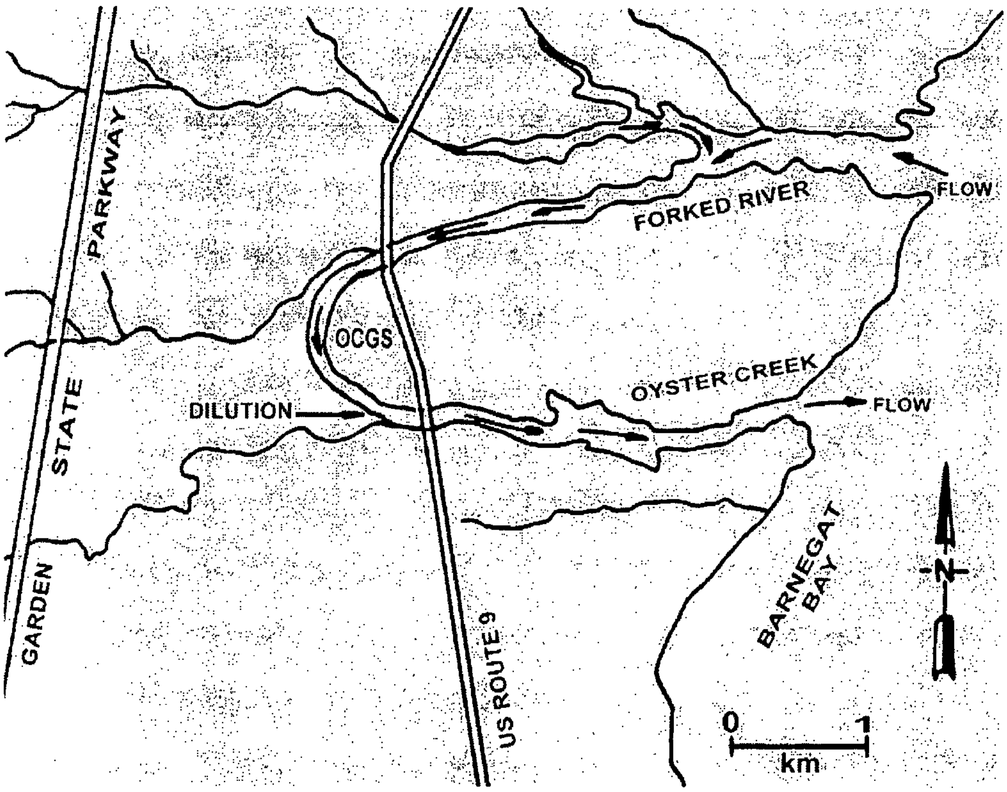


Figure 4-1
Flow characteristics at Forked River, Oyster Creek, and adjacent bay localities. (After Kennish and Olsson, 1975.) Note: OCGS in this figure is OCNGS.

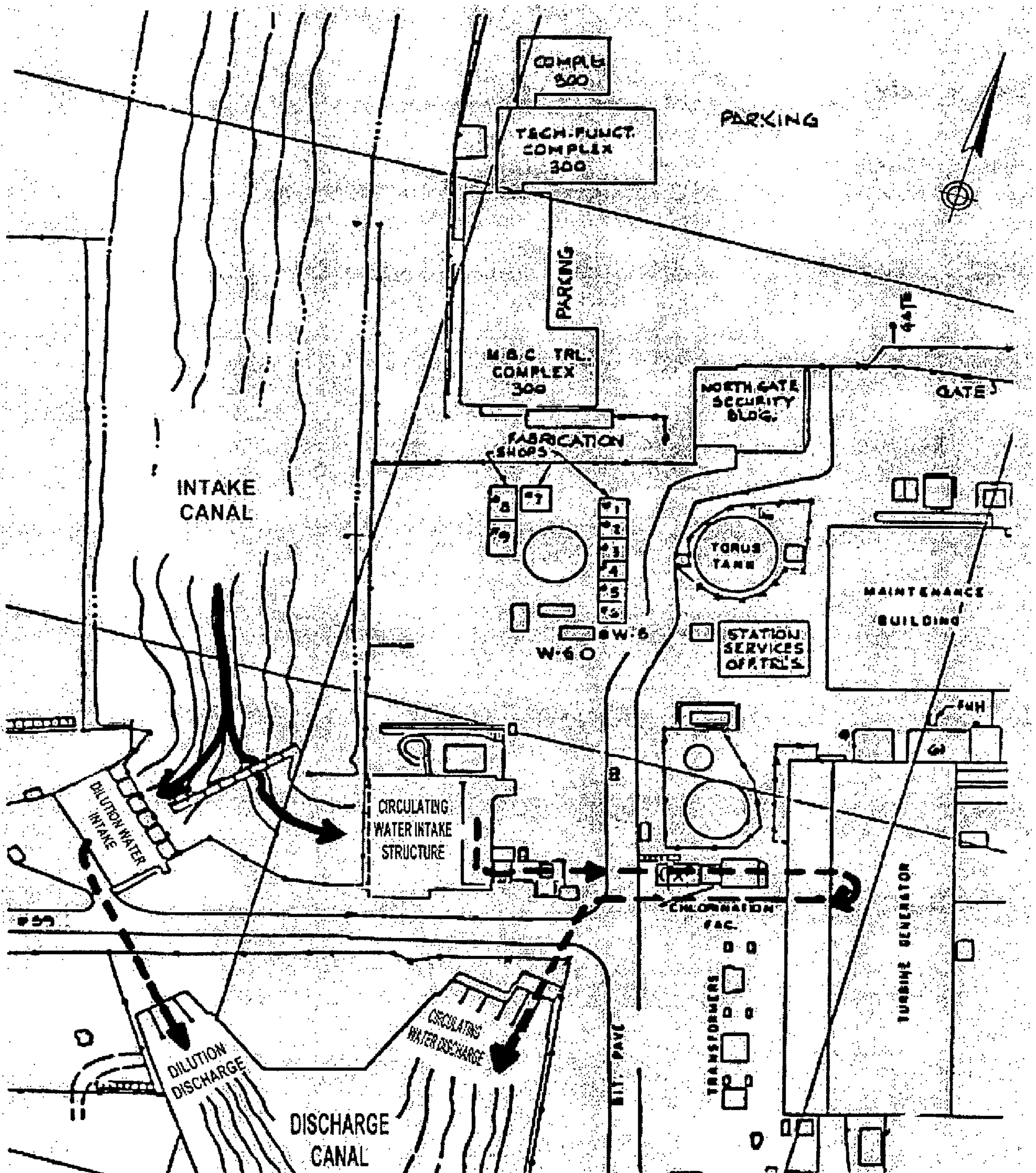


Figure 4-2
Schematic diagram of the Oyster Creek Nuclear Generating Station Circulating Water System (CWS) and Dilution Water System (DWS) flows.

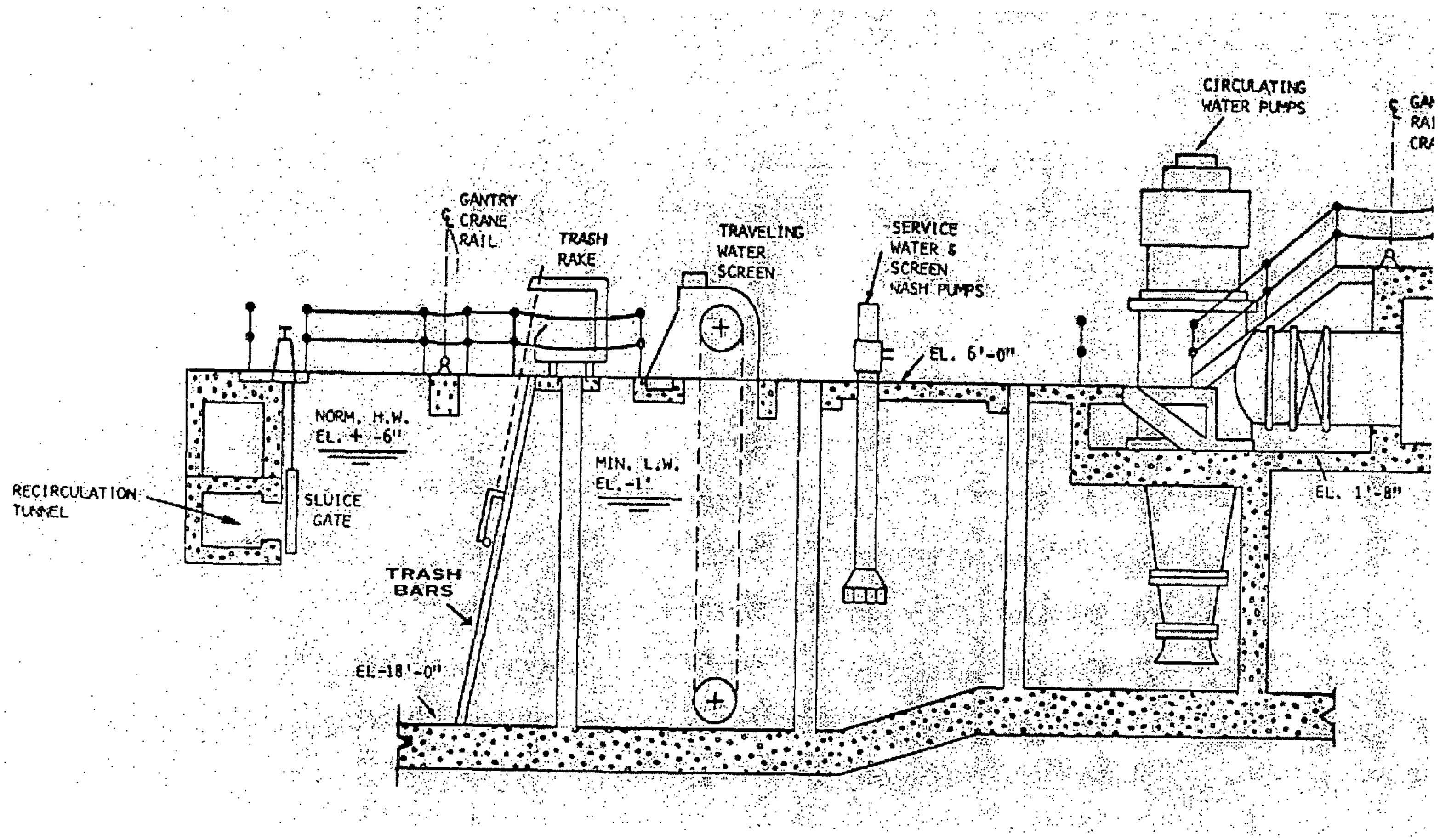


Figure 4-3
Oyster Creek Nuclear Generating Station Circulating Water System intake structure, section view.

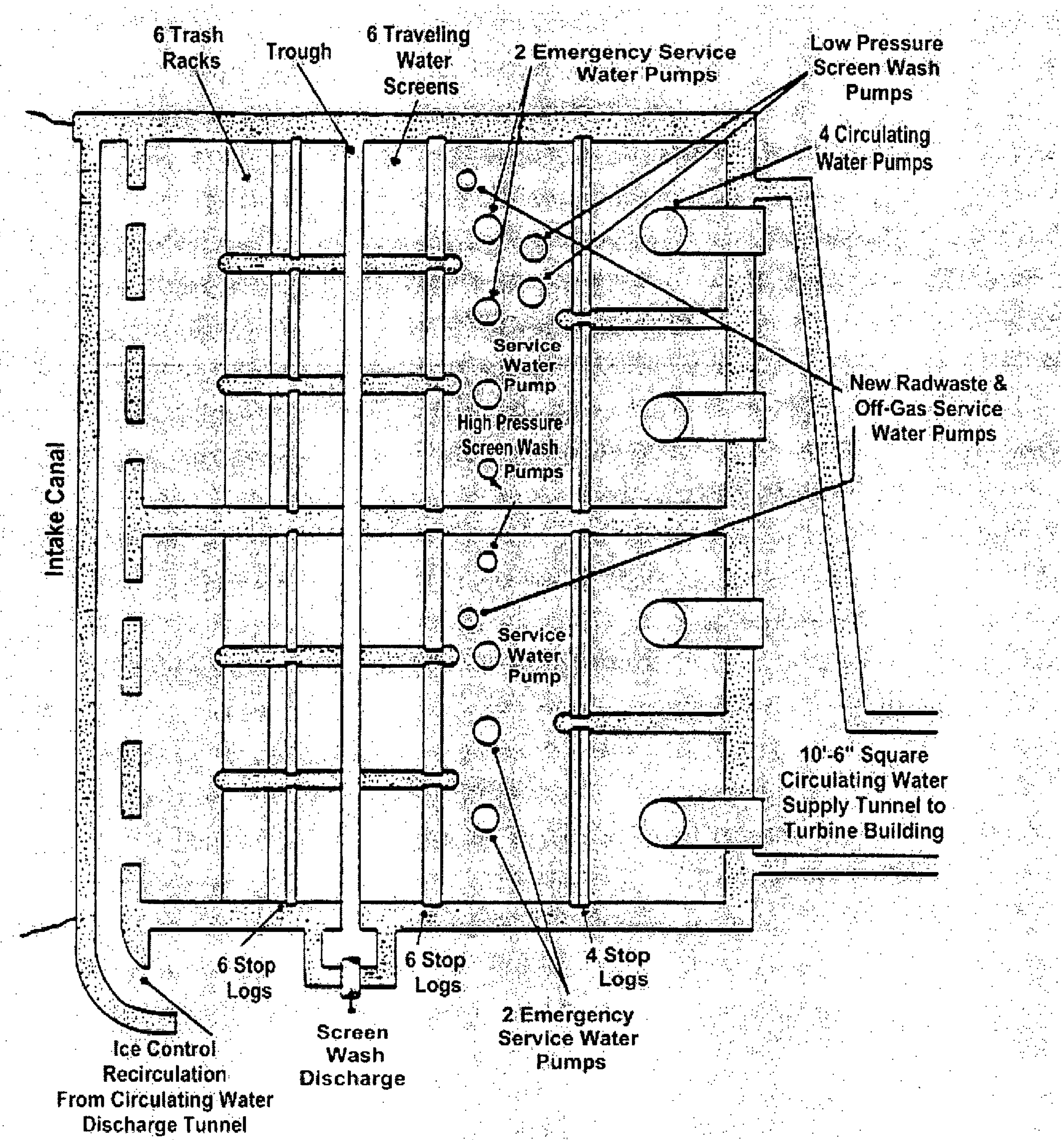


Figure 4-4
Oyster Creek Nuclear Generating Station Circulating Water System intake structure plan view.

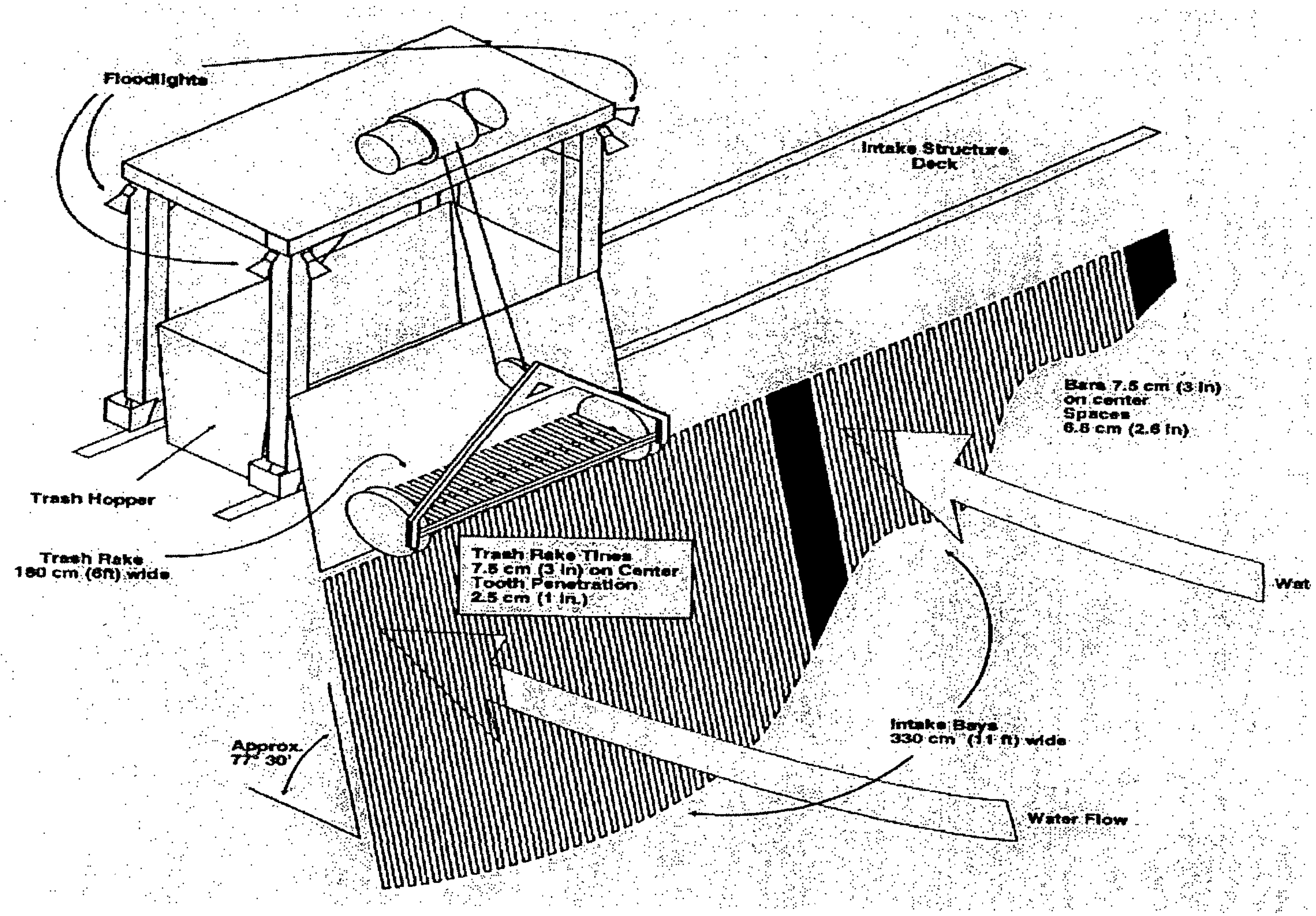


Figure 4-5
Schematic of the Oyster Creek Nuclear Generating Station Circulating Water System (CWS) and Dilution Water System (DWS) intake structures showing trash cart, trash rake and trash bars.

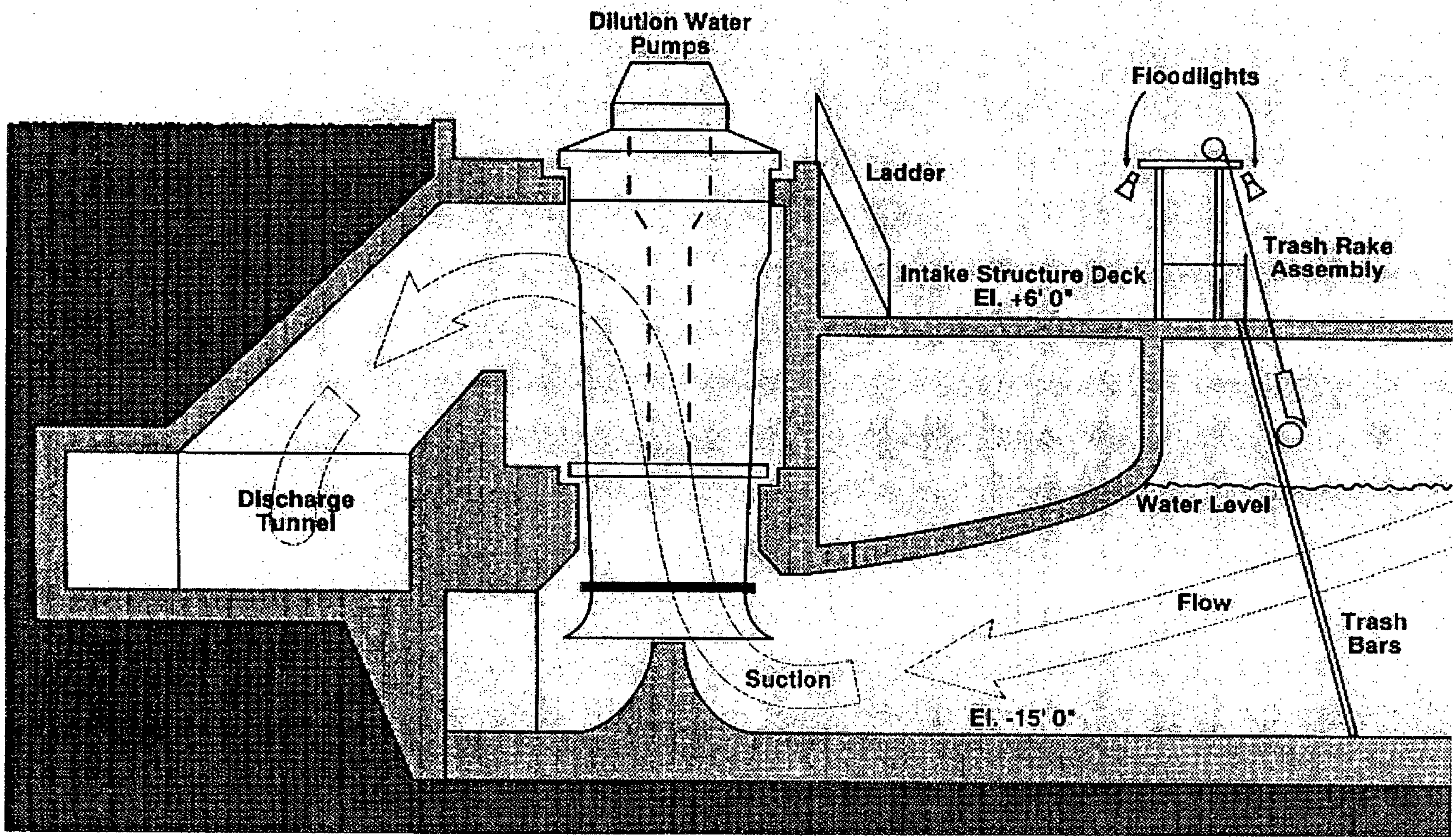
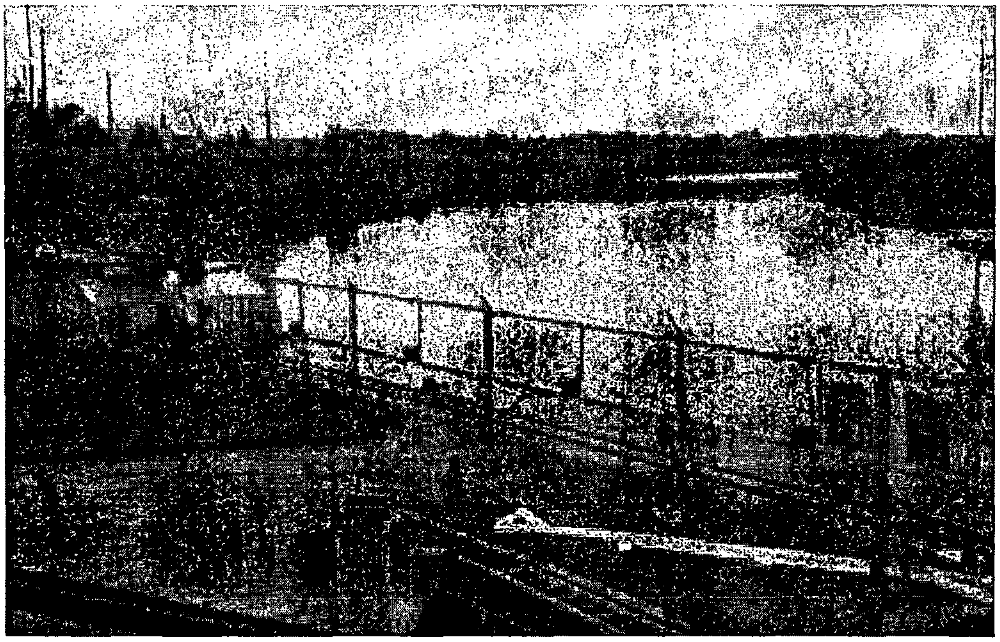


Figure 4-6
Oyster Creek Nuclear Generating Station Dilution Water System intake structure, section view.



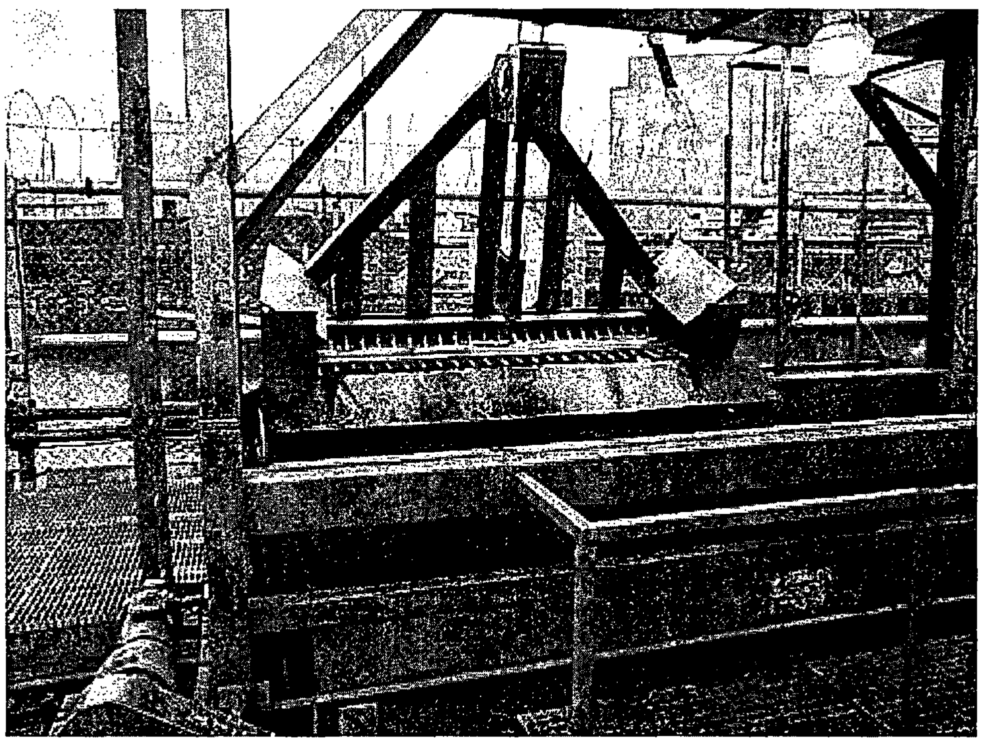


Figure 4-7
View of the Oyster Creek Nuclear Generating Station Intake Canal looking upstream from the Dilution Water System Intake (top); closeup of trash rake and trash cart (bottom).

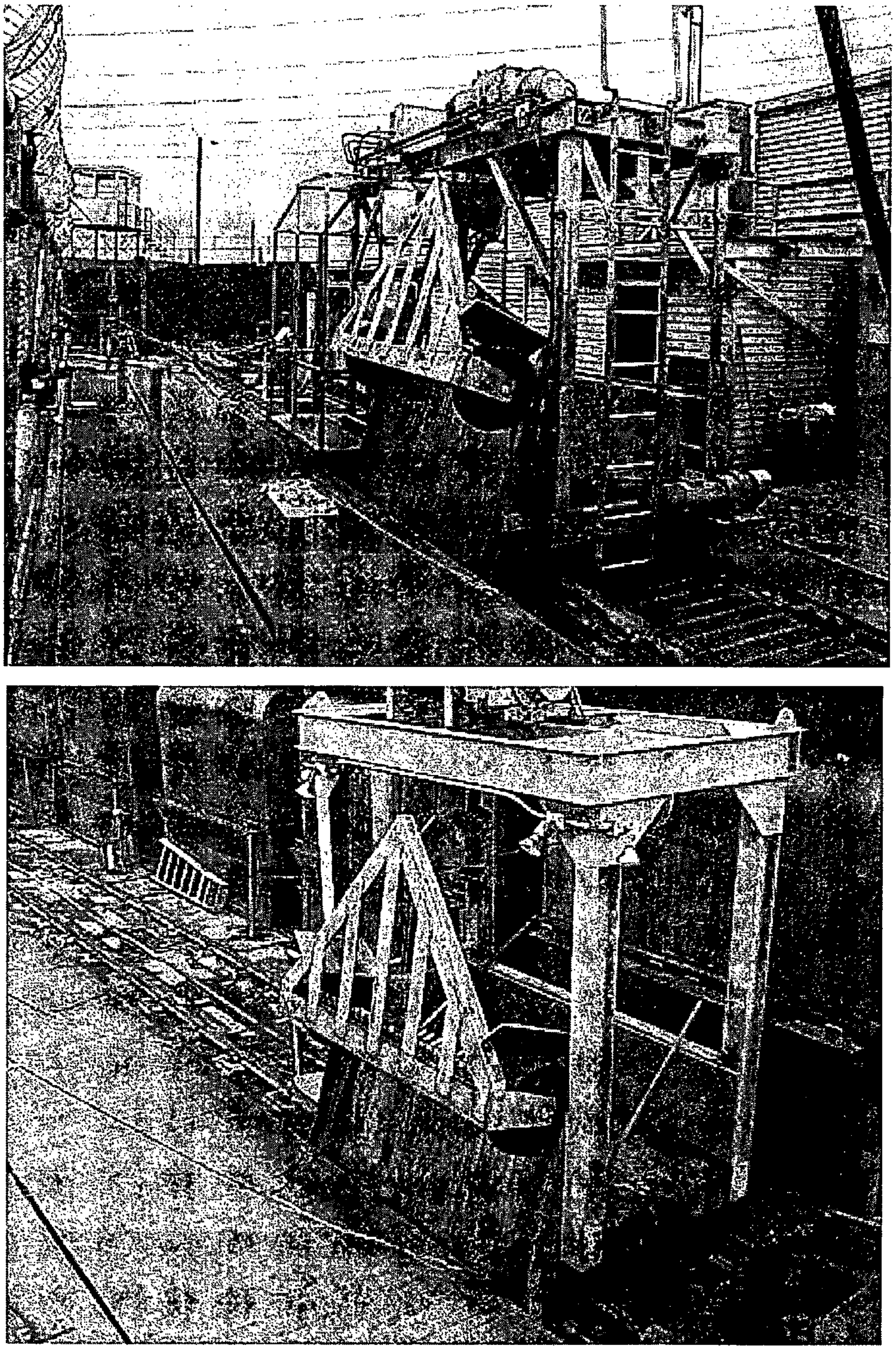


Figure 4-8
Trash rake and trash cart apparatus at the Dilution Water System (top) and the Circulating Water System (bottom) intakes at the Oyster Creek Nuclear Generating Station.
Note floodlights attached to trash carts.

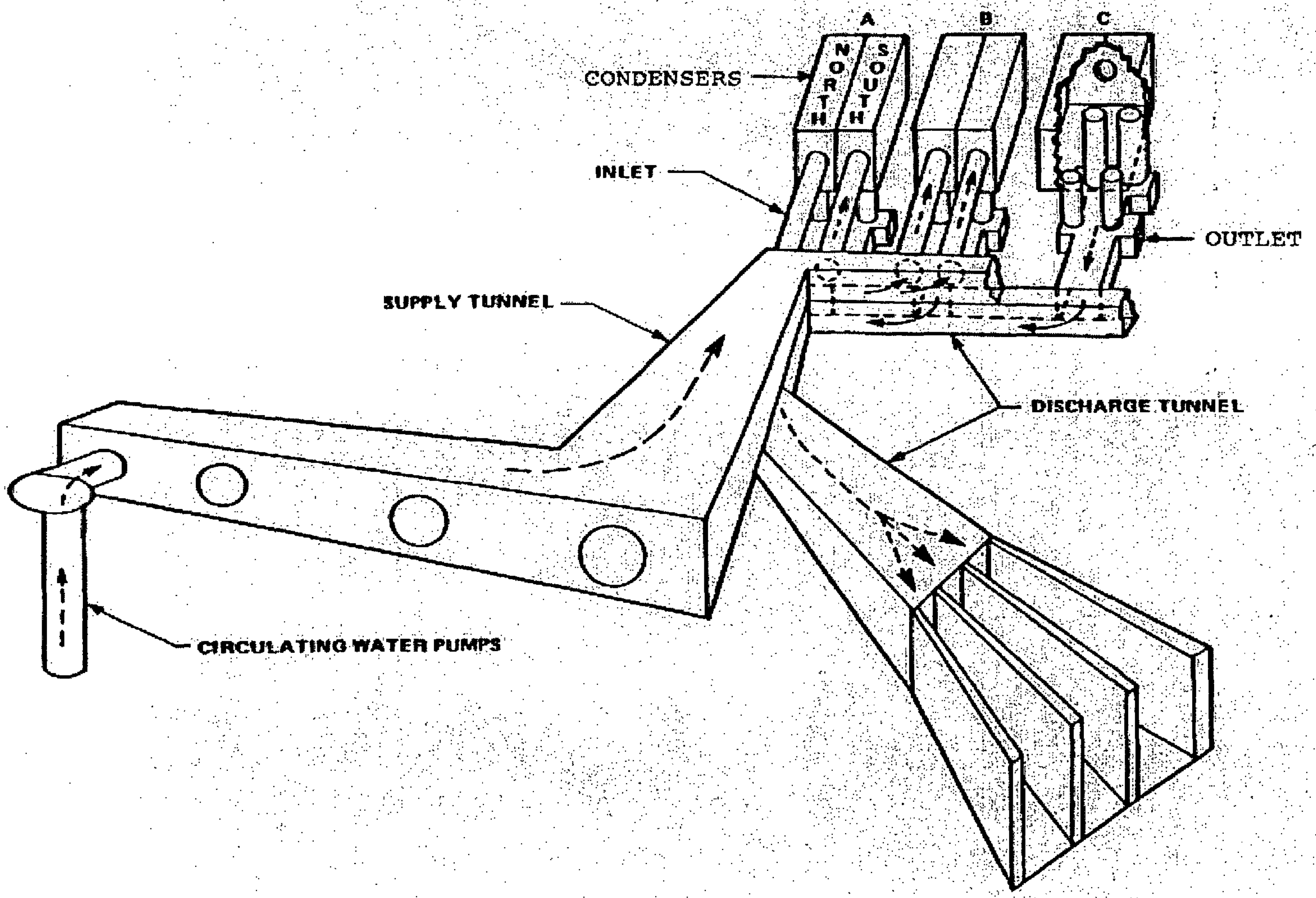


Figure 4-9
Schematic (oblique view) of the intake and discharge tunnels at the Oyster Creek Nuclear Generating Station.

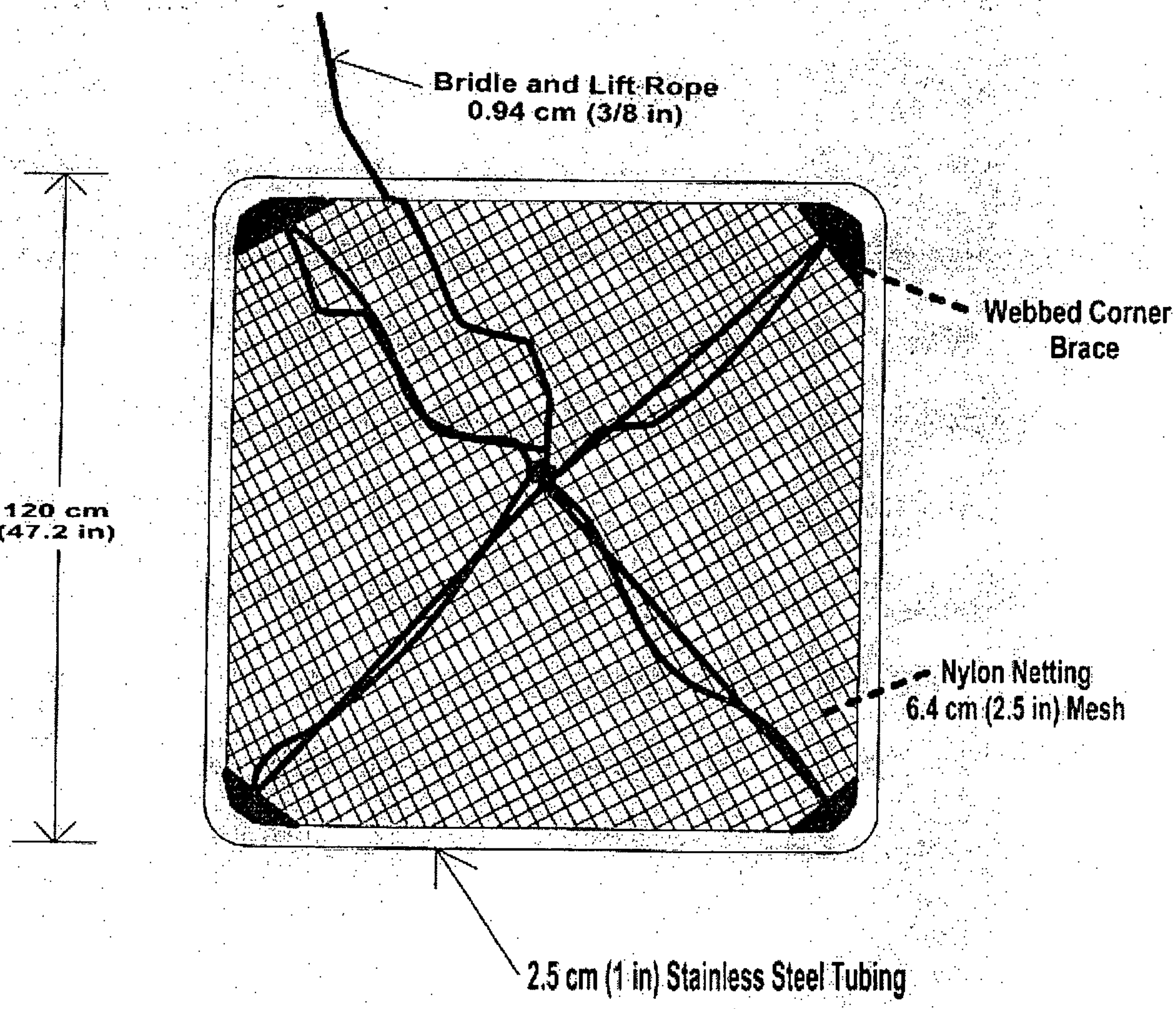


Figure 4-10
Sea turtle rescue sling/lift net.

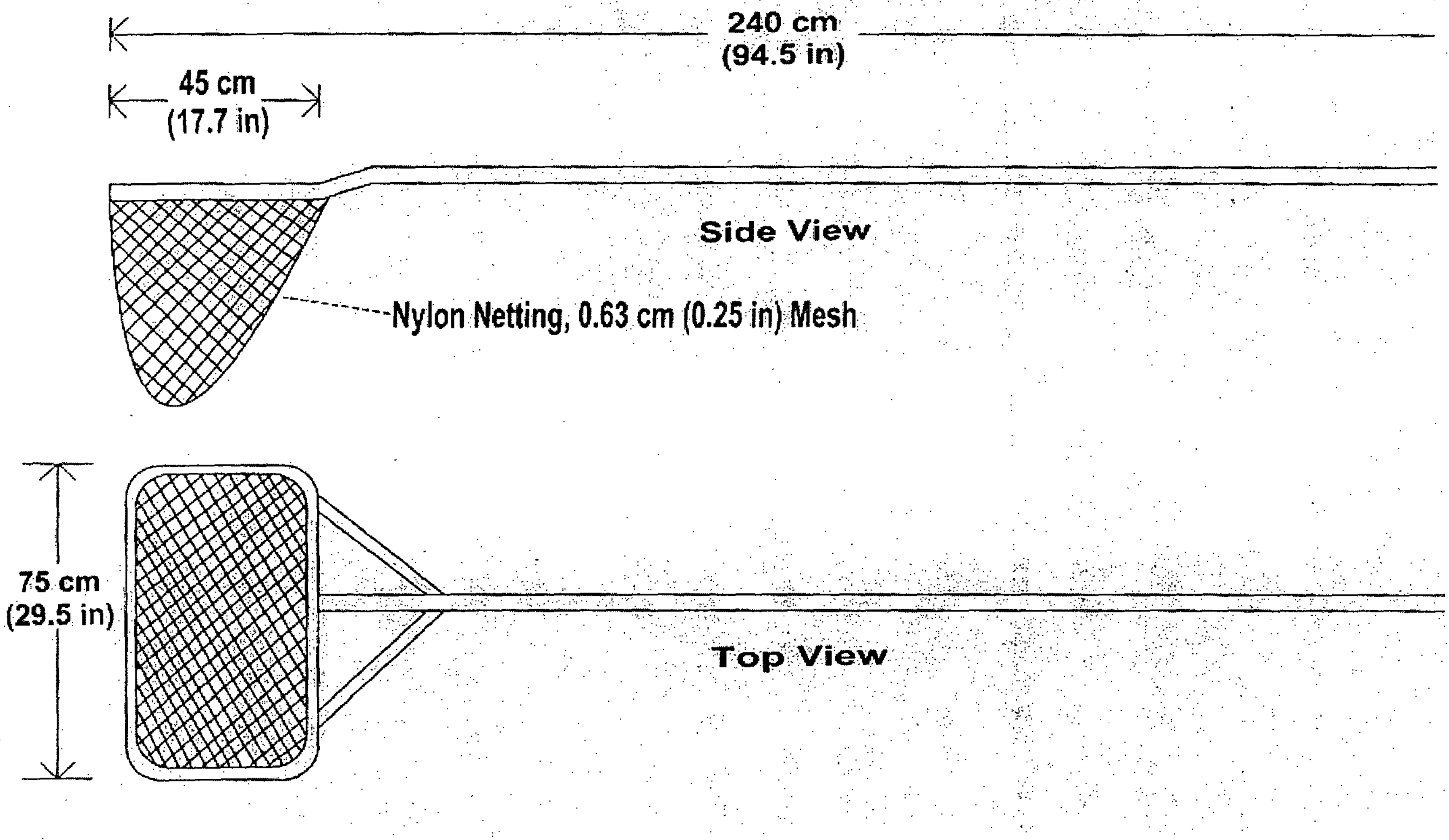


Figure 4-11
Long handled dipnet for sea turtle retrieval at the Oyster Creek Nuclear Generating Station.

5.0 Information on Sea Turtle Species

5.1 General Sea Turtle Information

Living sea turtles are taxonomically represented by two families, five genera, and seven species (Hopkins and Richardson 1984; Carr 1952). The family Cheloniidae is comprised of four genera and six distinct species. These species are *Caretta caretta* (loggerhead turtle), *Chelonia mydas* (green turtle), *Natador depressa* (flatback turtle), *Eretomochelys imbricata* (hawksbill turtle), *Lepidochelys kempii* (Kemp's ridley turtle), and *L. olivacea* (olive ridley turtle). The family Dermochelyidae is comprised of only one genus and species, *Dermochelys coriacea*, commonly referred to as the leatherback turtle.

Most sea turtle species are distributed throughout all of the tropical oceans. The flatback turtle is a major exception as it has a very limited range only in Pacific waters near Australia and Papua New Guinea. Also, the loggerhead occurs primarily in temperate latitudes, and the leatherback, although nesting in the tropics, frequently migrates into cold waters at higher latitudes because of its unique physiology (Mager 1985).

Sea turtles are believed to be descended from species known from the late Jurassic and Cretaceous periods that were included in the extinct family Thallassemyidae (Carr 1952; Hopkins and Richardson 1984). Modern sea turtles have short, thick, incompletely retractile necks, and legs that have been modified to become flippers (Bustard 1972; Carr 1952). All species, except the leatherback, have a hard, bony carapace modified for marine existence by streamlining and weight reduction (Bustard 1972). Chelonians have only a thin layer of bone covered by overlaying scutes and *D. coriacea* has a smooth scaleless black skin and soft carapace with seven longitudinal keels (Carr 1952). These differences in structure are the principal reason for their designation as the only species in the monotypic family Dermochelyidae (Carr 1952).

Sea turtles spend most of their lives in an aquatic environment, and males of many species may never leave the water (Hopkins and Richardson 1984; Nelson 1988). The recognized life stages for these turtles are egg, hatchling, juvenile/subadult, and adult (Hirth 1971). A generalized sea turtle life cycle is presented in Figure 5-1.

Reproductive cycles in adults of all species involve some degree of migration in which the animals return to nest at the same beach year after year (Hopkins and Richardson 1984). Nesting generally begins about mid April and continues into September (Hopkins and Richardson 1984; Nelson 1988; Carr 1952). Mating and copulation occur just off the nesting beach, and it is theorized that sperm from one nesting season may be stored by the female and thus fertilize a later season's eggs (Ehrhart 1980). A nesting female moved shoreward by the surf lands on the beach and crawls to a point above the high water mark (Carr 1952). She then proceeds to excavate a shallow body pit by twisting her body in the sand (Bustard 1972). After digging the body pit she proceeds to excavate an egg chamber using her rear flippers (Carr 1952). Clutch size, egg size, and egg shape are species specific (Bustard 1972). Incubation periods for loggerhead, Kemp's ridley, Atlantic green, olive ridley, and flatback turtles average 55 days but range from 45 to 65 days depending on local conditions (Nelson 1988). Hawksbill and leatherback turtles have a slightly longer incubation period ranging from 50 to 74 days (Pacific Whale Foundation 2003; Connecticut Department of Environmental Protection 2000).

Hatchlings emerge from the nest at night, breaking the eggshell and digging their way out of the nest (Carr 1952). They find their way across the beach to the surf by orienting to light reflecting off the breaking surf (Hopkins and Richardson 1984). Once in the surf, hatchlings exhibit behavior known as "swim frenzy," during which they swim in a straight line for many hours (Carr 1986). Once into the waters off the nesting beach, hatchlings enter a period known as the "lost year." Researchers are presently trying to determine where young sea turtles spend their earliest years, what habitat(s) they prefer at this age, as well as typical survival rates during the "lost year" (i.e., during their post-hatchling early pelagic stage). It is currently believed the period encompassed by the "lost year" may actually turn out to be several years, and various hypotheses have been put forth regarding sea turtle activities during this period. One is that hatchlings may become associated with floating Sargassum rafts offshore. These rafts provide shelter and are dispersed randomly by the currents (Carr 1986). Another hypothesis is that the "lost year" of some species may be spent in a salt marsh/estuarine system (Garmon 1981).

The functional ecology of sea turtles in the marine and/or estuarine ecosystem is varied. The loggerhead is primarily carnivorous and has jaws well-adapted to crushing molluscs and crustaceans and grazing on encrusted organisms attached to reefs, pilings, and wrecks; the Kemp's ridley is omnivorous and feeds on swimming crabs, crustaceans, and molluscs (Seney et al. 2002); the Atlantic green turtle is a herbivore and grazes on marine grasses and algae; the leatherback is a specialized feeder preying primarily upon jellyfish; the olive ridley feeds mostly on shrimp, crabs, sea urchins, and jellfish; the hawksbill is an omnivorous scavenger feeding mostly on sponges affixed to coral reefs as well as a few other invertebrates; the flatback prefers to eat sea cucumbers, soft corals, and jellyfish. Until recently, sea turtle populations were relatively large and subsequently played a significant role in the marine ecosystem. This role has been greatly reduced in most locations as a result of declining turtle populations. These population declines were a result of, among other things, natural factors such as disease and predation, habitat loss, commercial overutilization, commercial fishing bycatch mortality and the lack of comprehensive regulatory mechanisms to ensure their protection throughout their geographic range. This has led to several species being threatened with extinction.

Due to changes in habitat use during different life history stages and seasons, sea turtle populations are difficult to census (Meylan 1982). Because of these problems, estimates of population numbers have been derived from various indices such as numbers of nesting females, numbers of hatchlings per kilometer of nesting beach and number of subadult carcasses (strandings) washed ashore (Hopkins and Richardson 1984). Six of the seven extant species of sea turtles are protected under the Endangered Species Act. Three turtles, Kemp's ridley, hawksbill, and leatherback, are listed as endangered. The Florida nesting population of Atlantic green turtle and Mexican west coast population of olive ridley are also endangered. All of the remaining populations of Atlantic green turtle, olive ridley, and loggerhead are threatened. The only unlisted species is the locally-protected Australian flatback turtle (Hopkins and Richardson 1984). Only three species of sea turtles (loggerheads, Kemp's ridleys and occasionally Atlantic greens) have been reported from Barnegat Bay and coastal waters near the OCNGS. Leatherbacks do occur in coastal New Jersey waters but typically are found at considerable distances offshore. Although they have been reported, occurrences of hawksbills are rare north of Florida. This BA addresses loggerheads, Kemp's ridleys, Atlantic greens, and leatherbacks; the ranges for olive ridleys, hawksbills, and flatbacks are beyond the scope of this BA and will not be discussed in detail. Regional sea turtle distribution will be discussed in more detail later in this section.

5.2 Loggerhead (*Caretta caretta*)

5.2.1 Description

The adult loggerhead turtle has a slightly-elongated, heart-shaped carapace that tapers towards the posterior and has a broad, triangular head (Pritchard et al. 1983). Loggerheads normally weigh up to 200 kg (450 lb) and attain a SCL up to 120 cm (48 in) (Pritchard et al. 1983). Their general coloration is reddish-brown dorsally and cream-yellow ventrally (Hopkins and Richardson 1984). Morphologically, the loggerhead is distinguishable from other sea turtle species by the following characteristics: 1) a hard shell; 2) two pairs of scutes on the front of the head; 3) five pairs of lateral scales on the carapace; 4) plastron with three pairs of enlarged scutes connecting the carapace; 5) two claws on each flipper; and, 6) reddish-brown coloration (Nelson 1988; Dodd 1988; Wolke and George 1981).

Loggerhead hatchlings are brown dorsally with light margins ventrally and have five pairs of lateral scales (Pritchard et al. 1983).

5.2.2 Distribution

Loggerhead turtles are circumglobal, inhabiting continental shelves, bays, lagoons, and estuaries in the temperate, subtropical and tropical waters of the Atlantic, Pacific, and Indian Oceans (Dodd 1988; Mager 1985).

In the western Atlantic Ocean, loggerhead turtles occur from Argentina northward to Newfoundland including the Gulf of Mexico and the Caribbean Sea (Carr 1952; Dodd 1988; Mager 1985; Nelson 1988; Squires 1954). Sporadic nesting is reported throughout the tropical and warmer temperate range of distribution, but the most important nesting areas are the Atlantic coast of Florida, Georgia, and South Carolina (Hopkins and Richardson 1984). The Florida nesting population of loggerheads has been estimated to be the second largest in the world (Ross 1982).

The foraging range of the loggerhead sea turtle extends throughout the warm waters of the U.S. continental shelf (Shoop et al. 1981). On a seasonal basis, loggerhead turtles are common as far north as the Canadian portions of the Gulf of Maine (Lazell 1980), but during cooler months of the year, distributions shift to the south (Shoop et al. 1981). Loggerheads frequently forage around coral reefs, rocky places, and old boat wrecks; they commonly enter bays, lagoons and estuaries (Dodd 1988). Aerial surveys of loggerhead turtles at sea indicate that they are most common in waters less than 50 m (164 ft) in depth (Shoop et al. 1981), but they occur pelagically as well (Carr 1986).

5.2.3 Food

Loggerheads are primarily carnivorous (Mortimer 1982). They eat a variety of benthic organisms including molluscs, crabs, shrimp, jellyfish, sea urchins, sponges, squids, and fishes (Nelson 1988; Seney et al. 2002). Adult loggerheads have been observed feeding in reef and hard bottom areas (Mortimer 1982). In the seagrass lagoons of Mosquito Lagoon, Florida, subadult loggerheads fed

almost exclusively on horseshoe crab (Mendonca and Ehrhart 1982). Loggerheads may also eat animals discarded by commercial trawlers (Shoop and Ruckdeschel 1982). This benthic feeding characteristic may contribute to the capture of these turtles in trawls.

5.2.4 Nesting

The nesting season of the loggerhead is confined to the warmer months of the year in the temperate zones of the northern hemisphere. In south Florida nesting may occur from April through September but usually peaks in late June and July (Dodd 1988; Florida Power & Light Company 1983).

Loggerhead females generally nest every other year or every third year (Hopkins and Richardson 1984) but multi-annual remigration intervals ranging from one to six years have been reported (Bjorndal et al. 1983; Richardson et al. 1978). When a loggerhead nests, it usually lay two to three clutches of eggs per season and lay 35 to 180 eggs per clutch (Hopkins and Richardson 1984). The eggs hatch in 46 to 68 days and hatchlings emerge two or three days later (Crouse 1985; Hopkins and Richardson 1984; Kraemer 1979).

Hatchling loggerheads are a little less than 5 cm (2 in) in length when they emerge from the nest (Hopkins and Richardson 1984; Florida Power & Light Company 1983). They emerge from the nest as a group at night, orient themselves seaward and rapidly move towards the water (Hopkins and Richardson 1984). Many hatchlings fall prey to sea birds and other predators following emergence. Those hatchlings that reach the water quickly move offshore and exist pelagically (Carr 1986).

There are at least four loggerhead nesting subpopulations in the western North Atlantic (Turtle Expert Working Group 2000). The Northern Nesting Subpopulation occurs from North Carolina to northeast Florida. The Southern Florida Nesting Subpopulation is the largest loggerhead nesting assemblage in the Atlantic, occurring from 29° N on the east coast to Sarasota on the west coast. The Florida Panhandle Nesting Subpopulation is found at Eglin Air Force Base and the beaches near Panama City, Florida. The Yucatan Nesting Subpopulation occurs on the eastern Yucatan Peninsula, Mexico. Historically, only minor nesting activity has occurred elsewhere in the western North Atlantic, with the exception of Central America (Turtle Expert Working Group 2000).

Nesting by loggerheads as far north as the New Jersey coast is considered rare. Anecdotal reports of loggerhead nests at Ocean City, NJ and Island Beach State Park during the 1980s are among the few known nesting activities in local waters (Schoelkopf, personal communication, 1993). More recently, a loggerhead nest was found at Holgate, NJ on Long Beach Island during the summer of 1994 (Schoelkopf, personal communication, 1994).

5.2.5 Population Size

Loggerhead sea turtles are the most common sea turtle in the coastal waters of the United States. Population size and temporal trends in abundance have been estimated using nesting data, stranding data and aerial surveys.

Based on numbers of nesting females, hatchlings per kilometer of nesting beach, and subadult carcasses (strandings) washed ashore, the total number of mature loggerhead females in the southeastern United States has been estimated to be from 35,375 to 72,520 (Hopkins and

Richardson 1984; Gordon 1983). The annual average adult female population along the U.S. Atlantic and Gulf coasts for the period 1989-1998 was estimated to be 44,780 individuals based upon nesting data (Turtle Expert Working Group 2000).

Adult and subadult (shell length greater than 60 cm [24 in]) population estimates have also been based on aerial surveys of pelagic animals observed by NOAA Fisheries during 1982 to 1984. Based on these studies, the number of adult and subadult loggerhead sea turtles from Cape Hatteras, North Carolina to Key West, Florida was estimated to be 387,594 individuals (NMFS 1987). This number was arrived at by taking the number of observed turtles and converting it to a population abundance estimate using information on the amount of time loggerheads typically spend at the surface.

Some sea turtles that die at sea wash ashore and are found stranded. The NOAA Fisheries Sea Turtle Salvage and Stranding Network (STSSN) collects stranded sea turtles along both the Atlantic and Gulf Coasts (Turtle Expert Working Group 2000; STSSN 2004). The largest number of loggerhead strandings during the period 1986-2001 (Figure 5-2) occurred along the southeast Atlantic Coast (14,404 turtles; 61 percent of total), followed by the Gulf Coast (5,320 turtles; 22 percent of total) and the northeast Atlantic Coast (4,047 turtles; 17 percent of total). Strandings in the southeast U.S. and the Gulf of Mexico declined in the early 1990's, but have generally increased since then. Strandings in the northeast have more than doubled during the same time period (Turtle Expert Working Group 2000; STSSN 2004).

Frazer (1986) suggested that loggerhead turtle nesting populations in the U.S. were declining, but positive steps have been taken to reverse that trend. In September of 1989, NOAA Fisheries regulations requiring the use of turtle excluder devices (TEDs) on commercial shrimp trawls were implemented. Based upon onboard observations of offshore shrimp trawling in the southeast Atlantic, NOAA Fisheries estimated that over 43,000 loggerheads were captured in shrimp trawls annually. The number of loggerhead mortalities from this activity was estimated to be 9,874 turtles annually (NMFS 1987). An estimated 5,000 to 50,000 loggerheads were killed annually during commercial shrimp fishing activities prior to regulations requiring the use of TEDs (NMFS 1991a). The use of TEDs may reduce sea turtle mortality in shrimp trawls by as much as 97 percent (Crouse et al. 1992). Studies of TED effects on reducing strandings in South Carolina and Georgia during the period 1980-1997 demonstrated reductions in strandings ranging from 40 to 58 percent (Crowder et al. 1995; Royle and Crowder 1998). Following the implementation of the TED requirement, strandings of drowned threatened and endangered sea turtle species, in areas where strandings were historically high, were dramatically lower for a few years (Figure 5-2), suggesting a reduction in shrimp trawl related mortality (Crouse et al. 1992; Turtle Expert Working Group 2000). Increases in strandings since 1993 are indicative of an increasing loggerhead population (Turtle Expert Working Group 2000).

Sea turtle nesting activity on two key beaches also increased considerably subsequent to the implementation of the TED regulations (Crouse et al. 1992). The total number of loggerhead nests laid along the U.S. Atlantic and Gulf coasts from 1989 through 1998 ranged from 53,014 to 92,182 per year. The number of nests increased at an average rate of approximately 3.6 percent per year and reached the maximum observed number (92,182) in 1998 (Turtle Expert Working Group 2000).

In addition to the apparent success of the TED program, restrictions on development in coastal areas have become more widespread in recent years and may reduce the rate of nesting habitat loss for sea turtles.

The observed trends in strandings and nesting activity in recent years, along with some evidence of a shift in size class distribution toward smaller turtles, suggest that the U.S. loggerhead population is increasing (Turtle Expert Working Group 2000) and that effective measures have been taken to mitigate a major source of loggerhead mortality. Various population estimates suggest that the number of adult and subadult turtles is probably in the hundreds of thousands in the southeastern United States alone. In addition, large populations of loggerheads occur in many other parts of the world (Ross and Barwani 1982; NMFS 1991a). These facts suggest that although this species needs to be conserved, it is not in any immediate risk of becoming endangered.

5.3 Kemp's Ridley (*Lepidochelys kempii*)

5.3.1 Description

The adult Kemp's ridley has a circular carapace and a medium-sized pointed head. Kemp's ridleys are the smallest of extant sea turtles. They normally weigh up to 42 kg (90 lb) and attain a SCL up to 70 cm (27 in) (Pritchard et al. 1983). Their general coloration is olivegreen dorsally and yellow ventrally (Hopkins and Richardson 1984). Morphologically, the Kemp's ridley is distinguishable from other sea turtle species by the following characteristics: 1) a hard shell; 2) two pairs of scutes on the front of the head; 3) five pairs of lateral scutes on the carapace; 4) plastron with four pairs of scutes, with pores, connecting the carapace; 5) one claw on each front flipper and two on each back flipper; and, 6) olive green coloration (Pritchard et al. 1983; Pritchard and Marquez 1973).

Kemp's ridley hatchlings are dark grey-black dorsally and white ventrally (Pritchard et al. 1983; Pritchard and Marquez 1973).

5.3.2 Distribution

Kemp's ridley turtles inhabit sheltered coastal areas and frequent larger estuaries, bays, and lagoons in the temperate, subtropical and tropical waters of the northwestern Atlantic Ocean and Gulf of Mexico (Mager 1985).

The foraging range of adult Kemp's ridley turtles appears to be restricted to the Gulf of Mexico. However, juveniles and subadults occur throughout the warm coastal waters of the U.S. Atlantic coast (Hopkins and Richardson 1984; Pritchard and Marquez 1973). Juveniles and subadults travel northward with vernal warming to feed in the productive coastal waters of Georgia through New England, but return southward with the onset of winter to escape the cold (Henwood and Ogren 1987; Lutcavage and Musick 1985; Morreale et al. 1988; Ogren 1989).

5.3.3 Food

Kemp's ridleys are omnivorous and feed on swimming crabs, crustaceans, fish, jellyfish, and molluscs (Pritchard and Marquez 1973; Seney et al. 2002).

5.3.4 Nesting

Nesting of Kemp's ridleys is mainly restricted to a stretch of beach near Rancho Nuevo, Tamaulipas, Mexico (Pritchard and Marquez 1973; Hopkins and Richardson 1984). Occasional nesting has

been reported in Padre Island, Texas and Veracruz, Mexico (Mager 1985; Turtle Expert Working Group 2000). An estimated 40,000 females nested on a single day in 1947, but between 1978 and 1990 there were less than 1,000 nests per season (Figures 5-3 and 5-4).

The nesting season of the Kemp's ridley is confined to the warmer months of the year primarily from April through July. Kemp's ridley females generally nest every year to every third year (Márquez et al. 1982; Pritchard et al. 1983). They lay two to three clutches of eggs per season and lay 50 to 185 eggs per clutch. The eggs hatch in 45 to 70 days and hatchlings emerge two to three days later (Hopkins and Richardson 1984).

Hatchling Kemp's ridleys are about 4.2 cm (a little less than 2 in) in length when they emerge from the nest (Hopkins and Richardson 1984). They emerge from the nest as a group at night, orient themselves seaward and rapidly move towards the water (Hopkins and Richardson 1984). Following emergence, many hatchlings fall prey to sea birds, raccoons, and crabs. Those hatchlings that reach the water quickly move offshore. Their existence after emerging is not well understood but is probably pelagic (Carr 1986). The post-pelagic stages are commonly found dwelling over crab-rich sandy or muddy bottoms. Juveniles frequent bays, coastal lagoons, and river mouths (NMFS 1992b).

5.3.5 Population Size

The Kemp's ridley is the most endangered of the sea turtle species. Based on nesting information from Rancho Nuevo, Ross (1989) estimated that the population was declining at a rate of approximately three percent per year. The lowest number of nests was observed in 1985 (740 nests), but since that time the number of nests has increased by approximately 11.3 percent per year (Turtle Expert Working Group 2000). In 1994, 1,565 nests were observed at Rancho Nuevo, and more Kemp's ridley nests have been laid each year since 1990 than in any previous year on record since 1978 (Byles, 1994). By 2000, the number of nests found at Rancho Nuevo increased to 3,788 (Marquez et al. 2001). It has been suggested that this increase in nesting activity reflects the reduction in shrimp trawl related mortality realized since the implementation of the NMFS TED regulations in September of 1989 (Crouse et al. 1992; Turtle Expert Working Group 2000). This hypothesis is supported by analyses of the number of nests counted versus hatchlings released (Turtle Expert Working Group 2000). The results of those analyses indicate that there has been an increase in survivorship from hatchling to maturity during the late 1980s and early 1990s. The increase in nesting activity is also likely to be attributable in part to an increase in recruitment to the population as a result of beach and nest protection efforts at Rancho Nuevo (Marquez et al. 1999; Turtle Expert Working group 2000). The adult Kemp's ridley population was estimated by Márquez (1989) to be approximately 2,200 adults based on the numbers of nests produced at Rancho Nuevo, this species's nesting cycle, male-female ratios, and fecundity. More recently, the Turtle Expert Working Group (1998; 2000) reported that age-based population models suggest that the Kemp's ridley population is increasing rapidly and that the trend was expected to continue into the future. While there is no current population estimate, the nesting population is estimated to be increasing ten percent each year (NOAA Fisheries 2003). As a result, we can expect to find increasing numbers of juveniles and subadults migrating northward each year as Atlantic coastal waters warm, to feed in the productive coastal estuaries.

Population estimates of immature *Lepidochelys kempii* are difficult to develop. Increases have been noted in the number of juvenile captures during the late 1980's and early 1990's in long-term tagging

studies in the northeast Gulf of Mexico (Ogren, unpublished data). If this increase is indicative of an overall increase in the juvenile population, more recruitment into the adult population should occur in the future (NMFS 1991a).

Kemp's ridleys also die at sea and wash ashore. The NOAA Fisheries Sea Turtle Salvage and Stranding Network (STSSN) collects stranded sea turtles along both the Atlantic and Gulf Coasts (Turtle Expert Working Group 2000; STSSN 2004; Figure 5-5). The largest number of Kemp's ridley strandings during the period 1986-2001 occurred along the Gulf Coast (3,495 turtles; 60 percent of total), followed by the southeast Atlantic Coast (1,555 turtles; 27 percent of total) and the northeast Atlantic Coast (748 turtles; 13 percent of total). The number of strandings along the Gulf Coast increased sharply in 1994 and 1995 but subsequently remained fairly constant (Turtle Expert Working Group 2000). Along the southeast Atlantic Coast, the number of strandings decreased somewhat during the early 1990s but tended to increase from 1993 through 2001. The number of strandings along the northeast Atlantic Coast was low and variable through 1997, but a noticeable increase was observed during the 1998-2001 period (Figure 5-5). A dramatic increase in strandings of Kemp's ridleys was also observed along the North Carolina coast from 1993 to 1999 (Boettcher 2002). Prior to 1993, 20 or fewer Kemp's ridley strandings were reported annually. The number of stranded individuals steadily increased from 12 in 1992 to a maximum of 122 in 1999. The timing of these increases in Kemp's ridley strandings seems to coincide with the implementation of the NOAA Fisheries TED regulations described above, and suggests that the population is increasing.

An analysis of the size of stranded Kemp's ridleys indicated that many more large immature individuals were stranded during the 1990s relative to the 1980s (Turtle Expert Working Group 2000). These results also suggest that juvenile mortality has decreased and that the population is increasing.

Onboard observation of offshore shrimp trawling by NOAA Fisheries in the southeast Atlantic indicated that over 2,800 Kemp's ridleys are captured in shrimp trawls annually. The number of Kemp's ridley mortalities attributable to this activity was estimated to be 767 turtles annually and most of these (65 percent) occurred in the western portion of the Gulf of Mexico (NMFS 1987). Magnuson et al. (1990) estimated the annual shrimp trawl bycatch mortality to be between 500 and 5,000 individuals. As discussed above, significant reductions in this source of mortality have been achieved as a result of the implementation of the TED regulations by the NOAA Fisheries in 1989 (Crouse et al. 1992). The reduction in shrimp-trawl-related mortality, as well as the efforts to protect nesting beaches, have probably resulted in the recent indications that the population is steadily increasing (Turtle Expert Working Group 1998; 2000).

Despite these improvements, the data suggest that this population remains at critically-low levels. This species was listed as endangered in 1970 and is considered the most endangered of all sea turtles (NMFS 1991a; Burke et al. 1994).

5.4 Atlantic Green Turtle (*Chelonia mydas*)

5.4.1 Description

The Atlantic green turtle is a medium-to-large sea turtle with a nearly oval carapace and a small, rounded head (Pritchard et al. 1983). Its carapace is smooth and olive brown in color with darker streaks and spots. Its plastron is yellow. Full-grown adult Atlantic greens normally weigh 100 to 150

kg (220 to 330 lb) and attain a SCL of 90 to 100 cm (35 to 40 in) (Pritchard et al. 1983; Hopkins and Richardson 1984; Witherington and Ehrhart 1989). Morphologically, this species can be distinguished from the other sea turtles by the following characteristics: 1) a relatively smooth shell with no overlapping scutes; 2) one pair of scutes on the front of the head; 3) four pairs of lateral scutes on the carapace; 4) plastron with four pairs of enlarged scutes connecting the carapace; 5) one claw on each flipper; and, 6) olive, dark brown mottled coloration (Nelson 1988; Pritchard et al. 1983; Carr 1952).

Hatchlings are about 25 grams (0.88 ounces) and 55 millimeters (2.2 in) long. They are have a black carapace that is white on the ventral side.

5.4.2 Distribution

Atlantic green turtles are circumglobally distributed mainly in waters between the northern and southern 20 °C (68 °F) isotherms (Mager 1985). Preferred nesting grounds include sandy beaches of mainland shores, barrier islands, coral islands, and volcanic islands (NOAA Fisheries 2002).

In the western Atlantic, several major assemblages have been identified and studied (Parsons 1962; Pritchard 1966; Schulz 1975; 1982; Carr et al. 1978). In U.S. Atlantic waters, Atlantic green turtles are found around the U.S. Virgin Islands, Puerto Rico, and the continental United States from Texas to Massachusetts (NMFS, 1991b). Nesting grounds extend from Texas to North Carolina as well as in the U.S. Virgin Islands and Puerto Rico. Eastern Florida has some of the main nesting beaches; other important nesting beaches are found on St. Croix and Puerto Rico (NOAA Fisheries 2002). Critical habitat is designated in waters around Isla Culebra, Puerto Rico.

5.4.3 Food

Atlantic green turtles leave their pelagic habitat phase and enter benthic feeding grounds upon reaching a SCL of 20 to 25 cm (8-10 in). They are primarily herbivores eating sea grasses and algae (NMFS 1991b). Jellyfish, sponges, and other organisms living on sea grass blades and algae add to their diet (Mager 1985). Pelagic post-hatchlings are most likely omnivorous (NOAA Fisheries 2002).

5.4.4 Nesting

Atlantic green turtle nesting primarily occurs on the Atlantic coast of Florida from June to September (Hopkins and Richardson 1984). Other important nesting beaches include beaches in Yucatán and Tortuguero, Costa Rica. It is thought that nesting activity is increasing in Florida and Tortuguero; sparse data make it impossible to reliably estimate nesting trends in Yucatán (NOAA Fisheries 2002).

Although males mate annually, females only nest every two to four years (NOAA Fisheries 2002). Mature females may nest one to seven times per season at about 10-to-18-day intervals (Carr et al. 1978). Average clutch sizes vary between 100 and 200 eggs that usually hatch within 45 to 60 days (Hopkins and Richardson 1984). Hatchlings emerge, mostly at night, travel quickly to the water, and swim out to sea. At this point, they enter a period that is poorly understood but is likely spent pelagically in areas where currents concentrate debris and floating vegetation such as *Sargassum* spp. (Carr 1986).

5.4.5 Population Size

Elimination and deterioration of many nesting beaches and less-frequent encounters with green turtles provided inferential evidence of declining stocks in the early to mid 1980s (Mager 1985; Hopkins and Richardson 1984). The number of Atlantic green sea turtles that existed before commercial exploitation and the total number that now exists are not known. Records show drastic declines in the Florida catch during the 1800s, and similar declines occurred in other areas, such as Texas, where they were commercially harvested in the past (Hildebrand 1982; Hopkins and Richardson 1984). Although estimates are not available for the total population, it is estimated, while taking into account the two-year remigration interval, that the nesting population in the southeastern U.S. is recovering and has reached an approximate level of 1,000 nesting females (NOAA Fisheries 2002). Also, in Indian River Lagoon in Florida, a long-term study in juvenile foraging grounds found significant increases between the early and late 1980s in the population of juvenile green turtles (NOAA Fisheries 2002).

There are many ongoing threats to the Atlantic green turtle population. While TED regulations have helped reduce incidental take in trawl fisheries, incidental takes with fishing gear interactions continue to occur. Other threats at sea include pollution, foraging habitat loss through human-based direct destruction and secondary siltation, vessel strikes, and suction dredges. Nesting beaches are threatened by erosion control, artificial lighting, beach armoring, and disturbance. Finally, green turtle fibropapillomatosis disease, an often fatal tumor disease, is widespread and may be a contributor to population decline in Hawaii and Florida (NOAA Fisheries 2002). Outside the U.S., some areas continue direct takes of green turtles for their shells, eggs, and meat.

5.5 Leatherback Turtle (*Dermochelys coriacea*)

5.5.1 Description

The leatherback turtle is the largest sea turtle. It has an elongated, somewhat triangularly-shaped body with longitudinal ridges or keels. It has a leathery, blue-black shell composed of a thick layer of oily, vascularized, cartilaginous material, strengthened by a mosaic of thousands of small bones. This blue-black shell may also have variable white spotting (Pritchard et al. 1983). Its plastron is white. Leatherbacks normally weigh up to 300 kg (660 lb) and attain a SCL of 140 cm (55 in) (Pritchard et al. 1983; Hopkins and Richardson 1984). Specimens as large as 910 kg (2,000 lb) have been observed.

Morphologically, this species can be easily distinguished from the other sea turtles by the following characteristics: 1) its smooth unscaled carapace; 2) carapace with seven longitudinal ridges; 3) head and flippers covered with unscaled skin; and, 4) no claws on the flippers (Nelson 1988; Pritchard et al. 1983; Pritchard 1971; Carr 1952).

5.5.2 Distribution

Leatherbacks have a circumglobal distribution and occur in the Atlantic, Indian, and Pacific Oceans. They range as far north as Labrador and Alaska to as far south as Chile and the Cape of Good Hope. Their occurrence farther north than other sea turtle species is probably related to their ability

to maintain a warmer body temperature over a longer period of time (NMFS 1985). Thompson (1984) reported that leatherbacks prefer water temperatures of about 20 °C (±50) (68 °F) and were likely to be associated with cooler, more productive waters than the Gulf Stream.

Aerial surveys have shown leatherbacks to be present from April to November between North Carolina and Nova Scotia, but most likely to be observed from the Gulf of Maine south to Long Island during summer (Shoop et al. 1981).

5.5.3 Food

The diet of the leatherback consists primarily of soft-bodied animals such as jellyfish and tunicates, together with juvenile fishes, amphipods, and other organisms (Hopkins and Richardson 1984).

5.5.4 Nesting

Leatherback turtle nesting occurs on the mid-Atlantic coast of Florida from late February or March to September (Hopkins and Richardson 1984; NMFS 1992a). Mature females may nest one to nine times per season at about 9-to-17-day intervals. Average clutch sizes vary between 50 and 170 eggs that usually hatch within 50 to 75 days (Hopkins and Richardson 1984; Tucker 1988). Hatchlings emerge, mostly at night, travel quickly to the water, and swim out to sea. The life history of the leatherback is poorly understood since juvenile turtles are rarely observed.

5.5.5 Population Size

The world population estimates for the leatherback have been revised upward to over 100,000 females in recent years due to the discovery of nesting beaches in Mexico (Pritchard 1983).

5.6 Hawksbill Turtle (*Eretmochelys imbricata*)

5.6.1 Description

Hawksbills are small to medium turtles with elongated heads with pointy mouths. The hawksbill turtle is best known for its "tortoise shell" carapace, which is mostly brown, mottled with light and dark spots on the dorsal side. The ventral side is a light yellow or white, acting as a natural camouflage against predators. Identifying characteristics include overlapping costal scutes, serrated marginal scutes, two pairs of prefrontal scales, and two claws on each flipper. The hatchling and juvenile carapaces are heart-shaped and become elongated as the turtles mature.

5.6.2 Distribution

Posthatchlings are pelagic while juvenile, subadult, and adult hawksbills are found in coral reef environments or in bays and estuaries with mangroves when coral reefs are absent. Generally, hawksbills are found in tropical and subtropical waters, although they have been sighted as far north as Maine in Atlantic waters. Most sightings on the eastern coast of the U.S. have been reported from Florida and Texas.

5.6.3 Food

The hawksbill diet consists mostly of sponges found on coral reefs. Other common prey include mollusks, algae, sea anemones, squid, and other invertebrates. Hawksbills use their sharp beak-like mouth to forage for sponges in crevices of coral reefs (Pacific Whale Foundation 2003).

5.6.4 Nesting

Hawksbill turtles have solitary nesting behavior and are known to nest in the U.S. in Puerto Rico, U.S Virgin Islands, Florida, and Hawaii. Critical habitat is designated for nesting beaches in Puerto Rico. Individual nesting sites are often under vegetation. Females nest every two to three years, and lay up to six clutches per season with a 15-to-21-day interval; the average clutch size has 130 eggs (Pacific Whale Foundation 2003).

5.6.5 Population Size

Although there are little data about the hawksbill turtle, nesting populations are thought to be declining. An estimate based on data from the early to mid 1990s is approximately 34,000 nesting females (Caribbean Conservation Corporation 2003a). Critical habitat is designated for some nesting beaches in Puerto Rico, but Mexico probably has the biggest nesting population in the Altantic and Caribbean. Most sightings off Texas and Florida are thought to be of populations from the Mexican nesting beaches.

5.7 Sea Turtles in Coastal Waters of New Jersey

Four species of sea turtle – loggerhead, Kemp's ridley, green, and leatherback – are known to occur in the coastal marine and estuarine waters of New Jersey, based on the records of sea turtle strandings compiled by the Marine Mammal Stranding Center (MMSC) (Schoelkopf 1994; Schoelkopf 2000; Bailey 2004). The MMSC is a member of the Northeast Sea Turtle Salvage and Stranding Network supported by NOAA Fisheries. The records of the MMSC include strandings of sea turtles along the seaside beaches of New Jersey as well as New Jersey's coastal embayments and estuaries such as Barnegat Bay and Delaware Bay.

The MMSC reported 1,254 sea turtle strandings in coastal New Jersey, from Delaware Bay to Sandy Hook, between 1977 and 2004 (Table 5-1). A total of 32 strandings (2.6 percent of total for New Jersey) occurred at the OCNGS during 1977-2004. The details of the strandings that occurred at the OCNGS are discussed in Section 6.0.

Loggerheads were the most commonly stranded turtle, comprising about two-thirds of the strandings in New Jersey between 1977 and 2004. Kemp's ridleys and leatherbacks were less common (5.4 and 26 percent of the strandings, respectively). Less than two percent of the reported strandings were Atlantic green turtles (Schoelkopf 1994; Schoelkopf 2000; Bailey 2004). Similar to the trends observed at other locations along the Atlantic coast (Turtle Expert Working Group 2000; Boettcher 2002; STSSN 2004), the number of strandings in New Jersey has generally tended to increase since the late 1980s (Table 5-1).

The vast majority of the strandings in New Jersey have occurred between June and October (Table 5-2), coincident with the seasonal movements of juveniles and subadults along the Atlantic coast, although leatherbacks occur virtually all year in New Jersey.

Stomach content analyses from dead turtles have shown that primary food items for loggerheads are often blue crabs and horseshoe crabs. Blue crabs occur during most of the year in the OCNGS intake and discharge canals and adjacent areas of Barnegat Bay. Horseshoe crabs move into Barnegat Bay to lay eggs in the spring and summer, which coincides with the northward seasonal movement of loggerheads along the coast. Also, Kemp's ridley stomachs that have been examined often contain primarily blue crab. From a functional, ecological viewpoint, loggerheads and Kemp's ridleys would be secondary consumers. They are not likely to be an important link in the Barnegat Bay food web because of their apparently low abundance.

5.7.1 Sea Turtles in Barnegat Bay

Sea turtles are not commonly found in Barnegat Bay. From 1975 to 1985, GPU Nuclear Corporation (OCNGS owner prior to AmerGen) and its environmental consultants conducted a biological monitoring program designed to describe and quantify the marine biota of Barnegat Bay. The program included sampling organisms impinged upon the CWS traveling screens and entrained in the cooling water flow of the condenser and dilution pump intakes at the OCNGS. In addition, thousands of trawl, seine, and gillnet samples were collected in Barnegat Bay, Forked River, and Oyster Creek (Danila et al. 1979; Ecological Analysts, Inc. 1981; EA Engineering, Science and Technology, Inc. 1986; EA Engineering, Science, and Technology, Inc. 1986a; Jersey Central Power and Light Company 1978; Tatham et al. 1977; Tatham et al. 1978).

Impingement and entrainment sampling involved the presence of two to four biologists at the intake structures during day and night sampling periods. No sea turtles were captured or observed during more than 20,000 hours of sampling.

Nearly 3,000 trawl samples were collected during day and night sampling periods. These samples consisted of five-minute hauls of a 4.9-meter (16 ft) semiballoon otter trawl. The trawl had a 3.8-cm (1.5-in) stretch-mesh body, a 3.2-cm (1.25-in) stretch-mesh cod end, and a 1.3-cm (0.5-in) stretch-mesh inner liner. No sea turtles were found in any of these samples. More than 2,000 seine samples were collected during day and night periods using 12.2-meter (40-ft) and 45.7-meter (150-ft) seines with 0.6-cm (0.25-in) and 1.3-cm (0.5-in) stretch mesh, respectively. No sea turtles were found in any of these samples.

Gillnet samples were collected using a 91.4-by-1.8-meter (300-by-6-ft) net consisting of three, 30.5-m (100-ft) panels of 38-, 70-, and 89-millimeter(mm) (1.5-, 2.75-, and 3.5-in) monofilament stretch mesh or a 61.0-m (200-ft) net, identical to that described above but without the 70-mm (2.75-in) mesh panel. Several hundred samples were collected during day and night periods, but no sea turtles were captured.

The New Jersey Department of Environmental Protection, Division of Fish, Game, and Wildlife has conducted periodic trawl and seine sampling in Barnegat Bay since 1971 (NJDEP 1973; Makai 1993; McLain 1993; Byrne 2004) and have reported no sea turtle captures. The scarcity of sea turtles in Barnegat Bay is not surprising considering the fact that the only direct access to the bay from the Atlantic Ocean is through a single, narrow inlet, approximately 300 m (1000 ft) wide.

Similarly, Rutgers University reports that only one loggerhead turtle was captured during more than five years of periodic trawl sampling in Great Bay and Little Egg Harbor, estuaries located immediately south of Barnegat Bay (Able 1993).

The location of the generating station relative to the inlet from the ocean, as well as the rate and velocity of the cooling water flows, should be considered when considering incidental capture rates at OCNGS. A sea turtle entering Barnegat Bay must travel along several kilometers of narrow, relatively shallow navigation channels, characterized by very heavy boat traffic, and pass through the wooden support structures of three bridges to reach the OCNGS (Figure 5-6).

There were no changes in the design or the mode of operation of the OCNGS that could explain the occurrence of 32 sea turtles at the facility between 1992 and 2004, when none had been observed previously despite intensive sampling efforts. This phenomenon was most likely attributable to changes in the accessibility of Barnegat Bay and increases in sea turtle population levels that occurred in approximately the same time frame. These same factors likely explain the recent increase in the number of incidental captures of Kemp's ridleys at the OCNGS.

The modifications to Barnegat Inlet that were completed in 1991 resulted in a significant increase in the depth of the inlet, and concomitant increase in the volume of water moving through the inlet during each tidal cycle. The average tidal prism following completion of the inlet modifications is approximately 2.5 times greater than during the 1980s prior to the modifications (Seabergh et al. 2003). In addition, the removal of shoals near the inlet entrance reduced the amount of turbulence associated with breaking surf. These changes may have made the Barnegat Inlet and Bay more accessible to sea turtles migrating along the Atlantic coast.

The nesting and stranding data discussed above indicate that both the loggerhead and the Kemp's ridley populations have been increasing since the early 1990s. These increases are probably attributable to the implementation of the NOAA Fisheries TED requirements in September of 1989 and the efforts to protect nesting beaches (Crouse et al. 1992; Turtle Expert Working Group 1998; Marquez et al. 1999; Turtle Expert Working Group 2000; Marquez et al. 2001; STSSN 2004). The use of TEDs has apparently resulted in a significant reduction in shrimp trawl bycatch mortality. According to NOAA Fisheries estimates (NMFS 1991a), prior to the use of TEDs shrimp trawls may have killed 5,000 to 50,000 loggerhead and more than 700 Kemp's ridleys each year. As a result of this significant reduction in sea turtle mortality and associated increases in population size, increasing numbers of juvenile and subadult sea turtles should be seasonally migrating along the Atlantic coast. This theory is supported by the observed increases in sea turtle strandings along the Atlantic coast (Table 5-1; Figures 5-2 and 5-5; Turtle Expert Working Group 2000; Boettcher 2002; STSSN 2004) and the recent increase in the number of incidental captures of Kemp's ridleys at the OCNGS (Figure 6-1).

Environmental factors, as well as population size and the accessibility of Barnegat Bay, probably played a role in the increase in the number of incidental captures of Kemp's ridleys at the OCNGS during 2004. One key environmental factor affecting the seasonal migrations of juvenile and subadult Kemp's ridley sea turtles is water temperature. Ocean water temperatures along the southern New Jersey coast during June-September 2004 were the third warmest since record keeping began more than 90 years ago in 1912 (National Weather Service 2004). The average ocean water temperature during the summer of 2004 was 1.4 °C (2.5 °F) above normal and 3 °C (5.4 °F) warmer than the previous year. These abnormally-high ocean water temperatures provided

excellent conditions to entice juvenile and subadult Kemp's ridleys to migrate further up the Atlantic coast in search of foraging grounds during 2004.

In addition to favorable water temperatures, the New Jersey coast also offered rich feeding grounds for Kemp's ridleys migrating up the Atlantic Coast. According to MacKenzie (2003), New Jersey landings of blue crabs, a favorite food item for Kemp's ridley turtles, increased from less than one million pounds per year during the 1960s to nearly eight million pounds in 1993. Although landings declined somewhat after 1993, they remained in the four-to-seven million-pound range through 2002.

It is difficult to predict future trends in the occurrence of sea turtles at the OCNGS. Environmental factors, such as water temperature and food availability, probably play a role in determining the number of sea turtles that enter Barnegat Bay in a given year. These factors are difficult to predict, however, and their impact on the movements of sea turtles is difficult to quantify. If the number of individuals migrating up and down the Atlantic coast is the major determining factor, incidental captures may increase if the TED regulations are as effective as they seem to be after the first several years of experience. Also, the efforts to protect nesting beaches result in increased recruitment to the populations. If accessibility to Barnegat Bay is the most important factor, the frequency of incidental captures at the OCNGS may decline with time. Barnegat Inlet is notoriously dynamic. The position of the channel shifts frequently, and the volume of the tidal prism continuously decreases due to sedimentation (Table 3-1; Ashley 1987; Seabergh et al. 2003b). As a result, accessibility to the bay through the inlet was probably at its maximum following the completion of the inlet modifications in 1991 and subsequent dredging in 1993, and is likely to decrease with time.

Table 5-1
Sea Turtle Strandings in New Jersey Coastal and Estuarine Waters Reported by the Marine Mammal Stranding Center

ANNUAL DISTRIBUTION					
YEAR	LOGGERHEAD	KEMP'S RIDLEY	LEATHERBACK	GREEN	UNKNOWN
1977	1	0	1	0	0
1978	4	0	2	0	0
1979	11	0	10	0	0
1980	9	0	2	0	0
1981	4	0	13	0	0
1982	2	0	13	0	0
1983	8	4	9	0	0
1984	8	0	2	0	0
1985	22	1	7	0	0
1986	15	0	2	0	0
1987	37	1	33	0	0
1988	13	0	6	0	0
1989	17	7	3	0	0
1990	26	0	9	1	0
1991	55	4	13	2	0
1992	39	5	5	1	0
1993	17	6	28	2	1
1994	33	4	9	1	1
1995	74	1	40	1	8
1996	51	2	5	0	0
1997	35	1	14	0	0
1998	47	1	4	0	1
1999	79	4	9	1	1
2000	40	5	9	3	5
2001	35	4	13	1	5
2002	44	6	19	0	5
2003	38	2	19	1	2
2004*	45	10	26	2	7
TOTAL	809	68	325	16	36

Notes: * 2004 data as of November 6, 2004.
No hawksbill strandings have been reported in New Jersey.
Sources: Schoelkopf 1993; Schoelkopf 2000; Bailey 2004.

Table 5-2
Seasonal Occurrence of Sea Turtle Strandings in New Jersey Coastal and Estuarine Waters
1980-2001

MONTHLY DISTRIBUTION (INCIDENTAL TAKES AT OCNGS)					
MONTH	LOGGERHEAD	KEMP'S RIDLEY	LEATHERBACK	GREEN	UNKNOWN
January	1(0)	1(0)	4(0)	0	0
February	0	1(0)	3(0)	0	0
March	0	0	0	0	1(0)
April	0	0	1(0)	0	0
May	0	0	2(0)	0	0
June	61(3)	1(1)	5(0)	0	3(0)
July	116(1)	12(9)	20(0)	1(1)	11(0)
August	150(1)	10(3)	44(0)	1(1)	7(0)
September	170(2)	11(6)	75(0)	2(0)	7(0)
October	80(0)	3(2)	54(0)	2(2)	0
November	8(0)	1(0)	18(0)	3(0)	1(0)
December	1(0)	1(0)	3(0)	0	0
TOTALS	587(7)	41(21)	229(0)	9(4)	30(0)
Note: No hawksbill strandings have been reported in New Jersey. Sources: NMFS 2000; STSSN 2004.					

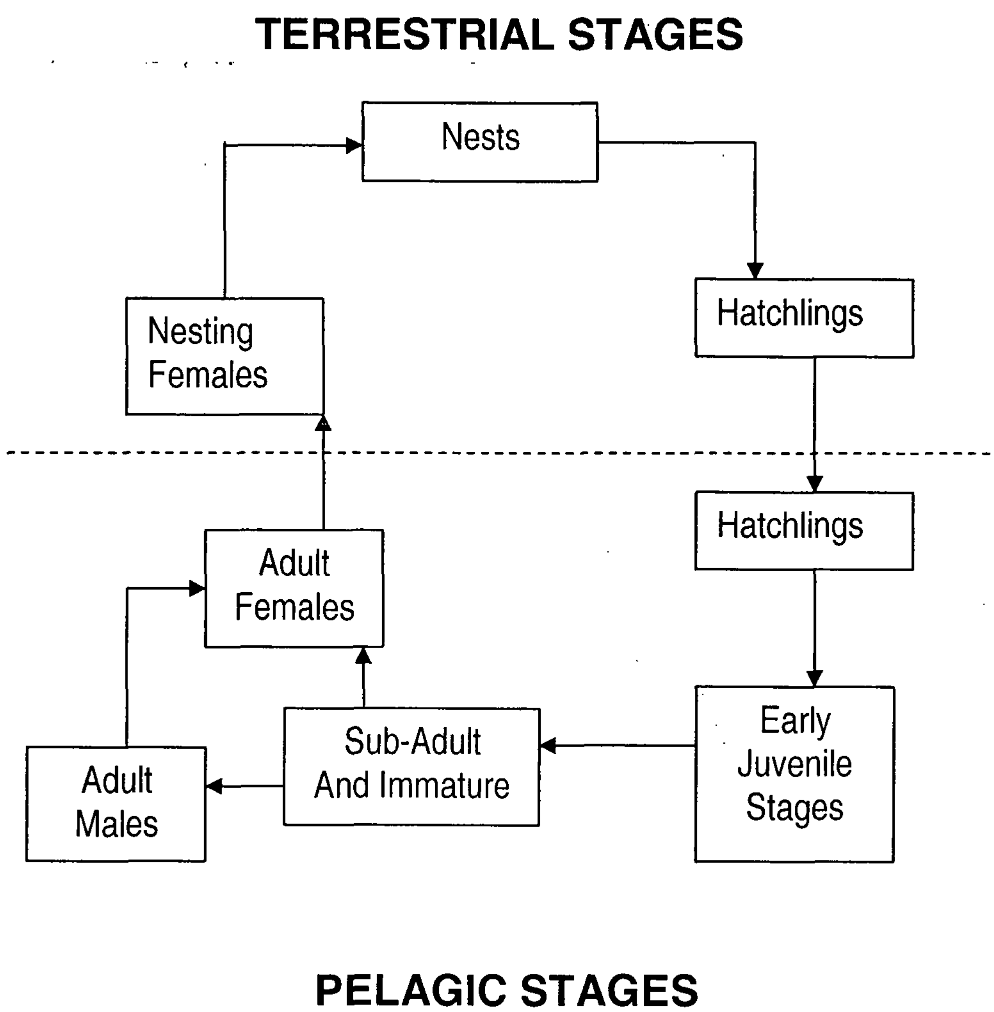


Figure 5-1
Generalized sea turtle life cycle (After PSE&G 1989).

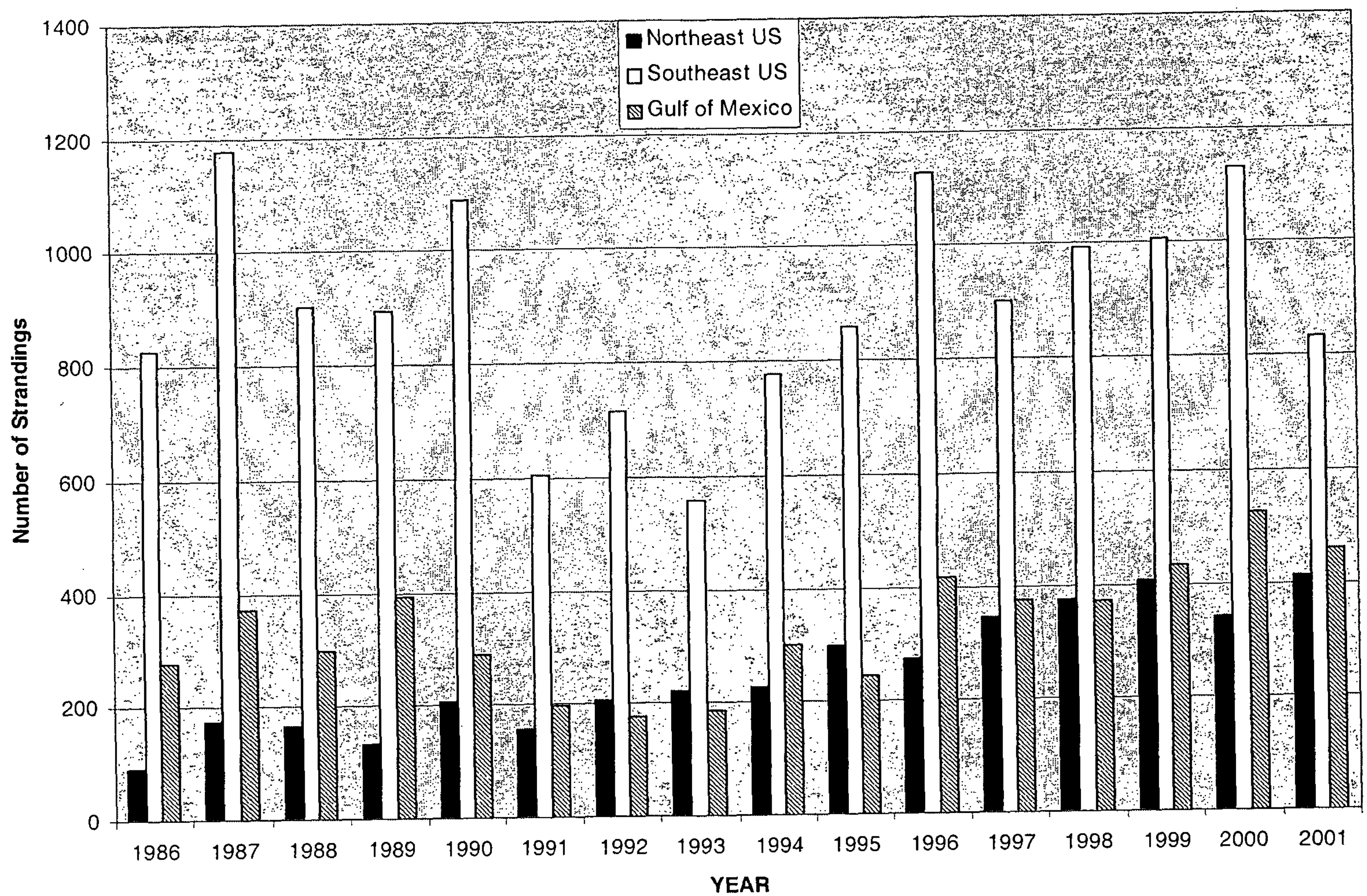


Figure 5-2

Loggerhead sea turtle strandings by region, 1986-2001 (After Turtle Expert Working Group 2000 and STSSN 2004).

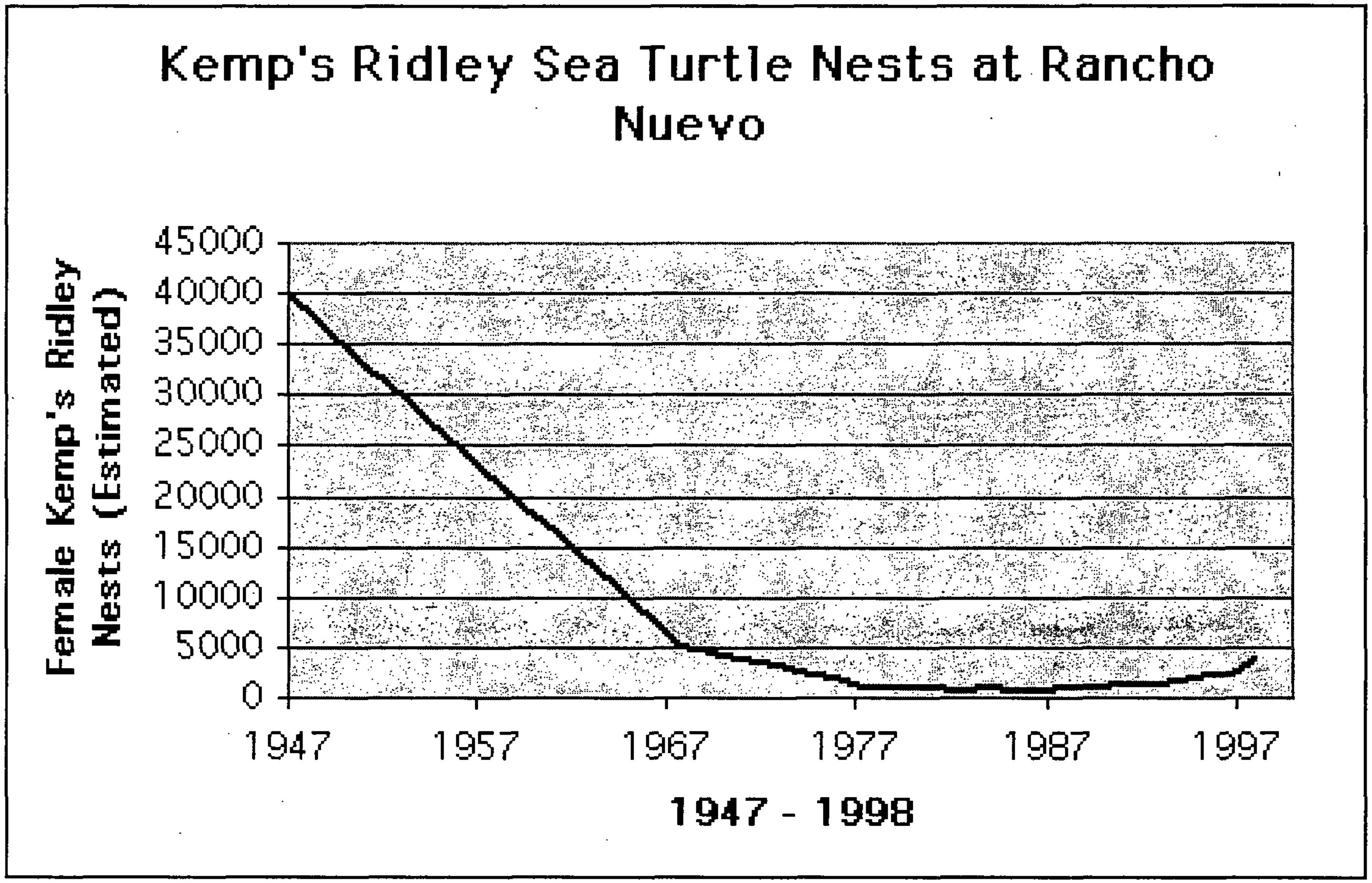


Figure 5-3
Estimated annual number of nesting female Kemp's Ridley sea turtles at Rancho Nuevo (HEART 1999).

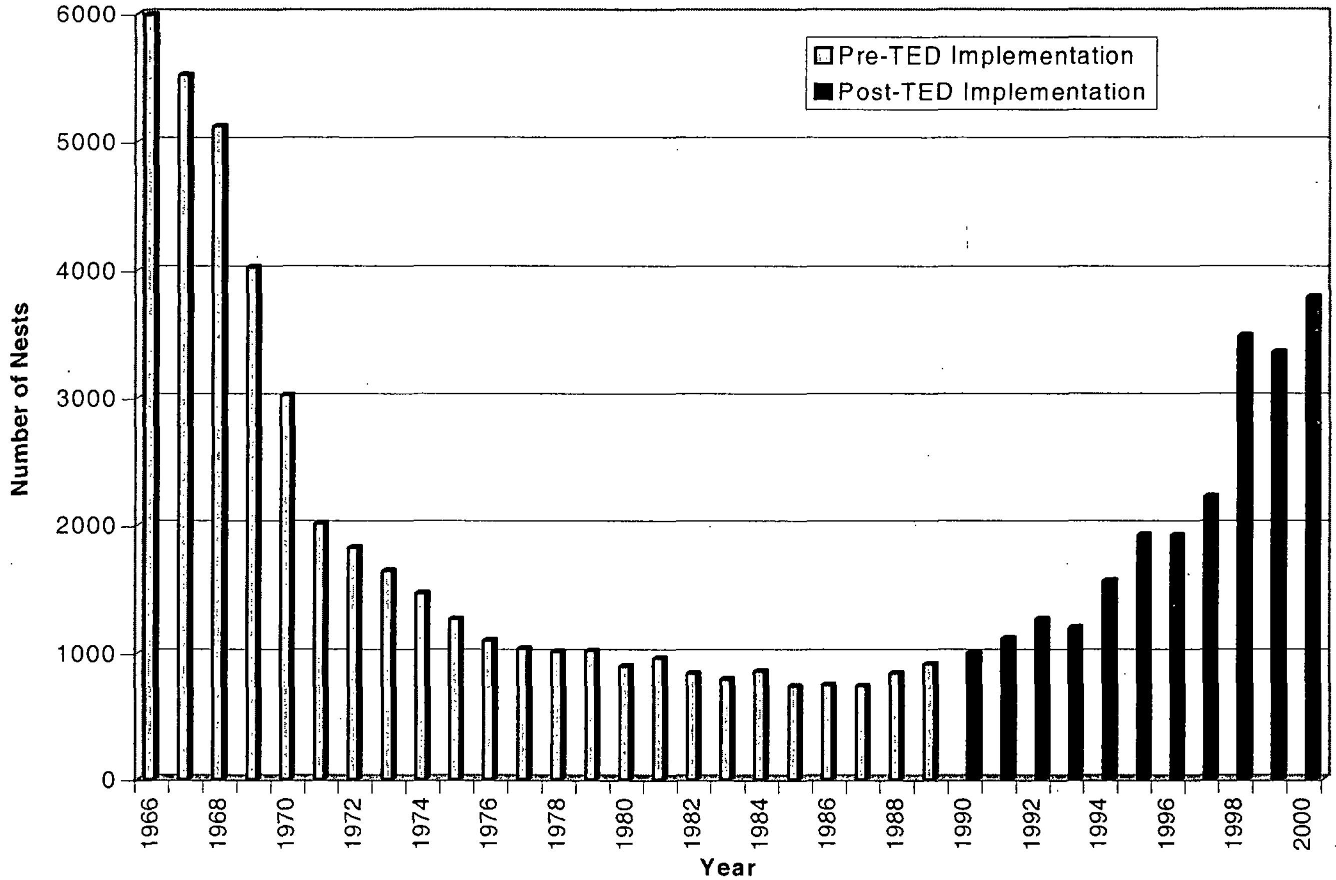


Figure 5-4
Number of Kemp's ridley nests at Rancho Nuevo before and after implementation of the TED Regulations in 1989.
(After Turtle Expert Working Group 2000 and Marquez et al. 2001)

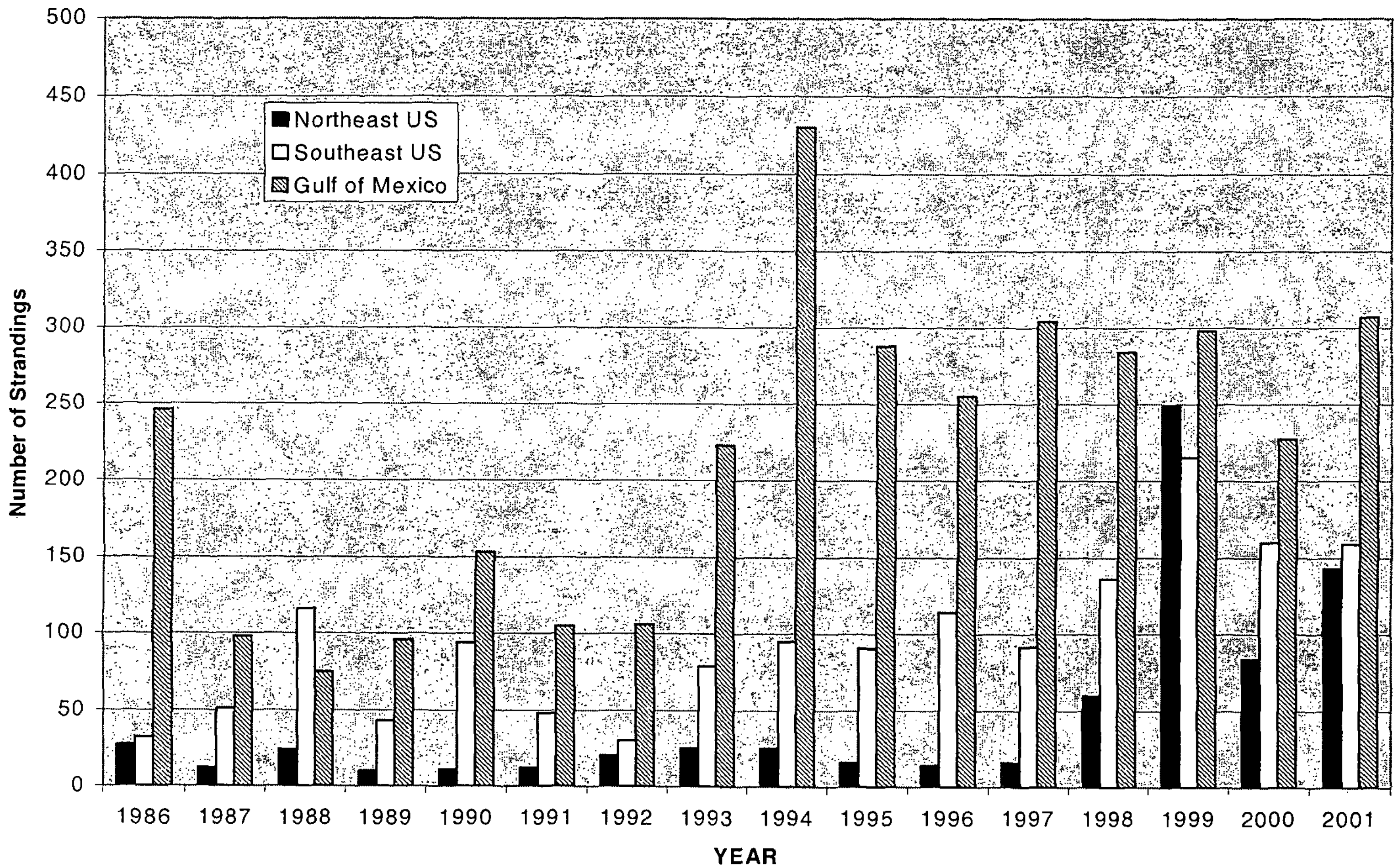


Figure 5-5
Kemp's ridley sea turtle strandings by region, 1986-2001.
(After Turtle Expert Working Group 2000 and STSSN 2004)

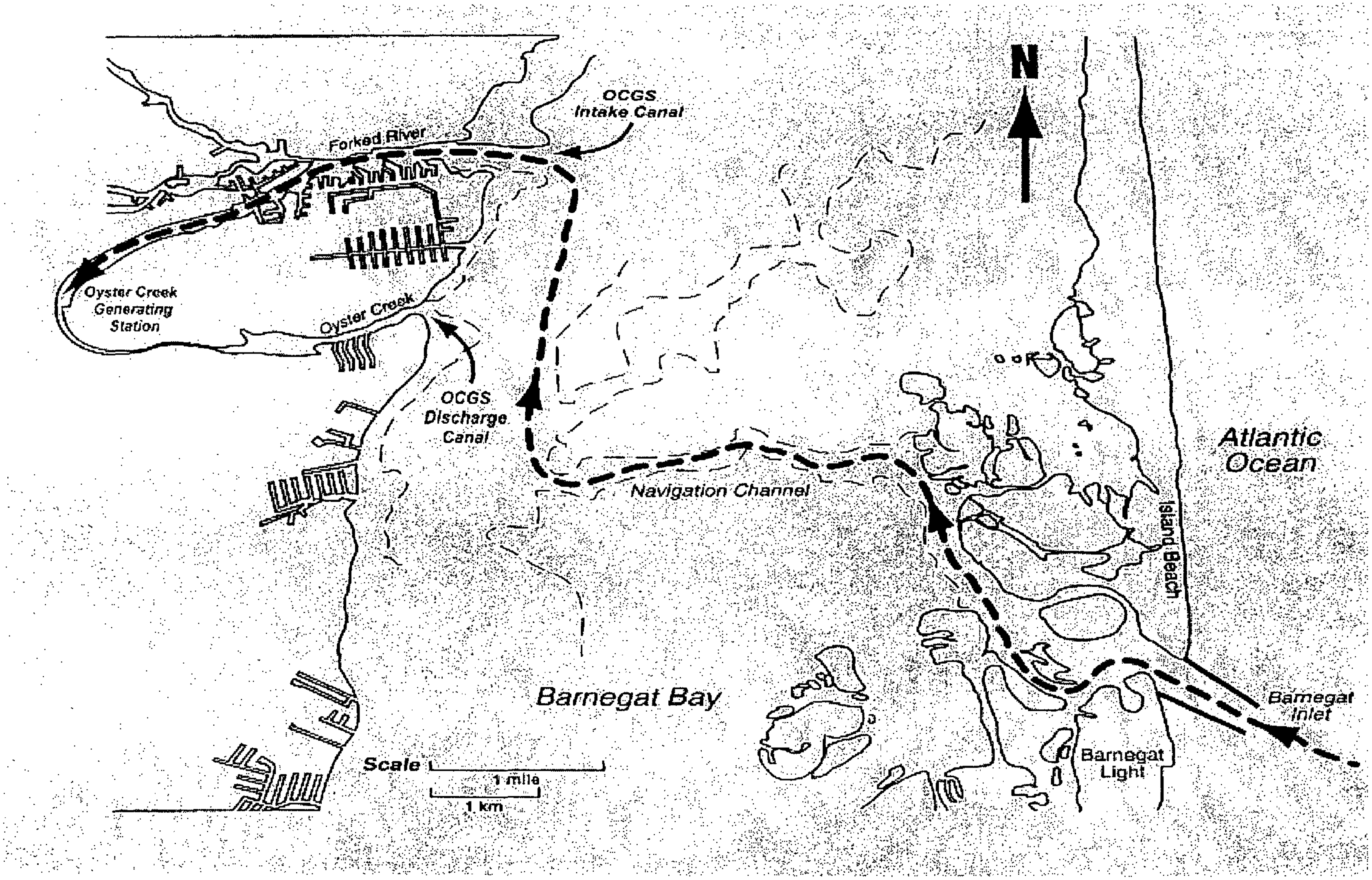


Figure 5-6
Probable pathway of sea turtles moving from the Atlantic Ocean to the OCNGS via Barnegat Inlet.

6.0 Onsite Information

6.1 Occurrence of Sea Turtles at the Oyster Creek Nuclear Generating Station

As discussed in Section 5.0, despite intensive sampling efforts, no sea turtles were observed during the first 22 years of OCNGS operation (prior to 1992); 32 sea turtles have been captured since 1992 (Tables 5-2 and 6-1; Figure 6-1). Three sea turtles were taken in 1992: a dead loggerhead (*Caretta caretta*) with deep boat propeller wounds drifted into the dilution water intake on June 25, 1992; a live loggerhead taken twice in September 1992; and a live Kemp's ridley turtle (*Lepidochelys kempii*) was taken October 26, 1992.

During 1993, the only sea turtle observed at the OCNGS was a dead juvenile Kemp's ridley turtle taken on October 17, 1993.

Four sea turtles were taken in 1994: a live juvenile loggerhead in June, a dead loggerhead subadult in July (and for which the necropsy showed that death due to infections and boat propeller wounds had occurred prior to capture at the OCNGS), and two dead Kemp's ridley juveniles in July (Table 6-1).

No sea turtles were observed or taken at the OCNGS during the three-year period from August 1994 to August 1997.

One sea turtle was taken each year in 1997 and 1998: a dead Kemp's ridley subadult taken during September 1997, and a live loggerhead subadult taken during August 1998 and was transported to Florida and subsequently released into the Atlantic Ocean.

Two sea turtles were taken in 1999: a live Kemp's ridley subadult taken during September 1999 and was transported to Virginia and subsequently released into the Atlantic Ocean, and a dead juvenile Atlantic green turtle (*Chelonia mydas*) taken during October 1999.

Five sea turtles were taken in 2000: a live loggerhead juvenile was taken during June 2000 and was transported to the Marine Mammal Stranding Center (MMSC) in Brigantine, NJ, and subsequently released into the Atlantic Ocean in New Jersey; a dead juvenile Kemp's ridley was taken during early July 2000; a live Atlantic green sea turtle juvenile and a live Kemp's ridley juvenile were taken during August and a live loggerhead subadult was taken during September of 2000. The latter three sea turtles were taken to the MMSC and subsequently released into the Atlantic Ocean in North Carolina.

Three sea turtles were taken in 2001: a live Atlantic green turtle was taken in July, delivered to the MMSC, and subsequently released into the Atlantic Ocean in New Jersey; two dead Kemp's ridley juveniles were taken during July and August of 2001. The Kemp's ridley taken during July exhibited wounds possibly attributable to an encounter with a boat propeller.

Two sea turtles were taken in 2002. Live Kemp's ridley juveniles were taken during late June and early July; both individuals were taken to the MMSC and subsequently released into the Atlantic Ocean.

Two sea turtles were taken in 2003: a live Kemp's ridley juvenile taken in September was delivered to the MMSC and later released into the Atlantic Ocean in New Jersey; a live Atlantic green turtle juvenile

taken during the latter part of October was transferred to the MMSC where arrangements were made to have it released into the Atlantic Ocean in Virginia, to eliminate the possibility of post-release cold shock.

Eight sea turtles were taken in 2004: all sea turtles taken during 2004 were Kemp's ridley juveniles – five were captured alive, and the remaining three were dead. The live individuals taken during July and August were delivered to the MMSC and subsequently released into the Atlantic Ocean in New Jersey; the live sea turtles captured in September were also taken to the MMSC where arrangements were made to have them released into the Atlantic Ocean in Virginia, to eliminate the possibility of post-release cold shock.

6.1.1 Details of Incidental Captures at the OCNGS

Descriptions of the circumstances surrounding each incidental capture at the OCNGS based on available information are provided in Sections 6.1.1.1 through 6.1.1.32. This information is also summarized in Table 6-1. In some cases, observations or inferences about the turtles' behaviors or orientations could be made. However, when turtles were removed from more than about 1 m (3 ft) below the surface, or if they were obscured by debris near the surface, detailed information on their exact location and orientation was not always available. The OCNGS Sea Turtle Observation/Capture Report Form, an attachment to the Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A), was implemented in June 1995 to standardize data collection related to incidental captures.

6.1.1.1 Incidental Capture of June 25, 1992

A dead sea turtle was removed from the DWS intake trash bars at approximately 12:50 PM on June 25, 1992. Members of the OCNGS Environmental Affairs Department identified it as a juvenile loggerhead measuring 35.5 cm (14 in) in SCL and noted that this turtle had several deep gashes on its side that appeared to be boat propeller wounds. The MMSC of Brigantine, NJ was notified and requested to perform a necropsy. MMSC confirmed that the specimen was a juvenile loggerhead. The MMSC necropsy determined that the cause of death was from boat propeller wounds and that the specimen had died prior to becoming impinged on OCNGS trash bars.

6.1.1.2 Incidental Captures of September 9 and 11, 1992

During the early evening (approximately 6:00 PM) of September 9, 1992 a live sea turtle was noticed by OCNGS Operations personnel during a routine inspection of the CWS intake trash bars. The turtle was removed by several plant personnel, tentatively identified as a juvenile loggerhead, and released alive into the OCNGS discharge canal. Although this individual was alive and healthy when released, it was noted that it had a small wound surrounded by scar tissue just behind its head. The turtle's SCL was 46.7 cm (18.4 in).

During a mid-afternoon (approximately 2:00 PM) tour of the CWS intake structure on September 11, 1992, an OCNGS security officer noticed a live sea turtle impinged on the CWS trash bars. When the turtle was removed from the intake structure, it was identified as a juvenile loggerhead with a neck wound identical to that noted on the loggerhead released at OCNGS on September 9, 1992. The MMSC was notified, and the turtle was released in healthy condition to MMSC personnel who took it their Brigantine facility for examination, holding, tagging, and subsequent release. MMSC personnel

confirmed the turtle to be a juvenile loggerhead and observed that it had a small (0.6-cm [0.25-in]) wound with scar tissue on the dorsal midline just behind the head. MMSC Director Robert Schoelkopf stated that he believed it to be the same juvenile loggerhead that was collected and released at the OCNGS on September 9, 1992. The turtle was tagged by MMSC personnel and released in the Atlantic Ocean near Brigantine in healthy condition.

6.1.1.3 Incidental Capture of October 26, 1992

During an early morning routine inspection of the CWS intake, an OCNGS Operations department representative noticed a live sea turtle impinged against the trash bars. The turtle was initially found at about 3:00 AM with its head out of the water and pointing upward. The turtle was retrieved and found to be in good condition. Environmental Affairs department personnel who took custody of the turtle identified it as a Kemp's ridley subadult and made arrangements for its immediate transfer to the MMSC. Although it was impossible to say precisely how long the turtle had been on the intake structure prior to removal, it may have been there between three and eight hours.

MMSC personnel who examined the turtle found that it was very healthy, swam freely, and required no direct care. However, two scars from slash-like wounds were apparent on the plastron, indicating that the turtle had been wounded at some time prior to its incidental capture at the OCNGS. The turtle measured 32 cm (12.6 in) in SCL.

The water temperature in the OCNGS intake canal at the time of the impingement was 11.1 °C (52 °F). Because of concerns that the turtle might be subject to cold stunning if released into New Jersey coastal waters, MMSC personnel made arrangements for the turtle to be transported to North Carolina prior to being released to ensure that cold stunning would not occur. The turtle was tagged and released on October 31, 1992 at Kure Beach, North Carolina.

6.1.1.4 Incidental Capture of October 17, 1993

OCNGS Operations department personnel conducting a routine morning (approximately 12 noon) inspection of the DWS intake on October 17, 1993 noticed a sea turtle impinged against the trash bars. The turtle was found to be limp, immobile, and with no apparent breathing when retrieved. OCNGS Environmental Affairs personnel who examined the turtle identified it as a juvenile Kemp's ridley. No tags, prominent scars, or slash-like propeller wounds were apparent on the turtle. Minor scrape marks that were observed on the plastron may have occurred during removal of the turtle from the dilution intake area. The turtle measured 26 cm (10.3 in) in SCL.

The water temperature in the intake canal at the time of the impingement was approximately 14.4 °C (58 °F). Although it was impossible to say precisely how long the turtle had been on the intake structure prior to removal, it may have been between four and eight hours. Within three to four hours after its capture, the turtle was placed in a freezer for temporary storage at an on-site OCNGS biological laboratory. At the suggestion of the National Marine Fisheries Service, arrangements were made to have a necropsy of the turtle performed by sea turtle expert Dr. Steven Morreale of Cornell University and his associates at the New York State College of Veterinary Medicine. The following is an excerpt from Dr. Morreale's necropsy:

> "... The overall condition of this turtle was one of an otherwise healthy young Kemp's ridley, typical of the many that I have examined in northeastern waters. The

lack of food in the gut is typical of the sea turtles that I have seen at this time of year and is indicative of a behavioral change prior to migrating southward. The lack of any obvious trauma would tend to implicate drowning as the cause of death to this animal. The lack of fluid in the lungs is not necessarily contradictory to this conclusion. It is my opinion that sea turtles suffocate underwater rather than inhaling water. The superficial scrapes on the plastron and neck were very fresh and probably occurred on the intake (trash racks). However, I could not tell whether these occurred prior to or after death. The only potentially contradictory evidence of this turtle having died as a result of impingement was the condition of the specimen. From the information given to me about the timing of death, the water temperature, and the subsequent handling of the carcass, I expected to observe slightly less decomposition. The moderate levels of decomposition of liver and gonad tissues are usually more representative of a turtle that has been dead for one to two days at those temperatures."

6.1.1.5 Incidental Capture of June 19, 1994

During the early afternoon (approximately 1:30 PM) of June 19, 1994, OCNGS Operations personnel conducting a routine inspection of the CWS intake area observed a sea turtle in the #4 CWS intake bay (CWS and DWS intake bays are sequentially numbered from 1 through 6, north to south). The turtle was swimming freely a few feet upstream of the face of the CWS intake trash bars. The turtle was removed and found to be active, healthy and with no apparent wounds. OCNGS Environmental Affairs department personnel identified it as a juvenile loggerhead turtle and immediately notified the MMSC of the capture. The turtle measured 36.8 cm (14.5 in) in SCL.

Although it was impossible to determine precisely how long the turtle had been near the intake structure prior to retrieval, it is believed to have been in the vicinity for a relatively short period of time. Within three to four hours of the time of its capture, the turtle was taken to MMSC. Personnel at MMSC examined and tagged it, and subsequently released it offshore of Brigantine, NJ.

6.1.1.6 Incidental Capture of July 1, 1994

During a routine mid-morning (approximately 10:00 AM) cleaning of the DWS intake trash bars on July 1, 1994, a dead sea turtle was retrieved from the trash bars in front of DWS bay #5. The turtle was removed quickly by OCNGS Operations personnel. It was found to be inactive and exhibited a strong odor of decomposition. Environmental Affairs personnel identified it as a juvenile Kemp's ridley turtle and tried unsuccessfully to resuscitate it. The turtle measured 27.7 cm (10.9 in) in SCL.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it is known that the intake bay in which the turtle was found had been cleaned during the previous afternoon. No prominent scars or slash-like propeller wounds were apparent on the turtle. The turtle was sent to marine turtle experts at the Center for the Environment, Cornell University for necropsy. However, no record of the necropsy was received despite several requests.

6.1.1.7 Incidental Capture of July 6, 1994

At approximately 6:15 AM on July 6, 1994, OCNGS Operations personnel conducting routine cleaning of the DWS intake area removed a sea turtle from the DWS trash bars in bay #4. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a subadult loggerhead

(SCL of 61.4 cm [24.5 in]) and tried unsuccessfully to resuscitate it. Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, the trash bars at the DWS intake had previously been cleaned 6-8 hours earlier.

At least three deep scars or slash-like propeller wounds were apparent on the turtle. These scars were not fresh because blue mussels were attached and growing within the scars.

Several hours after its capture, the turtle was taken to the MMSC in Brigantine, NJ. MMSC Director Robert Schoelkopf performed a necropsy of the carcass. Mr. Schoelkopf reported that the turtle did not die at the intake nor did it suffocate. The lungs were found to be in good condition. The turtle was believed to have died one to two days prior to arriving at the OCNGS, probably due to a long-term illness. Decomposition of all four appendages, as well as a large notch along the turtle's marginal scutes, were attributed by Schoelkopf to bacterial or fungal infections.

6.1.1.8 Incidental Capture of July 12, 1994

At approximately 10:40 PM on July 12, 1994, OCNGS Operations personnel conducting routine cleaning of the DWS intakes removed a sea turtle from the trash bars at bay #4. The turtle was found to be inactive, but had no apparent wounds. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a juvenile Kemp's ridley turtle (26.7 cm or 10.5 in SCL) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle.

This turtle was sent to marine turtle experts at the Center for the Environment, Cornell University for necropsy. However, no record of the necropsy was received despite several requests.

6.1.1.9 Incidental Capture of September 4, 1997

During the early morning (approximately 3:18 AM) of September 4, 1997, Operations personnel conducting routine cleaning of the DWS intakes noticed a sea turtle among the eelgrass on the trash bars at bay #6 of the DWS. The turtle, which was removed quickly, was limp, immobile, and had no apparent breathing. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a subadult Kemp's ridley turtle (48.8 cm [19 in] in SCL) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle. Damage to two dorsal scutes, which may have occurred either during removal of the turtle from the DWS or prior to its capture, was noted. Because this turtle was collected immediately after the Labor Day weekend, which is one of the periods of busiest Barnegat Bay boat traffic, the damage to the turtle may have resulted from a collision with a boat.

6.1.1.10 Incidental Capture of August 18, 1998

During the morning (approximately 9:59 AM) of August 18, 1998, OCNGS Operations personnel conducting a routine inspection of the CWS intake area observed a sea turtle in the #4 CWS intake bay. The turtle was swimming freely a few feet upstream of the face of the CWS intake trash bars. The turtle was removed using a sea turtle dip net and found to be alive and moving about actively. However, a 3.7-m (12-ft) length of 0.6-cm- (0.25-in-) diameter polypropylene rope with a bucket attached to one end was tightly wrapped around the base of the right front flipper of the turtle, causing restricted circulation and movement of that limb. It was apparent from the atrophied and partially-decayed condition of the right front flipper that the turtle had been injured by becoming entangled in the rope long before its incidental capture. OCNGS Environmental Affairs department personnel identified it as a subadult loggerhead turtle and notified the MMSC of the capture.

The water temperature at the time of the incidental capture was 26.9 °C (80.5 °F) and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps in operation. The turtle measured 50.8 cm (20.0 in) in SCL and weighed 24.4 kg (53.9 lb).

After the turtle was examined by Environmental Affairs personnel, it was transferred to the MMSC in Brigantine, NJ. MMSC personnel attempted to locate a facility where the turtle could receive appropriate medical treatment and rehabilitation prior to releasing it. The turtle was transported to Sea World in Orlando, FL, which provided specialized surgery and rehabilitation and eventually released the turtle in the ocean.

6.1.1.11 Incidental Capture of September 23, 1999

During an early morning routine inspection of the CWS intake, an OCNGS Operations department representative noticed a live sea turtle impinged against the trash bars. The turtle was initially found at about 3:10 AM. The turtle was retrieved and found to be in good condition. The turtle was identified as a subadult Kemp's ridley and made arrangements for its immediate transfer to the MMSC. The turtle measured 26.4 cm (10.3 in) in SCL and weighed 2.9 kg (6.3 lb).

The water temperature at the time of the capture was approximately 19.6 °C (67.2 °F) and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating.

After the turtle was examined by the licensee's Environmental Affairs personnel, it was transferred to the MMSC in Brigantine, NJ. MMSC personnel attempted to locate a facility in a warmer climate where the turtle could be transferred for eventual release in the ocean. The turtle was transported to the Virginia State Aquarium, which tagged and eventually released the turtle in the ocean off of Virginia Beach, VA.

6.1.1.12 Incidental Capture of October 23, 1999

During an early morning routine inspection of the DWS intake, an OCNGS Operations department representative noticed a sea turtle among materials removed from the trash bars in DWS bay #4. The turtle was initially found to be either dead or comatose at about 2:00 AM. Attempts were made to resuscitate the turtle for several hours after the incidental capture, but the attempts were unsuccessful. Environmental Affairs department personnel who took custody of the turtle identified it as a juvenile Atlantic green turtle. The turtle measured 27.0 cm (10.6 in) in SCL and weighed 2.8 kg (6.1 lb).

The water temperature at the time of the capture was approximately 17.1 °C (62.8 °F) and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating. Although it was impossible to say precisely how long the turtle had been near the intake structure prior to removal, the intake trash bars had been mechanically cleaned the previous day.

The cause of death was not immediately apparent. There were no obvious boat propeller wounds and no open wounds that would have been life threatening. After the turtle was examined by Environmental Affairs personnel, arrangements were made for it to be examined further by Dr. Steven Morreale, a Cornell University sea turtle expert who has conducted numerous necropsies on sea turtles in the past. However, no record of the necropsy was received despite several requests.

6.1.1.13 Incidental Capture of June 23, 2000

During an early morning routine inspection of the DWS intake, an OCNGS Operations department representative noticed a sea turtle in front of the trash bars in DWS bay #1. The turtle was dip-netted from the trash bars and found to be very active and with no visible wounds or signs of injury. OCNGS Environmental Affairs personnel who took custody of the turtle confirmed it to be a juvenile loggerhead. The turtle measured 47.8 cm (18.8 in) in SCL and weighed approximately 17.2 kg (38 lb). The water temperature at the time of the incidental capture was approximately 25.3 °C (77.5 °F), and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps operating.

After the turtle was examined by Environmental Affairs personnel, arrangements were made for it to be transferred to the MMSC. At the MMSC, the turtle was examined, fed, and eventually released in the Atlantic Ocean off Brigantine, NJ.

6.1.1.14 Incidental Capture of July 2, 2000

During the afternoon (approximately 3:00 PM) of July 2, 2000, Operations personnel conducting routine cleaning of the DWS intakes noticed a sea turtle approach the trash bars at bay #1 of the DWS. The turtle, which was removed and found to be limp, immobile, and had no apparent breathing. OCNGS Environmental Affairs personnel who took custody of the turtle identified it as a juvenile Kemp's ridley turtle (27.3 cm [10.8 in] in SCL) and tried unsuccessfully to resuscitate it.

Although it was impossible to say precisely how long the turtle had been at the intake structure prior to removal, it may have been there for up to several hours. No prominent scars or slash-like propeller wounds were evident on the turtle. Minor scrapes to two dorsal scutes, which may have occurred either during removal of the turtle from the DWS or prior to its capture, were noted. Because this turtle was collected during the Independence Day weekend, which is one of the periods of busiest Barnegat Bay boat traffic, the damage to the turtle may have resulted from a collision with a boat.

6.1.1.15 Incidental Capture of August 3, 2000

At approximately 3:25 PM on Thursday, August 3, 2000, an OCNGS operator performing a routine inspection of the dilution trash racks noticed a live sea turtle in bay # 4 of the DWS intake structure. The turtle was removed and found to be alive, moving about normally and with no apparent injury. OCNGS Environmental Affairs personnel who took custody of the turtle confirmed it to be a juvenile Atlantic green turtle. The water temperature at the time of the incidental capture was approximately 28.8ºC (83.9ºF), and the OCNGS was in operation at full power with four circulating water pumps and

two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the intake structure prior to removal, the dilution trash racks had been mechanically cleaned earlier the same day.

The turtle measured 29.2 cm (11.5 in) in SCL and weighed 3.4 kg (7.6 lb). Sex was not determined. No tags were present on the turtle when captured. The majority of the dorsal surface of the turtle was heavily encrusted with barnacles. Several marginal scutes on the posterior dorsal surface had a dull, grayish coloration, which may be an indication of a fungal infection.

The turtle was transferred to the MMSC in Brigantine, NJ on August 3, 2000, where it was examined and given initial care. It was transferred on September 7, 2000 to the Karen Beasley Sea Turtle Rescue and Rehabilitation Center in Topsail Island, NC for final care before release. It was released October 12, 2000 in the Atlantic Ocean off Topsail Beach, NC.

6.1.1.16 Incidental Capture of August 28, 2000

At approximately 1:12 AM on Monday August 28, 2000, an OCNGS operator performing a routine inspection of the DWS trash racks noticed a live sea turtle in bay # 1 of the dilution intake structure. The turtle was removed and found to be alive, moving about normally and with no apparent injury. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley sea turtle. The water temperature at the time of the incidental capture was approximately 26.5 °C (79.8 °F), and the OCNGS was in operation at 72 percent power with four circulating water pumps and two dilution pumps in operation. The turtle measured 26.2 cm (10.3 in) in SCL and weighed 2.9 kg (6.5 lb). Sex was not determined. No tags were present on the turtle when captured. Although it is impossible to say precisely how long the turtle had been on the intake structure prior to removal, the dilution trash racks had been mechanically cleaned the previous day and inspected earlier the same night that the turtle was captured.

The turtle was taken to the MMSC in Brigantine, NJ. At the MMSC, the turtle was examined, fed, tagged, and given initial care. The turtle was transferred on September 7, 2000 to the Karen Beasley Sea Turtle Rescue and Rehabilitation Center in Topsail Island, NC, where it received final care prior to being released in offshore Atlantic Ocean waters.

6.1.1.17 Incidental Capture of September 18, 2000

At approximately 1:10 PM on Monday September 18, 2000, an OCNGS operator performing a routine inspection of the trash racks noticed a live sea turtle in bay # 4 of the CWS intake structure. The turtle was removed and found to be alive, moving about normally and with no apparent injury. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a subadult loggerhead sea turtle. The water temperature at the time of the incidental capture was approximately 20.4 °C (68.8 °F), and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the intake structure prior to removal, the circulating water trash racks had been cleaned the previous afternoon.

The turtle measured 57.2 cm (22.5 in) in SCL and weighed 26.5 kg (58.5 lb). Sex was not determined. No tags were present on the turtle when captured. The majority of the dorsal surface of the turtle was heavily encrusted with barnacles. A few of the scutes on the posterior dorsal surface had partially peeled, which may have occurred when some barnacles scraped off of the turtle.

The turtle was taken to the MMSC in Brigantine, NJ. At the MMSC, the turtle was examined, fed, and tagged. The turtle was taken during late September to a more southerly location in Nags Head, NC (where cold-stunning was less likely) and released into the Atlantic Ocean.

6.1.1.18 Incidental Capture of July 8, 2001

At approximately 2:30 PM on Sunday, July 8, 2001, an (OCNGS) operator performing a routine inspection of the trash racks noticed a live sea turtle swimming freely in bay # 4 of the circulating water intake structure. The turtle was removed and found to be alive, moving about normally, and with no apparent injury. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Atlantic green turtle. The water temperature at the time of the incidental capture was approximately 26.7 °C (80.1 °F) and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been in the vicinity of the intake structure prior to removal, the circulating water trash racks had been cleaned the previous afternoon.

The turtle measured 26.7 cm (10.5 in) in SCL and weighed 2.3 kg (5.1 lb). Sex was not determined. No tags were present on the turtle when captured. The dorsal surface of the turtle was encrusted with several barnacles.

The turtle was taken on the date of capture to the MMSC in Brigantine, NJ. At the MMSC, the turtle was examined, fed, and tagged. After determining that the turtle was healthy and capable of swimming and feeding normally, MMSC personnel released it into the Atlantic Ocean near Brigantine, NJ.

6.1.1.19 Incidental Capture of July 22, 2001

At approximately 5:44 PM on Sunday, July 22, 2001, an OCNGS operator performing a routine inspection and cleaning of the trash racks noticed a dead sea turtle being removed from bay # 5 of the dilution water intake structure by the trash rake. The turtle was found to have a deep slice wound between its head and carapace on the left side of its neck. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 26.9 °C (80.4 °F), and the OCNGS was in operation at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been cleaned earlier the same day at 3:30 AM.

The turtle measured 26.0 cm (10.3 in) in SCL and weighed 2.9 kg (6.3 lb). Sex was not determined. No tags were present on the turtle when captured. The turtle was frozen and sent to Cornell University for necropsy; however, no results were obtained. Therefore, it cannot be determined if the death was related to OCNGS operations.

6.1.1.20 Incidental Capture of August 14, 2001

At approximately 3:34 AM on Tuesday, August 14, 2001, OCNGS Operations personnel removed a dead juvenile Kemp's ridley turtle from bay #6 of the DWS intake structure. The temperature of the intake canal at the time of capture was 27.8 °C (82.0 °F), and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation.

The turtle measured 22.8 cm (8.9 in) in SCL and weighed 1.8 kg (4.0 lbs). No tags were observed on the turtle, which appeared fresh dead and had some minor scrapes along its dorsal surface and near the posterior notch. There was no evidence of boat propeller damage.

The turtle was transferred to MMSC personnel who indicated that a necropsy would likely be performed by the University of Pennsylvania. However, the University of Pennsylvania advised MMSC that the turtle could not be necropsied because it had been frozen. Subsequently, all dead turtles have been kept unfrozen until transferred to MMSC.

6.1.1.21 Incidental Capture of June 29, 2002

At approximately 2:00 AM on Saturday, June 29, 2002, an OCNGS Operator performing a routine inspection of the trash racks noticed a sea turtle swimming freely in bay #5 and bay #6 of the CWS intake structure. The turtle was dip-netted from bay #6 and found to be apparently healthy and moving about normally. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 26.2 °C (79.2 °F), and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been in the vicinity of the intake structure, the circulating water trash racks had been cleaned at 10:00 PM on June 28, approximately four hours prior to the turtle's capture. The turtle was not observed during that trash rack cleaning process.

The turtle measured 25.4 cm (10.0 in) in SCL and weighed 2.6 kg (5.7 lbs). Sex was not determined. A scar was observed on the right side of the carapace; no tags were observed on the animal.

The turtle was taken to the MMSC at approximately 4:55 AM on June 29 where it was examined and fed. The wound on the carapace was determined not to be a significant concern. The turtle was held at the MMSC for a few days before it was tagged and released into the Atlantic Ocean near Brigantine, NJ.

6.1.1.22 Incidental Capture of July 3, 2002

At approximately 7:55 AM on Wednesday, July 3, 2002, an OCNGS operator performing a routine inspection of the trash racks noticed a sea turtle swimming freely in bay # 5 of the DWS intake structure. The turtle was dip-netted from bay #5 and found to be apparently healthy and moving about normally. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 28.2 °C (82.8 °F) and OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been cleaned earlier the same day at 5:00 AM. The turtle was not observed during that trash rack inspection and cleaning.

The turtle measured 35.6 cm (14.0 in) in SCL and weighed 6.0 kg (13.3 lb). Sex was not determined. A small scrape less than 1 cm (0.4 in) long was observed on one of the dorsal scutes of the carapace. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 10:15 AM on July 3. At the MMSC, the turtle was examined and fed. The scrape on the carapace was determined not to be a

significant concern. The turtle was held at the MMSC for a few days before it was tagged and released into near-shore waters around Brigantine, NJ.

6.1.1.23 Incidental Capture of September 24, 2003

At approximately 2:55 PM on Wednesday September 24, 2003, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 6 of the DWS intake structure. The turtle was found to be apparently healthy and moving about normally. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 22.8 °C (73.0 °F), and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been cleaned earlier the prior day at 1:45 PM. The turtle was not observed during that trash rack inspection and cleaning.

The turtle measured 31.1 cm (12.2 in) in SCL and weighed 5.2 kg (11.5 lb). Sex was not determined. Some small scrapes were observed on the dorsal and ventral surfaces of the carapace. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 5:45 PM on September 24, 2003. At the MMSC, the turtle was examined and fed. The scrapes on the carapace were determined not to be a significant concern. The turtle was held at the MMSC for less than a day before it was tagged and released into near-shore Atlantic Ocean waters around Brigantine, NJ.

6.1.1.24 Incidental Capture of October 24, 2003

At approximately 8:50 AM on Friday, October 24, 2003, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle against bay #4 of the CWS intake structure. The turtle was found to be apparently healthy and moving about normally. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Atlantic green turtle. The water temperature at the time of the incidental capture was approximately 11.7 °C (53.1 °F), and the OCNGS was operating at 98-percent power with three circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the circulating water trash racks had been inspected earlier the same morning at 5:00 AM. The turtle was not observed during that trash rack inspection.

The turtle measured 36.2 cm (14.2 in) in SCL and weighed 6.9 kg (15.3 lb). Sex was not determined. Some small scrapes and chips were observed on the dorsal and lateral surfaces of the carapace. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 10:30 AM on October 24, 2003. At the MMSC, the turtle was examined and fed. The scrapes on the carapace were determined not to be a significant concern. The turtle was held at the MMSC until arrangements were made to transfer it to the Virginia Marine Science Museum (VMSM). VMSM is a more southerly location where the turtle could be observed, fed, and eventually released without fear of it dying due to cold shock.

6.1.1.25 Incidental Capture of July 4, 2004

At approximately 12:15 PM on Sunday, July 4, 2004, an OCNGS Operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 4 of the dilution water intake structure. The turtle appeared to be either comatose or dead. In accordance with OCNGS procedures, operators initiated resuscitation of the sea turtle but were unable to revive it. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 25.6 °C (78.1 °F) and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been inspected earlier the same day at 8:00 AM. The turtle was not observed during that trash rack inspection.

The turtle measured 26.5 cm (10.4 in) in SCL and weighed 5.4 kg (11.9 lb). Some small scrapes were observed on the ventral surface of the carapace. It was not possible to determine definitively whether the turtle had died prior to arriving at OCNGS or as a result of interaction with the OCNGS intake. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 3:00 PM on July 4, 2004. At the MMSC, the turtle was examined and measured, and a necropsy was performed. MMSC personnel indicated that the necropsy indicated that the lungs were compressed, but that the cause of death was indeterminate. The turtle was buried by MMSC personnel at Brigantine, NJ.

6.1.1.26 Incidental Capture of July 11, 2004

At approximately 2:22 PM on Sunday, July 11, 2004, an OCNGS operator preparing to perform a routine cleaning of the trash racks noticed a sea turtle swimming in the water immediately upstream of the trash racks in bay # 5 of the DWS intake structure. The turtle appeared briefly at the water surface before diving out of sight. In accordance with OCNGS procedures, operators immediately initiated efforts to retrieve the turtle. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 27.5 °C (81.5 °F) and OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been swimming in the area of the trash bars prior to removal, the dilution water trash racks had been inspected earlier the same day at 1:15 PM. The turtle was not observed during that trash rack inspection.

The turtle measured 22.3 cm (8.8 in) in SCL and weighed 1.8 kg (4.0 lb). Some very minor scrapes were observed on the ventral surface of the carapace. No external tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 4:23 PM on July 11, 2004. At the MMSC, the turtle was examined and held to ensure it was feeding well. The turtle was released two days later off Brigantine, NJ.

6.1.1.27 Incidental Capture of July 16, 2004

At approximately 11:00 AM on Friday, July 16, 2004, an OCNGS Operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 5 of the DWS intake structure. The turtle appeared to be alive and in good condition when captured. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 24.4 °C (76.0 °F) and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been inspected earlier the same day at 9:00 AM. The turtle was not observed during that trash rack inspection.

The turtle measured 28.0 cm (11.0 in) in SCL and weighed 3.1 kg (6.9 lb). Some small scrapes were observed on the plastron (undersurface of the carapace). No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 1:00 PM on July 16, 2004. At the MMSC, the turtle was examined, fed, and observed. The turtle was released by MMSC personnel to a safe location off Brigantine, NJ.

6.1.1.28 Incidental Capture of July 20, 2004

At approximately 12:13 PM on Tuesday, July 20, 2004, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 1 of the CWS intake structure. The turtle appeared to be either comatose or dead. In accordance with OCNGS procedures, operators initiated resuscitation of the sea turtle but were unable to revive it. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 26.5 °C (79.7 °F) and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the circulating water trash racks had been inspected at 9:15 PM the previous evening. The turtle was not observed during that trash rack inspection.

The turtle measured only 18.3 cm (7.2 in) in SCL and weighed just 0.8 kg (1.8 lb). A small puncture wound about 1.3 cm (0.5 in) in diameter was observed on the left rear surface of the carapace, and internal organs were exposed. The cause of death was not obvious so it was not possible to determine definitively whether the turtle had died prior to arriving at OCNGS or as a result of interaction with the OCNGS intake. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 10:00 AM on July 21, 2004. At the MMSC, the turtle was examined and measured, and a necropsy was performed. MMSC personnel included the results of the necropsy on the STSSN form, and the turtle was buried by MMSC personnel at Brigantine, NJ.

6.1.1.29 Incidental Capture of August 7, 2004

At approximately 9:00 AM on Saturday, August 7, 2004, an OCNGS Operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay #5

of the dilution water intake structure.. The turtle appeared to be alive, healthy, and moving about normally. OCNGS personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 22.7 °C (72.8 °F) and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been inspected at 5:15 AM the same morning. The turtle was not observed during that trash rack inspection.

The turtle measured 27.0 cm (10.6 in) in SCL and weighed 3.2 kg (7.0 lb). A small bruise on the plastron was noted. Also, a healed scar from a previous injury (i.e., not related to interaction with the OCNGS) was noted on the left side of the turtle's head, immediately in front of its left eye. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ during the morning of August 7, 2004. At the MMSC, the turtle was examined, measured, observed, tagged, and subsequently released in the ocean off Brigantine, NJ.

6.1.1.30 Incidental Capture of September 11, 2004

At approximately 10:10 AM on Saturday, September 11, 2004, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 4 of the DWS intake structure. The turtle appeared to be either comatose or dead. In accordance with OCNGS procedures, operators initiated resuscitation of the sea turtle but were unable to revive it. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 24.3 °C (75.8 °F), and the OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the dilution water trash racks had been inspected and cleaned the previous morning. The turtle was not observed during that trash rack inspection and cleaning.

The turtle measured 22.3 cm (8.8 in) in SCL and weighed 2.2 kg (4.8 lb). A small puncture wound was observed on the underside of the neck. No tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 12:30 PM on September 11, 2004. At the MMSC, the turtle was examined and measured. The turtle was transferred to the New Bolton Center of the University of Pennsylvania School of Veterinary Medicine, where a necropsy was performed. It was not possible to determine definitively whether the turtle had died prior to arriving at OCNGS or as a result of interaction with the OCNGS intake.

6.1.1.31 Incidental Capture of September 12, 2004

At approximately 11:29 PM on Sunday, September 12, 2004, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay # 5 of the CWS intake structure. The turtle appeared to be healthy, alert, and moving about normally. OCNGS Environmental personnel confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 24.9 °C (76.8 °F), and the OCNGS was operating at 40-percent power with four circulating water pumps and two dilution pumps in

operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the circulating water trash racks had been inspected at 8:00 PM the same evening. The turtle was not observed during that trash rack inspection.

The turtle measured 21.0 cm (8.3 in) in SCL and weighed 1.4 kg (3.1 lb). The left front flipper was nearly entirely missing due to a previous injury that had completely healed. No tags or scarring from tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 7:00 AM on September 13, 2004. At the MMSC, the turtle was examined, measured, fed, and held for subsequent release. The turtle was transported to the VMSM during the week of September 27, 2004 for tagging and release to the Atlantic Ocean. The release of the turtle from a more southerly locale eliminated the possibility of autumn cold stunning effects that could have occurred if the turtle had been released from a New Jersey location at that time of year.

6.1.1.32 Incidental Capture of September 23, 2004

At approximately 9:45 PM on Thursday, September 23, 2004, an OCNGS operator performing a routine cleaning of the trash racks noticed a sea turtle among the vegetation and debris removed from bay #3 of the CWS intake structure. The turtle appeared to be alert and responsive. OCNGS Environmental personnel who took custody of the turtle confirmed it to be a juvenile Kemp's ridley turtle. The water temperature at the time of the incidental capture was approximately 21.9 °C (71.4 °F) and OCNGS was operating at full power with four circulating water pumps and two dilution pumps in operation. Although it is impossible to say precisely how long the turtle had been on the trash bars prior to removal, the circulating water trash racks had been inspected earlier the same day. The turtle was not observed during that trash rack inspection.

The turtle measured 24.2 cm (9.5 in) in SCL and weighed 1.9 kg (4.2 lb). Small abrasions on the underside of the carapace of the turtle were observed. No tags or scarring from previous tags were present on the turtle when captured.

The turtle was taken to the MMSC in Brigantine, NJ at approximately 6:00 AM on September 24, 2004. At the MMSC, the turtle was examined, measured, fed, and held for observation prior to release. The turtle was transported to the VMSM during the week of September 27, 2004 for tagging and release to the Atlantic Ocean. The release of the turtle from a more southerly locale eliminated the possibility of autumn cold stunning effects that could have occurred if the turtle had been released from a New Jersey location at that time of year.

6.1.2 Annual Comparison

During any particular year the number of sea turtles collected at the OCNGS CWS and DWS intakes ranged from zero (in all years from 1970 to 1991, as well as 1995 and 1996) to eight during 2004 (Table 6-2 and Figure 6-1). The number of loggerheads incidentally captured at the OCNGS ranged from zero to two animals annually. The number of Kemp's ridleys incidentally captured ranged from zero to eight animals annually. The number of Atlantic green turtles incidentally captured ranged from zero to one animal annually.

There have been no changes in the design or the mode of operation of the OCNGS that could explain the incidental take of eight Kemp's ridley turtles at the facility during 2004, when the previous annual maximum had been two individuals (Figure 6-1). This increase was probably ascribable to the combined effects of the rapidly-increasing population and the unusually-warm ocean water temperatures along the New Jersey coast during the summer of 2004.

As described above in Section 5.3.5, the size of the Kemp's ridley population has been rapidly increasing in recent years (Crouse et al. 1992; Turtle Expert Working Group 1998; Marquez et al. 1999; Turtle Expert Working Group 2000; Marquez et al. 2001). The 3,788 nests observed at Rancho Nuevo, Mexico in 2000 was the highest on record since 1969 and three to four times higher than the annual nest counts during the 1980s (Marquez et al. 2001). According to the Turtle Expert Working Group (1998; 2000), the Kemp's ridley population, as measured by the above-described nesting activity, is increasing exponentially. This contention is supported by observations from along the Atlantic coast where increasing numbers of Kemp's ridleys have been observed. A dramatic increase in strandings of this species has been observed, for example, along the North Carolina coast since 1993 (Boettcher 2000). Prior to 1993, 20 or fewer Kemp's ridley strandings were reported annually. The number of stranded individuals has steadily increased since 1993 to a maximum of 122 in 1999. A similar, although less dramatic, trend has been observed in New Jersey stranding data reported by the MMSC (Table 5-1). It has been suggested that this apparent increase in population size reflects the reduction in shrimp-trawl-related mortality realized since the implementation of the NOAA Fisheries TED regulations in September 1989 (Crouse et al. 1992; Turtle Expert Working Group 2000). The increase is also likely to be attributable in part to an increase in recruitment to the population as a result of beach and nest protection efforts at Rancho Nuevo (Marquez et al. 1999; Turtle Expert Working Group 2000). Given the evidence for the recent expansion of the Kemp's ridley population, it should not be surprising to see increasing numbers of this species in New Jersey waters, particularly if environmental conditions are favorable.

A key environmental factor affecting the seasonal migrations of juvenile and subadult Kemp's ridley turtles is water temperature. Ocean water temperatures along the southern New Jersey coast during June-September 2004 were the third warmest since record keeping began more than 90 years ago in 1912 (National Weather Service 2004). The average ocean water temperature during the summer of 2004 was 1.4 °C (2.5 °F) above normal and 3 °C (5.4 °F) warmer than the previous year. These abnormally-high ocean water temperatures provided excellent conditions to attract juvenile and subadult Kemp's ridleys migrating up the Atlantic coast in search of productive foraging grounds during 2004.

In addition to favorable water temperatures, the New Jersey coast also offers rich feeding grounds for Kemp's ridleys migrating up the Atlantic coast. According to MacKenzie (2003), New Jersey landings of the blue crab, a favorite food item for Kemp's ridley sea turtles, increased from less than one million pounds per year during the 1960s to nearly eight million pounds in 1993. Although landings declined somewhat after 1993, they remained in the four-to-seven-million-pound range through 2002.

Given the relatively small number of sea turtles captured at the OCNGS and the fact that they have only occurred during some of the years between 1992 and 2004, it is difficult to predict how many may be captured in the future. However, based on the levels of incidental capture observed at the OCNGS to date, it is estimated that zero to three loggerheads, zero to nine Kemp's ridleys, and zero to two Atlantic green turtles could be expected to be taken from the OCNGS intake during any given year.

6.1.3 Species Composition and Size

Seven loggerhead turtles, 21 Kemp's ridley turtles, and four Atlantic green turtles have been captured at the circulating and dilution water intakes of the OCNGS between 1992 and 2004 (Figure 6-1).

The loggerheads were all juveniles or subadults. SCLs ranged from 35.5 to 61.4 cm (14 to 24 in) with a mean of 48.0 cm (18.9 in) (Figure 6-2). The Kemp's ridleys were also juveniles or subadults. Their SCLs ranged from 18.3 to 48.8 cm (7.2 to 19.2 in) with a mean of 27.2 cm (10.7 in) (Figure 6-2). The four Atlantic green turtles were all juveniles. Their SCLs ranged from 27.0 to 36.2 cm (10.6 to 14.3 in), with an average length of 29.8 cm (11.7 in).

6.1.4 Seasonal Distribution of Occurrences

Four out of 32 sea turtle strandings at the OCNGS were reported during June, 11 during July, five during August, eight during September, and four during October. No sea turtles were collected during the late fall to winter (November-February) or spring (March-May) (Table 6-3).

The timing of sea turtle occurrences at the OCNGS corresponds well with the available information on the seasonal movements of these animals. Based on aerial surveys of pelagic turtles (Shoop et al. 1981), sea turtles migrate up the coast from the southeast in the spring and summer months. They move into the bays and coastal waters as water temperatures reach suitable levels and forage on crabs and other preferred foods (Keinath et al. 1987; Morreale and Standora 1989; Seney et al. 2002). As water temperatures in the bays and coastal waters start to decline, these animals move southward to the warmer waters of the southeast Atlantic Coast. Recapture information from tagged animals provides evidence for such movements in loggerheads and Kemp's ridleys (Shoop et al. 1981; Henwood 1987; PSE&G 1989).

6.1.5 Location of Incidental Captures at the OCNGS

The incidental captures of loggerhead and Atlantic green turtles at the OCNGS were equally divided between the CWS and DWS intake structures. Four loggerheads were captured at the CWS, compared with three at the DWS. Two Atlantic green turtles were taken at the CWS intake and two at the DWS intake.

Seventy-one percent (15 out of 21) of the Kemp's ridley turtles incidentally captured at the OCNGS were taken at the DWS intake structure. The water velocity is about four times greater at the DWS intake than at the CWS intake; therefore, it is much harder for turtles to fight the current at the DWS intake. During normal operation, the DWS employs two dilution pumps that withdraw 1,968 m^3/min (520,000 gpm) producing a flow velocity of 73 cm/sec (2.4 ft/sec) in front of the DWS trash bars. Also during normal operation, the CWS employs four circulating pumps that withdraw 1,740 m^3/min (460,000 gpm) producing a flow velocity of 17-20 cm/sec (0.56-0.66 ft/sec) in front of the CWS trash bars. Additionally, the floating debris/ice barrier described in Section 4.1.2.1.2 is designed to divert floating debris away from the CWS and towards the DWS intake. This passive device may also divert sea turtles toward the DWS intake, however, the barrier only extends about 60 cm (2 ft) below the surface and it is unclear why only Kemp's ridleys would be affected in this manner.

The size and associated swimming ability of the sea turtles may also be a factor. The average SCL of the Kemp's ridleys taken at the OCNGS was 27.2 cm (10.7 in), compared with average lengths of

29.8 cm (11.7 in) for Atlantic green turtles and 48.0 cm (18.9 in) for loggerheads. The loggerhead and Atlantic green turtles may be stronger swimmers than the smaller Kemp's ridleys, and may be able to avoid the higher flow area near the DWS intake selectively moving towards the lower flow area near the CWS intake.

6.1.6 Conditions of Turtles Captured at the Intake Structures

Nearly 60 percent (19 of 32) of all sea turtles captured at the OCNGS intakes were alive at the time of capture and subsequently released (Tables 6-1 and 6-2). The remaining 40 percent (13 of 32) were dead at the time of capture. The survival rate of the most commonly encountered species, the Kemp's ridley, averaged 51 percent during the ten years that they were captured at the OCNGS (Figure 6-3). The Kemp's ridley survival rate during 2004, the year that the highest number of individuals was taken (8 individuals compared to a maximum of 2 in prior years), was 63 percent, exceeding the mean survival rate by 12 percent (Figure 6-3). Detailed descriptions of each incidental capture at the OCNGS are provided in Section 6.1.1. The following paragraphs summarize the condition of the sea turtles captured during the 1992-2004 period.

Table 6-1
Sea turtle incidental captures at the Oyster Creek Nuclear Generating Station 1969-2004.

DATE OF CAPTURE	TIME OF CAPTURE	SPECIES AND LIFE STAGE	SCL (cm) AND WEIGHT (kg)	CAPTURED AT CWS OR DWS (# PUMPS OPERATING)	INTAKE TEMPERATURE °F (°C)	ALIVE?	FRESH DEAD?	BOAT WOUNDS?	RELEASE SITE
6/25/1992	12:50 pm	Loggerhead juvenile	35.5 cm 9.6 kg	DWS 2 pumps	70.8 (21.6)	no	no	yes	N/A
9/9/1992	6:00 pm	Loggerhead juvenile	46.7 cm 19.1 kg	CWS 4 pumps	78.2 (25.6)	yes	N/A	no	NJ
9/11/1992*	2:00 pm	Loggerhead juvenile	46.7 cm 19.1 kg	CWS 4 pumps	79.2 (26.2)	yes	N/A	no	NJ
10/26/1992	3:00 am	Kemp's ridley adult	32.0 cm 5.7 kg	CWS 4 pumps	52.0 (11.1)	yes	N/A	no	NC
10/17/1993	12:00 noon	Kemp's ridley juvenile	26.0 cm 3.0 kg	DWS 2 pumps	58.0 (14.4)	no	yes	no	N/A
6/19/1994	1:30 pm	Loggerhead juvenile	36.8 cm 9.8 kg	CWS 4 pumps	81.1 (27.3)	yes	N/A	no	NJ
7/1/1994	10:00 am	Kemp's ridley juvenile	27.7 cm 3.6 kg	DWS 2 pumps	78.3 (25.7)	no	no	no	N/A
7/6/1994	6:40 am	Loggerhead subadult	61.4 cm 40.4 kg	DWS 2 pumps	80.5 (26.9)	no	no	yes	N/A
7/12/1994	10:40 pm	Kemp's ridley juvenile	26.7 cm 3.3 kg	DWS 2 pumps	83.2 (28.4)	no	yes	no	N/A

Table 6-1
Sea turtle incidental captures at the Oyster Creek Nuclear Generating Station 1969-2004.

DATE OF CAPTURE	TIME OF CAPTURE	SPECIES AND LIFE STAGE	SCL (cm) AND WEIGHT (kg)	CAPTURED AT CWS OR DWS (# PUMPS OPERATING)	INTAKE TEMPERATURE °F (°C)	ALIVE?	FRESH DEAD?	BOAT WOUNDS?	RELEASE SITE
9/4/1997	3:18 am	Kemp's ridley subadult	48.8 cm 18.1 kg	DWS 2 pumps	73.2 (22.9)	no	yes	no	N/A
8/18/1998	9:59 am	Loggerhead subadult	50.8 cm 24.4 kg	CWS 4 pumps	80.5 (26.9)	yes	N/A	no	FL
9/23/1999	3:10 am	Kemp's ridley subadult	26.4 cm 2.9 kg	CWS 4 pumps	67.2 (19.6)	yes	N/A	no	VA
10/23/1999	2:00 am	Green juvenile	27.0 cm 2.8 kg	DWS 2 pumps	62.8 (17.1)	no	**	no	N/A
6/23/2000	1:00 am	Loggerhead juvenile	47.8 cm 17.2 kg	DWS 2 pumps	77.5 (25.3)	yes	N/A	no	NJ
7/2/2000	3:00 pm	Kemp's ridley juvenile	27.3 cm 3.2 kg	DWS 2 pumps	78.1 (25.6)	no	**	no	N/A
8/3/2000	3:25 pm	Green juvenile	29.2 cm 3.4 kg	DWS 2 pumps	83.9 (28.8)	yes	N/A	no	NC
8/28/2000	1:12 am	Kemp's ridley juvenile	26.2 cm 2.9 kg	DWS 2 pumps	79.8 (26.5)	yes	N/A	no	NC
9/18/2000	1:10 pm	Loggerhead subadult	57.2 cm 26.5 kg	CWS 4 pumps	68.6 (20.4)	yes	N/A	no	NC

Table 6-1
Sea turtle incidental captures at the Oyster Creek Nuclear Generating Station 1969-2004.

DATE OF CAPTURE	TIME OF CAPTURE	SPECIES AND LIFE STAGE	SCL (cm) AND WEIGHT (kg)	CAPTURED AT CWS OR DWS (# PUMPS OPERATING)	INTAKE TEMPERATURE °F (°C)	ALIVE?	FRESH DEAD?	BOAT WOUNDS?	RELEASE SITE
7/8/2001	2:30 pm	Green juvenile	26.7 cm 2.3 kg	CWS 4 pumps	80.1 (26.7)	yes	N/A	no	NJ
7/22/2001	5:44 pm	Kemp's ridley juvenile	26.0 cm 2.9 kg	DWS 2 pumps	80.4 (26.9)	no	**	possible	N/A
8/14/2001	3:34 am	Kemp's ridley juvenile	22.8 cm 1.8 kg	DWS 2 pumps	82.0 (27.8)	no	**	no	N/A
6/29/2002	2:00 am	Kemp's ridley juvenile	25.4 cm 2.6 kg	CWS 4 pumps	79.2 (26.2)	yes	N/A	possible	NJ
7/3/2002	7:55 am	Kemp's ridley juvenile	35.6 cm 6.0 kg	DWS 2 pumps	82.8 (28.2)	yes	N/A	no	NJ
9/24/2003	2:55 pm	Kemp's ridley juvenile	31.1 cm 5.2 kg	DWS 2 pumps	73.0 (22.8)	yes	N/A	no	NJ
10/24/2003	8:50 am	Green juvenile	36.2 cm 6.9 kg	CWS 3 pumps	53.0 (11.7)	yes	N/A	no	VA
7/4/2004	12:15 pm	Kemp's ridley juvenile	26.5 cm 5.4 kg	DWS 2 pumps	78.0 (25.6)	no	yes	no	N/A
7/11/2004	2:22 pm	Kemp's ridley juvenile	22.3 cm 1.8 kg	DWS 2 pumps	81.5 (27.5)	yes	N/A	no	NJ

Table 6-1
Sea turtle incidental captures at the Oyster Creek Nuclear Generating Station 1969-2004.

DATE OF CAPTURE	TIME OF CAPTURE	SPECIES AND LIFE STAGE	SCL (cm) AND WEIGHT (kg)	CAPTURED AT CWS OR DWS (# PUMPS OPERATING)	INTAKE TEMPERATURE °F (°C)	ALIVE?	FRESH DEAD?	BOAT WOUNDS?	RELEASE SITE
7/16/2004	11:00 am	Kemp's ridley juvenile	28.0 cm 3.1 kg	DWS 2 pumps	76.0 (24.4)	yes	N/A	no	NJ
7/20/2004	12:13 am	Kemp's ridley juvenile	18.3 cm 0.8 kg	CWS 4 pumps	79.7 (26.5)	no	yes	no	N/A
8/7/2004	9:00 am	Kemp's ridley juvenile	27.0 cm 3.2 kg	DWS 2 pumps	72.8 (22.7)	yes	N/A	no	NJ
9/11/2004	10:10 am	Kemp's ridley juvenile	22.3 cm 2.2 kg	DWS 2 pumps	75.8 (24.3)	no	yes	yes (healed)	N/A
9/12/2004	11:29 pm	Kemp's ridley juvenile	21.0 cm 1.4 kg	CWS 4 pumps	76.8 (24.9)	yes	N/A	no	VA
9/23/2004	9:45 pm	Kemp's ridley juvenile	24.2 cm 1.9 kg	CWS 4 pumps	71.4 (21.9)	yes	N/A	no	VA

Note: No sea turtles were captured during the first 22 years of OCNGS operation, 1969-1991.
* Loggerhead captured on 9/11/1992 was the same individual that was captured on 9/9/1992.
** Necropsy report was unavailable; therefore, whether the turtle was fresh dead could not be determined.

TABLE 6-2
MORTALITY OF SEA TURTLES CAPTURED FROM INTAKE TRASH BARS AT THE OYSTER CREEK NUCLEAR GENERATING STATION 1969-2004 (LIVE/DEAD).

YEAR	LOGGERHEAD	KEMP'S RIDLEY	GREEN	TOTALS
1969	0/0	0/0	0/0	0/0
1970	0/0	0/0	0/0	0/0
1971	0/0	0/0	0/0	0/0
1972	0/0	0/0	0/0	0/0
1973	0/0	0/0	0/0	0/0
1974	0/0	0/0	0/0	0/0
1975	0/0	0/0	0/0	0/0
1976	0/0	0/0	0/0	0/0
1977	0/0	0/0	0/0	0/0
1978	0/0	0/0	0/0	0/0
1979	0/0	0/0	0/0	0/0
1980	0/0	0/0	0/0	0/0
1981	0/0	0/0	0/0	0/0
1982	0/0	0/0	0/0	0/0
1983	0/0	0/0	0/0	0/0
1984	0/0	0/0	0/0	0/0
1985	0/0	0/0	0/0	0/0
1986	0/0	0/0	0/0	0/0
1987	0/0	0/0	0/0	0/0
1988	0/0	0/0	0/0	0/0
1989	0/0	0/0	0/0	0/0
1990	0/0	0/0	0/0	0/0
1991	0/0	0/0	0/0	0/0
1992	1/1	1/0	0/0	2/1
1993	0/0	0/1	0/0	0/1
1994	1/1	0/2	0/0	1/3
1995	0/0	0/0	0/0	0/0
1996	0/0	0/0	0/0	0/0
1997	0/0	0/1	0/0	0/1
1998	1/0	0/0	0/0	1/0
1999	0/0	1/0	0/1	1/1
2000	2/0	1/1	1/0	4/1
2001	0/0	0/2	1/0	1/2
2002	0/0	2/0	0/0	2/0
2003	0/0	1/0	1/0	2/0
2004	0/0	5/3	0/0	5/3
TOTALS	5/2	11/10	3/1	19/13

TABLE 6-3
SEASONAL OCCURRENCE OF SEA TURTLES AT THE OYSTER CREEK NUCLEAR GENERATING STATION INTAKES 1969-2004

MONTH	LOGGERHEAD	KEMP'S RIDLEY	GREEN	TOTALS
JANUARY	0	0	0	0
FEBRUARY	0	0	0	0
MARCH	0	0	0	0
APRIL	0	0	0	0
MAY	0	0	0	0
JUNE	3	1	0	4
JULY	1	9	1	11
AUGUST	1	3	1	5
SEPTEMBER	2	6	0	8
OCTOBER	0	2	2	4
NOVEMBER	0	0	0	0
DECEMBER	0	0	0	0
TOTALS	7	21	4	32

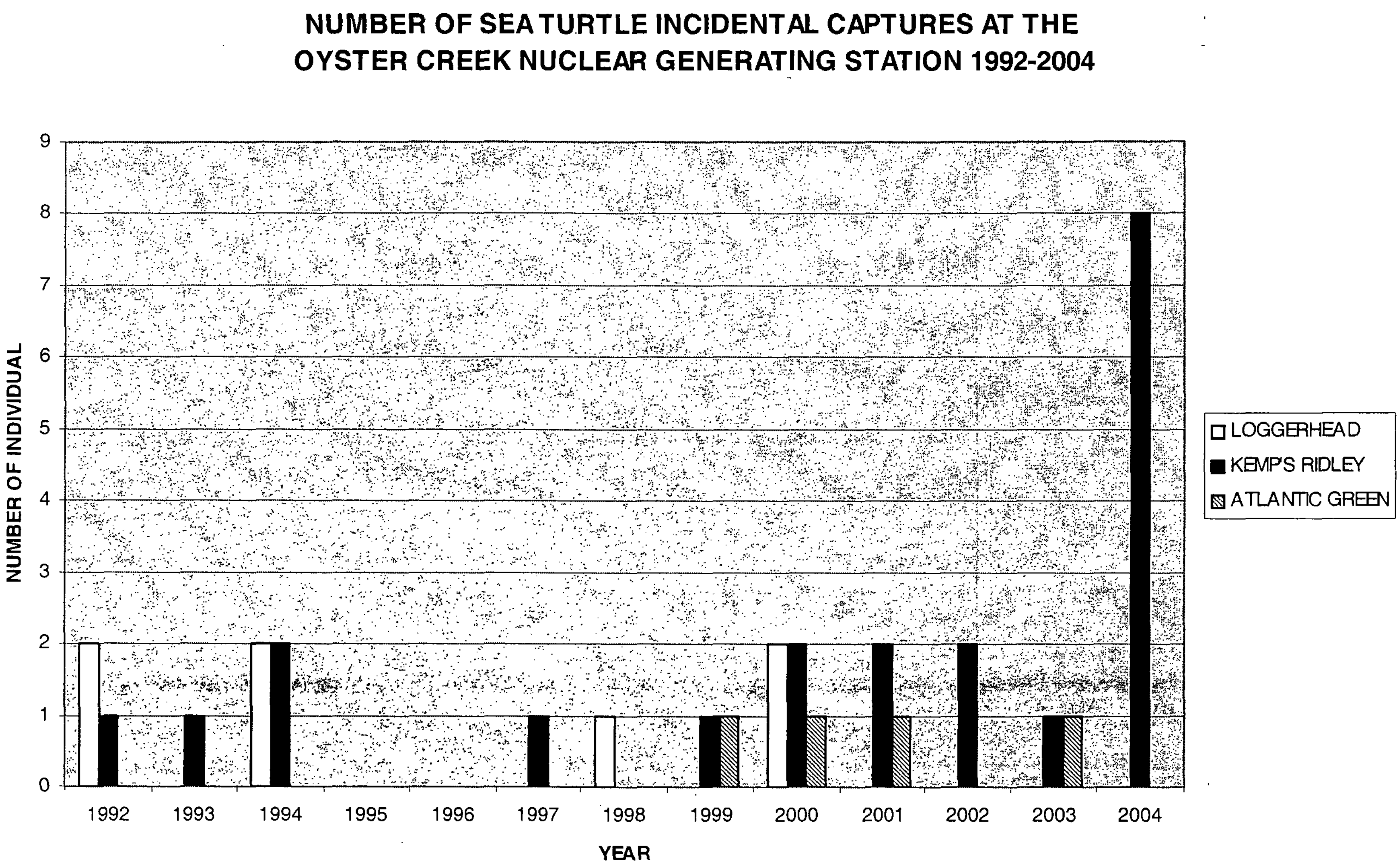
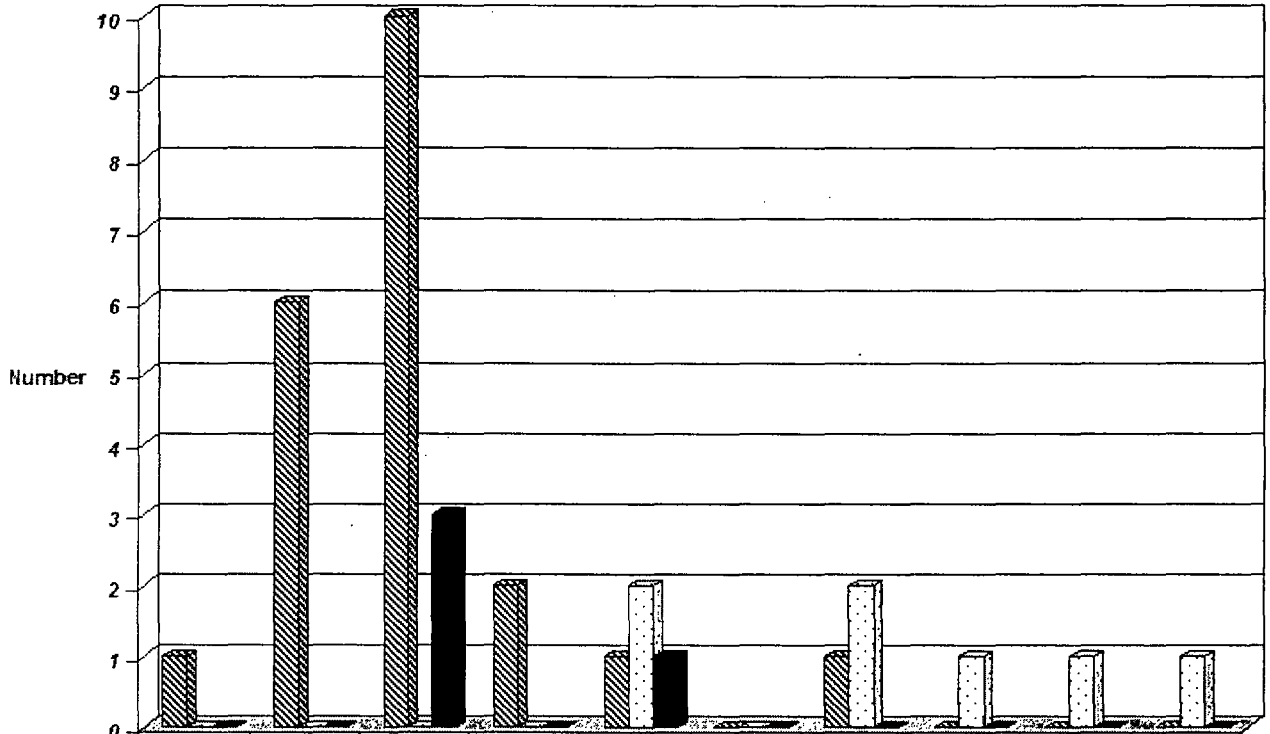


Figure 6-1
Number of sea turtle incidental captures at the OCNGS, 1992-2004.
Note: No sea turtles were captured during the first 22 years of OCNGS operation, 1969-1991.

OYSTER CREEK NUCLEAR GENERATING STATION
SEA TURTLE LENGTH FREQUENCY DISTRIBUTION 1969-2004
Standard Carapace Length (cm)



	16-20 cm	21-25 cm	26-30 cm	31-35 cm	36-40 cm	41-45 cm	46-50 cm	51-55 cm	56-60 cm	61-65 cm
L. kempii	1	6	10	2	1	0	1	0	0	0
C. caretta	0	0	0	0	2	0	2	1	1	1
C. mydas	0	0	3	0	1	0	0	0	0	0

Figure 6-2
Frequency distribution of SCLs for Kemp's ridley, loggerhead, and green turtles captured from intake structures at the OCNGS from 1969 through 2004.

SURVIVAL RATE OF KEMP'S RIDLEY SEA TURTLES CAPTURED AT THE OYSTER CREEK NUCLEAR GENERATING STATION

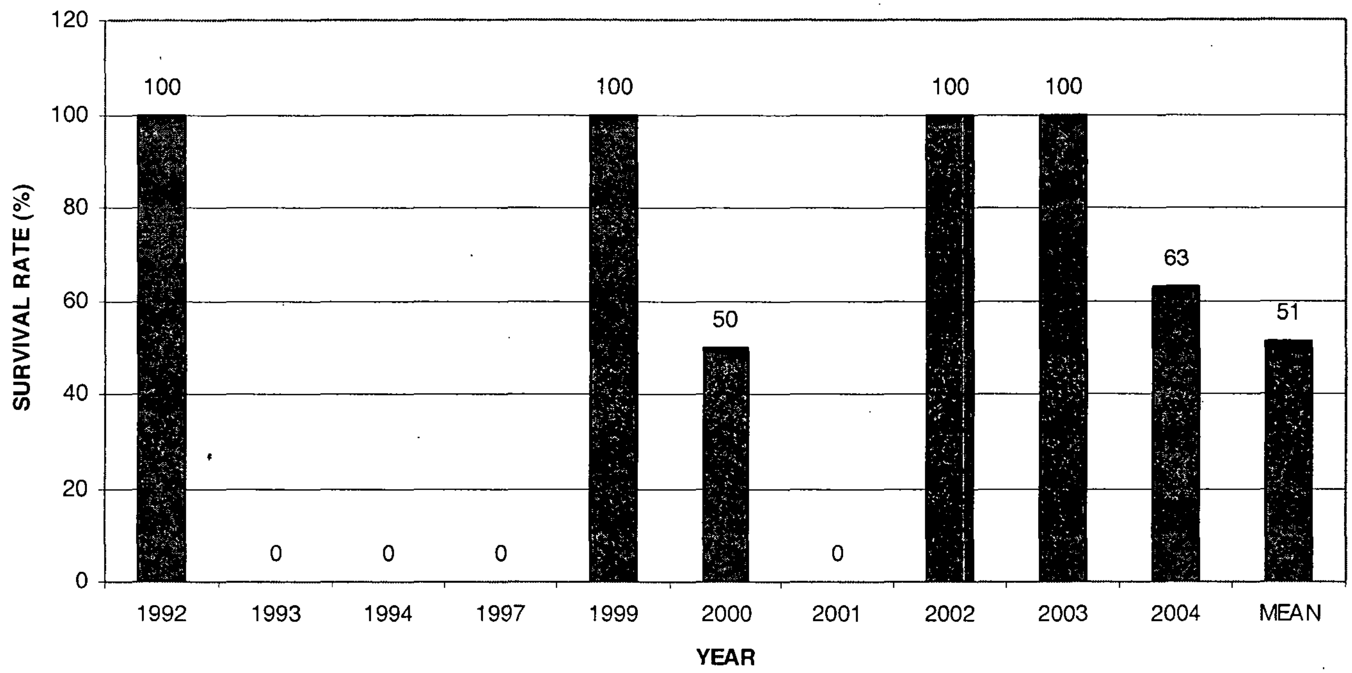


Figure 6-3
Survival rate of Kemp's ridley turtles captured at the OCNGS.
Note: No Kemp's ridleys were taken during 1995, 1996, and 1998;
no sea turtles were captured during the first 22 years of OCNGS operation, 1969-1991.

7.0 Assessment of Present Operations

The primary concern with sea turtles at the OCNGS is whether or not any station related losses of these endangered or threatened sea turtle species "jeopardizes their continued existence." Federal regulation (50 CFR 402) defines "jeopardizes the continued existence" as "engaging in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of that species." Therefore, the question relative to the OCNGS is: Do the activities associated with the operation of the OCNGS "appreciably reduce" the reproduction, numbers, or distribution of the loggerhead, Kemp's ridley, or Atlantic green turtles?

7.1 Impacts of Continued Operation of Oyster Creek Nuclear Generating Station on Sea Turtle Populations

7.1.1 Impacts due to Incidental Capture (Impingement) of Turtles on CWS and DWS Intake Trash Racks

Thirty-two sea turtles have been retrieved from either the CWS or DWS intake at the OCNGS during the period from 1969 to 2004. Nineteen turtles were alive and returned to the Atlantic Ocean. Typically, the live sea turtles were delivered to the Marine Mammal Stranding Center (MMSC) in Brigantine, New Jersey and subsequently released into nearby ocean waters by MMSC personnel. However, five Kemp's ridleys, two Atlantic greens, and two loggerheads were transported by MMSC personnel to warmer Atlantic Ocean waters for release in North Carolina, Virginia, and Florida due to the cold and falling ocean water temperatures in New Jersey at the time they were captured at the OCNGS (Table 6-1).

Thirteen turtles removed from the OCNGS intake were dead at the time of capture. Of these, two loggerheads exhibited severe boat prop wounds and were moderately decomposed indicating that death occurred prior to encountering the intake. The intake trash bars routinely capture floating debris during normal operation; dead and injured turtles, buoyed by the gases of decomposition, would be expected to be part of the debris load in the intake canal removed by the station. One dead sea turtle was a juvenile green turtle captured during late October 1999. This individual exhibited no significant wounds, but given the time of year, its death may have been related to cold stunning. The remaining ten sea turtles found dead at the OCNGS intake structures were all Kemp's ridleys. The condition of four dead Kemp's ridleys at the time of capture suggests that the causes of death were indeterminate regarding interaction with the OCNGS intake (Section 6.1.1). One of the two dead Kemp's ridleys taken in 1994 exhibited a strong odor of decomposition, suggesting that it may have died prior to becoming impinged on the DWS intake. It also could have drowned after being impinged on the trash bars at a depth beyond the range of visibility from the surface decomposing over time. A Kemp's ridley taken in July 2001 had a deep slice wound on its neck that could have also been caused by an encounter with a boat. Two of the three dead Kemp's ridleys taken during 2004 had puncture wounds on the carapace or neck that could have resulted from collisions with boats or could have been caused by the tines of the trash rakes, although the tines have a diameter slightly greater than that of the puncture wounds. The most likely cause of death of one individual taken in 1993 was determined by necropsy to be drowning at the DWS intake. The deaths of the remaining five Kemp's ridleys may also be attributable to drowning at

either the DWS or CWS intake, although the causes of death were not definitively determined. Therefore, there have been a maximum of eleven, and as few as six, dead turtles removed from the intake during the 35 years since the OCNGS began operation in 1969 whose cause of death may have been attributable to station operations.

Based on these levels of incidental capture at the OCNGS intake, it is estimated that zero to three loggerheads, zero to nine Kemp's ridleys, and zero to two greens would be expected to be taken from the intake during any given year.

7.1.1.1 Assessment of Impacts on Loggerhead Turtle Populations

The annual number of loggerheads incidentally captured at the OCNGS has ranged from zero to two turtles. Five of the seven loggerheads captured were alive and released back into the wild. The two dead loggerheads taken were moderately decomposed when collected, suggesting death prior to involvement with the station. Carapace wounds suggested that the damage from boat propellers caused the death of one, and the effects of a variety of diseases had resulted in the death of the other. Therefore, if live and long-dead animals are removed from the assessment of impact, the OCNGS has had no impact on loggerhead turtle populations to date.

To determine if any future losses attributable to the OCNGS "appreciably reduce" the reproduction, numbers, or distribution of loggerheads, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species.

Although three loggerhead nests were reported from New Jersey in the 1980s and 1990s (Schoelkopf 1994), loggerhead nesting in the U.S. primarily occurs along coastal beaches in Florida, Georgia, South Carolina, and North Carolina. Also, all loggerheads incidentally captured at the CWS and DWS intakes were juveniles or subadults, which are more prevalent along the mid-Atlantic coast than adults (Van Buskirk and Crowder, 1994).

Therefore, based on the immaturity of the specimens captured and the fact that loggerhead nesting does not typically occur in New Jersey, the only loss to loggerhead reproduction would be from production foregone due to the loss of juvenile/subadult animals, which could have been recruited into the breeding female population at some time in the future.

The observed worst-case incidental catch level for loggerheads at the OCNGS has been two turtles during any given year, with no mortality attributable to the OCNGS. If we compare this with the estimated adult female population size of 44,780 animals (Turtle Expert Working Group 2000), this mortality would represent 0.004 percent of the adult female population in the Atlantic. The worst-case estimate of losses attributable to the OCNGS is overestimated. Mortality at this level would not "appreciably reduce," or for that matter measurably reduce, the distribution or numbers of loggerhead turtles along the Atlantic coast of the U.S.

7.1.1.2 Assessment of Impacts on Kemp's Ridley Turtle Populations

The number of Kemp's ridleys incidentally captured at the OCNGS has ranged from zero to eight per year during the 1969-2004 period. Eleven of the 21 Kemp's ridleys captured at the OCNGS were alive and were successfully released back into the wild. Six of the ten Kemp's ridleys found dead at the OCNGS appeared to have died recently and exhibited no significant wounds. The

remaining four had significant wounds or a strong odor of decomposition, suggesting that their deaths could have been attributable to factors other than interaction with the OCNGS intake. The observed worst-case incidental catch level was in 2004 when five live and three dead Kemp's ridleys were taken at the OCNGS CWS and DWS intakes.

To determine if the OCNGS "appreciably reduces" the reproduction, numbers, or distribution of Kemp's ridley turtles, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species. The adult Kemp's ridley turtle population was estimated to be approximately 2,200 turtles in 1989 (Márquez 1989), based on breeding females observed in Mexico. Since, with a few minor exceptions, this breeding colony is the only known colony in the world, this estimate essentially represents the worldwide breeding population for Kemp's ridleys. All specimens captured at the OCNGS were juveniles or subadults, not yet capable of reproducing (Van Buskirk and Crowder, 1994). Therefore, based on the immaturity of the specimens captured and the fact that Kemp's ridley nesting does not occur in New Jersey, the only loss to Kemp's ridley reproduction would be from production foregone due to the mortality of juvenile/subadult animals, which could have been recruited into the breeding female population at some time in the future.

If we assume a worst-case incidental mortality rate at the OCNGS of three Kemp's ridley turtles during any given year and compare it with the estimated population size of 2,200, they would represent 0.14 percent of the population. This population estimate does not include juveniles and subadults. Also, studies of Kemp's ridley nesting activity have shown that the population has been increasing rapidly since the population estimate was developed in 1989 (Turtle Expert Working Group 1998; Turtle Expert Working Group 2000; Márquez et al. 2001). Therefore, this is a significant underestimate of the actual population size. It is unlikely that losses at this level would "appreciably reduce," or for that matter measurably reduce, the distribution or numbers of Kemp's ridley turtles along the Atlantic coast of the U.S.

7.1.1.3 Assessment of Impacts on Atlantic Green Turtle Populations

Only four Atlantic green turtles were incidentally captured at the OCNGS during the 1969-2004 period, with one individual taken each year in 1999, 2000, 2001, and 2003. Three turtles were alive at the time of capture and released back into the wild. The only dead specimen was taken in late October 1999, and its death could have been attributable to cold stunning. All Atlantic green turtles taken at the OCNGS were juveniles.

To determine if the OCNGS "appreciably reduces" the reproduction, numbers, or distribution of Atlantic green turtles, it is necessary to compare on-site information with breeding information, population estimates, and distribution information for this species. Although the green turtle occurs worldwide in tropical and semitropical waters, they are found in U.S. Atlantic waters around the Virgin Islands, Puerto Rico, and the continental U.S. from Texas to Massachusetts (NMFS and USFWS, 1991b). In U.S. Atlantic waters, green turtles nest in small numbers in the U.S. Virgin Islands and Puerto Rico, and in larger numbers along the eastern coast of Florida. As many as 477 Atlantic green turtle nests per year have been documented to occur along a 21-km (13-mi) stretch of beach in Melbourne Beach, Florida. The Florida Department of Natural Resources (FDNR) has found up to 2,288 clutches of Atlantic green turtle eggs per year in nests on Florida beaches (FDNR,

unpublished data). However, more information is needed before detailed maps or estimates of population number and structure can be made for green turtle populations in U.S. territorial waters (NMFS and USFWS, 1991b).

Based on the immaturity of the Atlantic green turtles captured at the OCNGS and the fact that nesting of Atlantic green turtles is not known to occur as far north as New Jersey, the only loss to green turtle reproduction would be from production foregone due to the mortality of juvenile/subadult animals, which could have been recruited into the breeding female population at some time in the future.

If we assume a worst-case incidental mortality rate at the OCNGS of one Atlantic green turtle during any given year and compare it with an assumed population size of several thousand, this loss would represent only a very small fraction of one percent of the population. It is unlikely that losses at this level would "appreciably reduce," or for that matter measurably reduce, the distribution or numbers of Atlantic green turtles along the Atlantic coast of the U.S.

7.2 Other Potential Station Impacts on Turtles

7.2.1 Acute Thermal Effects

The discharges from OCNGS's CWS and DWS are located 45 and 105 m (150 and 450 ft) west of the reactor building, respectively (Figure 4-2). As discussed in Section 4.0, the temperature rise of the CWS discharge is typically about 11 °C (20 °F) above ambient intake canal temperatures. Because of the relatively high discharge velocities (65-95 cm/sec [2.1-3.1 ft/sec]), a sea turtle is not likely to remain in the immediate vicinity of the condenser discharge for any length of time. Furthermore, turtles in the area would easily be able to avoid entrainment in the thermal discharge flow by swimming away. Downstream of the condenser discharge, complete mixing with ambient temperature water from the DWS occurs, reducing the discharge canal water temperatures by approximately 5.6 °C (10 °F) when two dilution pumps are operating. The resulting water temperature of approximately 5.6 °C (10 °F) above ambient should not be stressful for any sea turtle species. Therefore, it is concluded that no adverse, acute, thermally-related impacts would be sustained by any sea turtle species.

7.2.2 Chronic Thermal Effects

The thermal discharge from OCNGS would not adversely impact the reproduction or migratory behavior of sea turtles inhabiting Barnegat Bay or coastal oceanic waters in the vicinity of the OCNGS.

Because the vast majority of reproduction occurs in the southeastern U.S. or other distant locations in the case of the loggerhead and green turtles, and Mexico in the case of the Kemp's ridley, no reproductive impacts are expected.

The New Jersey Department of Environmental Protection evaluation of the impact of the OCNGS thermal plume on Barnegat Bay concluded that the effects on fish distribution and abundance were small and localized with few or no regional consequences (Summers et al. 1989). Similarly, due to the shallow nature of the plume, the relatively small area affected, and the small temperature

increases within Barnegat Bay, the movements of sea turtles in the bay are not expected to be adversely impacted. The extent of the thermal plume, as measured by the 1.1 °C (34 °F) excess temperature isotherm, depends upon prevailing wind conditions and tidal stage but has been estimated to be less than 1.6 km (5,300 ft) in an east-west direction by 5.6 km (18,500 ft) in a north-south direction, under all conditions (Starosta et al. 1979, JCP&L 1986). More importantly, as discussed in Section 4.1.3, outside of the immediate vicinity of the mouth of Oyster Creek, the plume is primarily a surface phenomenon. As such, it is easily avoidable by sea turtles that move freely about in the water column, spending a large portion of their time foraging on the bottom.

7.2.3 Cold Shock

Cold shock mortalities of fishes have occurred at the OCNGS in the past. These events occurred when migratory species, attracted to the heated condenser discharge, remained in the discharge canal after they normally would have migrated out of Barnegat Bay in response to falling autumn water temperatures. Subsequent station outages, after ambient water temperatures had fallen below 10 °C (50 °F), resulted in cold-shock fish kills. The number and severity of these events has been reduced as a result of the operation of two dilution pumps in the fall, when ambient water temperatures began to drop, to decrease the attractiveness of the discharge canal as overwintering habitat (Summers et al. 1989).

Cold stunning, which is a possible cause of death for some turtles that were taken at OCNGS, differs from cold shock. Cold stunning occurs when a turtle or other migratory animal fails to migrate in advance of declining temperatures and becomes trapped and unable to escape from water becoming progressively colder. The declining temperature results in reduced mobility and ultimately death. Basically, the animal suffers from exposure to the cold because the animal did not migrate soon or fast enough toward the tropics. Cold shock occurs in conjunction with station outages during the winter. Typically, an animal that suffers cold shock has taken up temporary residence in or near the warm-water discharge and did not migrate toward the tropics per usual migratory patterns. When a winter outage occurs, an animal near the warm-water discharge is shocked when the ambient temperatures quickly drop to levels below the animal's tolerance.

Cold-shock mortality of sea turtles has not been observed and is not expected to occur at the OCNGS for a number of reasons. The area where sea turtles could overwinter is extremely limited, including only the immediate vicinity of the condenser discharge, prior to any mixing with the DWS flow. Winter water temperatures in the discharge canal, downstream of the area where CWS and DWS flows mix, routinely fall below 7.2 °C (45 °F).

The small area where winter water temperatures would be suitable for overwintering sea turtles is characterized by a relatively high discharge velocity of 65-95 cm/sec (2.1-3.1 ft/sec). This would require continuous swimming activity, 24 hours per day, for a sea turtle to maintain its position in the heated discharge flow.

Food availability in the potential overwintering area would be extremely limited and probably insufficient to support the amount of swimming activity required to maintain a turtle in the heated discharge flow throughout the winter. Their preferred food, blue crabs and horseshoe crabs, would not be found in this area during the winter months. In addition, the canal bottom has a very hard substrate in the vicinity of the condenser discharge, and does not support a wide variety of benthic organisms that might support sea turtle diets.

7.2.4 Biocides

Low-level, intermittent chlorination is used to control biofouling in the OCNGS service water system and CWS. New Jersey Pollutant Discharge Elimination System (NJPDES) permit conditions limit chlorine discharge levels to a maximum daily concentration of 0.2 mg/l (2.7×10^{-5} ounces per gallon) or a maximum daily chlorine usage of 41.7 kg/day (91.9 lbs/day). The main condenser cooling water is chlorinated for approximately two hours per day. The chlorine demand in the main condenser discharge consumes almost all remaining free chlorine and results in essentially no chlorine being released to the discharge canal.

Given the very small quantities of chlorine applied, the short duration of the application periods, the fact that residual chlorine levels in the condenser discharge are at or near zero, and the fact that the condenser discharge is combined with unchlorinated DWS flow, the use of this biocide would not have any impact on sea turtles that may occur in the discharge canal or Barnegat Bay.

7.3 Mitigating Measures

To minimize the potential impact of station operations on threatened or endangered sea turtles, a variety of mitigating measures have been instituted at the OCNGS. These measures include all of the "reasonable and prudent measures necessary to minimize the impact on listed species" specified in the ITS dated July 18, 2001, and are described in this section.

7.3.1 Sea Turtle Surveillance and Handling

The surveillance and handling requirements necessary to minimize the impact of OCNGS operations on sea turtles are defined in the Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A) for operations personnel and associated Operations Department tour sheets. These instructions apply to all Operations Department personnel responsible for conducting surveillances of the intake structures, cleaning trash bars, and making notifications.

7.3.1.1 Surveillance of CWS and DWS Intakes

The CWS and DWS intake trash bars, and the area immediately upstream of the trash bars, are inspected for the presence of sea turtles at least twice per eight-hour shift from June 1 to October 31. This represents a doubling of the frequency of intake structure inspections specified prior to the incidental capture of two Kemp's ridley turtles during July of 1994. Prior to 1994, only two individuals of this species had been observed at the OCNGS, both during October. In response to the incidental takes of 1994, the frequency of intake structure inspections was increased to the current level. The first inspection is normally conducted one to two hours into the workshift; the second inspection is normally performed five to six hours into the workshift. Although emergencies or other responsibilities may periodically prohibit strict adherence to this schedule, the intent of the schedule is to prevent the individual inspections from being clustered together in a relatively short time period. The time that each inspection is completed is recorded on intake area tour sheets.

Because the sea turtle season typically coincides with the period of greatest debris loading at the intakes, additional inspections of the intakes are often made during this period to ensure they are sufficiently clean of debris. Cleaning all CWS and DWS intake trash bars may take several hours

when debris levels are high. These additional activities at the intake structures provide further opportunities for plant personnel to observe sea turtles.

The Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A) provides guidance on how to distinguish sea turtles from Diamondback Terrapins. In addition, large color posters which illustrate the distinguishing features of sea turtles have been placed in prominent locations at both CWS and DWS intake structures (Figure 7-1). This information is also published in the OCNGS employee newspaper each spring to increase the level of awareness of station personnel just prior to the period when sea turtles are likely to occur in the vicinity of the station.

Station personnel conducting sea turtle surveillances use portable spotlights during night inspections. It should be noted, however, that visibility is still limited to approximately 1 m (3 ft) below the water's surface.

7.3.1.2 Special Precautions during Trash Rack Cleaning

Personnel cleaning the CWS and DWS intake trash racks during the June 1 - October 31 period observe the trash rake while cleaning operations are underway so that the rake may be stopped if a sea turtle is sighted. The debris gathered from the trash racks is hand raked into the trash car hopper. Personnel performing this task are instructed to look for sea turtles and to take particular care to ensure sea turtles are not mistaken for horseshoe crabs. The floodlights attached to the trash rake unit (Figures 4-5 and 4-8) are utilized during the evening hours to aid station personnel in spotting sea turtles. Note, however, that organisms are only visible in the upper few feet of water at the intakes because water transparency is typically about 1 m (3 ft).

7.3.1.3 Actions Taken if a Sea Turtle is Observed

Sea turtles observed on the trash racks or in the vicinity of the intake structures are recovered as soon as possible, taking care to prevent injury to the animal. The method of recovery depends upon the size and location of the turtle. A rescue sling suitable for larger turtles (in excess of 18 kg [40 lbs]) is kept at the CWS intake structure. This device consists of large-mesh netting on a rigid metal frame with ropes attached to each corner (Figure 4-10). Long-handled dip nets have also been fabricated for the smaller turtles most commonly encountered (Figure 4-11). These dip nets are stored within easy reach, attached to fences, railings, or buildings at the CWS and DWS intake structures during the sea turtle season (June 1 – October 31).

Both the rescue sling and the long-handled dip nets are adequate for retrieving turtles from the surface to about 1 m (3 ft) below the surface. The use of either device requires that the sea turtles be visible from the surface. The retrieval of sea turtles from the trash bars, more than 1 m (3 ft) below the water's surface requires the use of the trash rake alone or in combination with the dip nets or rescue sling.

7.3.1.4 Sea Turtle Handling and Resuscitation

In accordance with the Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A), sea turtles removed from the intake structures, regardless of their condition, are kept moist and out of direct sunlight. Fiberglass tubs suitable for holding sea turtles are stored at the CWS intake structure. Station personnel are cautioned not to assume that an inactive turtle is dead and that

they should attempt to revive inactive animals immediately after they are retrieved. Specific guidance on handling and resuscitation is provided in the written instructions and on large color posters placed in prominent locations at both the CWS and DWS intake structures (Figure 7-2). NOAA Fisheries has sent updated procedures for resuscitating sea turtles, and new posters will be at the intake structures before the 2005 sea turtle season begins (expected to be posted in March 2005). Special instructions are also provided for cold-stunned turtles (Appendix A). Also, OCNGS provides appropriate personnel with training and guidance on handling sea turtles found at the CWS and DWS intake structures.

Live sea turtles are delivered to the local affiliate of the Sea Turtle Salvage and Stranding Network (Marine Mammal Stranding Center in Brigantine, New Jersey) for examination and subsequent release into the ocean. Dead sea turtles have been sent to Cornell University and the University of Pennsylvania for necropsy.

7.4 Notification and Reporting of Incidental Captures

OCNGS Procedure OP-OC-106-101 "Significant Event Notification and Reporting" and LS-MA-1253 "Exelon Reportability Reference Manual, Reportable Event Plant Specific, OC-08", direct station personnel to report all sightings or captures of sea turtles to the NRC and the NOAA Fisheries within 24 hours of the event. The Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A) call for the OCNGS Control Room to be notified immediately of any sea turtle observations or captures. The OCNGS Shift Manager or designee is required to complete the Sea Turtle Observation/Capture Report form (an attachment to Appendix A). In addition, a written report is prepared by OCNGS Chemistry/Environmental personnel and submitted to the NRC and NOAA Fisheries within 30 days of the event. The written report provides the details of the capture or sighting including the time and place of capture; the length, weight and condition of the turtle; the disposition of the turtle; and any other pertinent information. Annual reports of sea turtle captures have been provided as part of the Annual Environmental Operating Report for the OCNGS.

7.5 Discussion of General Impacts on Sea Turtle Populations

Five factors have been listed by the Federal government as factors contributing to the decline in sea turtle populations (43 FR 146:32800-32811):

1. Destruction or modification of habitat;
2. Overutilization for commercial, scientific or educational purposes;
3. Inadequate regulatory mechanisms;
4. Disease and/or predation; and
5. Other natural or man-made sources.

The destruction and/or modification of habitat from coastal development and losses due to incidental capture during commercial fishing are likely the two major factors impacting sea turtle populations along the Atlantic coast of the U.S. The continued development of beachfront and estuarine shoreline areas is likely to be impacting foraging and nesting grounds for several sea turtle species. Incidental capture (take) is defined as the capture of species other than those towards which a particular fishery is directed. As implied by this definition, the commercial fishing industry has been implicated in many of the turtle carcass strandings on southeastern U.S. beaches. The annual bycatch of sea turtles by shrimp trawlers in the southeast alone has been estimated by Henwood

and Stuntz (1987) to be nearly 48,000 turtles (primarily loggerheads), resulting in over 11,000 turtle deaths per year. In a study conducted for Congress, the National Academy of Sciences concluded that incidental drowning in shrimp trawls "kills more sea turtles than all other human activities combined..." and may result in as many as 55,000 sea turtle drownings annually in U.S. waters (Magnuson et al. 1990).

The drowning of sea turtles in commercial fishing nets is not the only anthropogenic source of mortality. Other human-related causes include injuries from encounters with boats, plastic ingestion, and entanglement in trash. In New Jersey and New York, boat-related damage is a commonly-observed injury in stranded turtles. The loggerhead, because it is the most abundant sea turtle in U.S. coastal waters, is the species most frequently encountered by fishermen and other boat operators. More research needs to be conducted to identify all sources of sea turtle mortality and to develop mitigation methods.

The unintentional entrapment of sea turtles during non-fishery-related industrial processes, such as the generation of electricity, is another source of incidental capture and mortality. We have documented the capture of 32 sea turtles at the OCNGS during more than 35 years of operation. A maximum of 11 and as few as 6 of these turtles may have died as a result of their encounter with the station's intakes. Relative to losses from other sources, such as commercial fishery bycatch, this loss is extremely small. According to the Turtle Expert Working Group (2000), the cumulative effect of all power plant related sea turtle mortality is considered to be relatively small. Even though any loss of any individual of an endangered or threatened species is important, the magnitude of the potential losses of loggerhead, Kemp's ridley, and Atlantic green turtles associated with the operation of the OCNGS would not be expected to significantly impact the U.S. Atlantic coast populations of these sea turtle species.

7.6 Recommendations for a Revised Incidental Take Statement for Sea Turtles at Oyster Creek Nuclear Generating Station

Due to the variable distribution of opportunistic feeding aggregations of sea turtles, the apparent recent increase in population size of the three species of sea turtles collected from the intake canal, and the other habitat related changes in Barnegat Bay and the Atlantic Ocean, it is impossible to predict with any certainty the sea turtle take at the OCNGS. The trend of gradual increase in incidental takes is expected to continue. Any numerical limits established based on past takes are likely to be exceeded. Therefore, it is recommended that no annual limit on live takes be established for the OCNGS. The licensee has demonstrated competency in collecting, processing, and returning captured individuals. A record will be made, and data collected for all live captures at the station. Limits would be retained, however, for causally-related mortalities, which is the appropriate focus of the staff's concern. The current limits for causally-related mortalities per calendar year are two lethal takes for loggerhead turtles, three lethal takes for Kemp's ridley turtles, and one lethal take for green turtles. The staff recommends retaining these limits. Justification for the determination that a moribund turtle collected from the DWS or the CWS is not causally related to plant operation would have to be provided. To assist in the determination of causally- or non-causally-related mortality the NRC staff is recommending that OCNGS staff be able to perform a gross necropsy near the time of discovery of a moribund turtle and preserve the necessary tissue samples during that preliminary examination so they could be sent off for a full evaluation. At the

time of initial collection, the licensee would make the determination, subject to change upon completion of a full necropsy, whether the mortality is causally related to plant operation. If the necropsy and other data obtained at the time the specimen was taken prove inconclusive as to the cause of death, the mortality would likely be causally related.

As part of the Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A), OCNGS personnel will continue to investigate and document the circumstances surrounding any sea turtle mortalities observed at the OCNGS.

Therefore, the NRC staff suggests that the incidental take statement be amended to eliminate the numerical limit on live and non-causally-related mortalities and impose only an annual lethal take limit per calendar year of two loggerheads, three Kemp's ridleys, and one green causally related to plant operations. The staff also recommends standardizing the following terms and conditions:

1. Implementation of the OCNGS Sea Turtle Surveillance, Handling, and Reporting Instructions (see Appendix A), which specifies surveillance, reporting requirements, rescue, care, and disposal/release of sea turtles.

2. That the licensee develop the capability to perform gross necropsies on moribund turtles, and that these examinations be performed close to the time of discovery of the expired turtle.

3. All sea turtle takes shall be recorded by species, size, date and time collected, location collected, individual condition, length, weight, disposal/release, and other pertinent information as appropriate. Details on the information to be collected and recorded shall be specified in the OCNGS Sea Turtle Surveillance, Handling, and Reporting Instructions (Appendix A). Data collected shall be tabulated and submitted to the NRC annually as part of the Annual Environmental Operating Report for the OCNGS. Copies will be forwarded to the NRC. Results of any completed necropsies from turtles collected in the previous year shall be included in the annual report.

4. Causally-related mortalities of any listed species shall be reported in writing to NMFS with copies to the NRC and the State within thirty days of the date of recovery. The report shall include a discussion of the circumstances surrounding the mortality, including but not limited to plant operating conditions at the time of recovery, location and circumstances of recovery, condition and description of the specimen, and disposition of the specimen as well as speculation as to the cause of death or injuries leading to death. The preliminary results of the necropsy should be included if available.

5. If the causally related mortality limit for any species is reached or exceeded, the licensee shall notify the NMFS within two business days, and the NRC promptly. The licensee shall make a preliminary assessment of the likely cause of death, subject to change upon completion of a detailed necropsy. Any subsequent causally-related mortalities exceeding the take limit would be reported in a similar manner.

Additionally, there is a number of site-specific requirements listed in the terms and conditions of the 2001 BO such as inspection frequency, lighting requirements, on-hand rescue equipment, disposal and release of recovered turtles, and other requirements. It is the staff's understanding that these requirements, as modified by the letter dated August 29, 2001, would be included in a new BO.

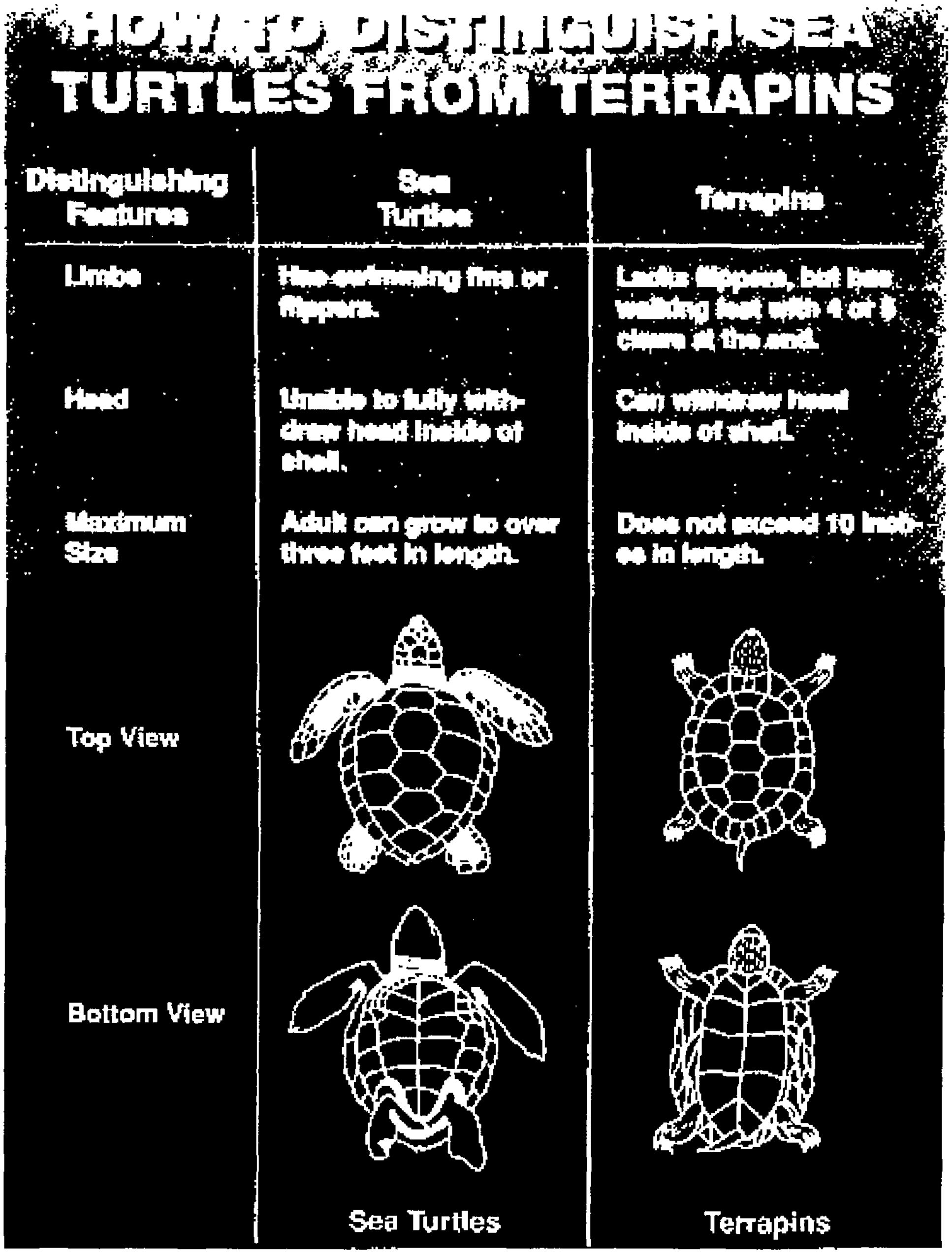


Figure 7-1
Sea Turtle Identification Poster placed at OCNGS intake structures.

SEA TURTLE RESUSCITATION

1. PLACE THE TURTLE ON ITS BREASTPLATE AND RAISE THE HIND FLIPPERS SLIGHTLY ABOVE THE FRONT FLIPPERS.

2. KEEP THE TURTLE SHADED AND MOIST AND OBSERVE FOR 24 HOURS.

3. PERIODICALLY, ROCK THE TURTLE SLIGHTLY FROM SIDE TO SIDE AND GENTLY PINCH TAIL TO CHECK FOR RESPONSE.

Figure 7-2
Sea Turtle Resuscitation Poster placed at OCNGS intake structures.

8.0 References

50 CFR 17.11, Endangered and Threatened Wildlife.

50 CFR 222.23(a), Endangered Fish or Wildlife Permits (under National Marine Fisheries Service jurisdiction).

50 CFR 227.4(b), Threatened Fish and Wildlife, Enumeration of Threatened Species.

50 CFR 402; Interagency cooperation - Endangered Species Act of 1973, as amended (Joint regulations of U.S. Fish and Wildlife Service and National Marine Fisheries Service).

43 FR 146:32800-32811; Proposed rulemaking listing loggerhead, Ridley and green turtles as threatened or endangered species (Joint regulations of U.S. Fish and Wildlife Service and National Marine Fisheries Service).

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Appendix A

SEA TURTLE SURVEILLANCE, HANDLING, AND REPORTING INSTRUCTIONS

AmerGen™ An Exelon Company	OYSTER CREEK GENERATING STATION PROCEDURE		Number 106.12
Title **Sea Turtle Surveillance, Handling, and Reporting Instructions**		Usage Level **3**	Revision No. 3

Prior Revision _2_ incorporated the following Temporary Changes:

N/A

This Revision _3_ incorporates the following Temporary Changes:

N/A

List of Pages

1.0 to 7.0
E1-1 to E1-2

PROCEDURE HISTORY

REV.	DATE	ORIGINATOR	SUMMARY OF CHANGE
1	10/01	T. Corcoran	Update Procedure based on changes with NJDEP.
2	11/03	H. Tritt	Update references.
3	07/04	J. Ruark	Update references, group titles, and format. (CAP 02004-0835)

1.0 PURPOSE

1.1 To establish the tour, handling, and reporting requirements necessary to minimize the impact of station operation on sea turtles.

1.2 Document the observation or capture of sea turtles in the vicinity of the station intake structures.

2.0 APPLICABILITY/SCOPE

To all Operations Department personnel responsible for conducting tours of the intake area, cleaning trash racks and making notifications.

3.0 DEFINITIONS

3.1 Cold-Stunned Turtle - a comatose turtle found in water less than 10°C (50°F). Most common in the fall and early winter.

3.2 Sea Turtle - a turtle characterized by the following distinguishing features:

- Possessing swimming fins or flippers.
- Unable to fully withdraw head inside of shell.
- Able to grow to over 3 feet in length.

4.0 PROCEDURE

4.1 **INSPECT** the Intake and Dilution trash racks **and** the area immediately upstream during the period June 1 and October 31 per the Intake Tour or Shutdown Intake/Turbine Tour.

4.2

> **NOTE**
>
> Information on how to identify a sea turtle and differentiate a sea turtle from a terrapin is posted at the Circulating Water and Dilution Pump intake structure.

IF a sea turtle is observed,

THEN complete the following:

4.2.1 IF the sea turtle is observed on a trash rack while the rack is being cleaned,

THEN immediately **STOP** cleaning the rack.

4.2.2 **REPORT** the observation to the Control Room.

4.2.3 **COMPLETE** the following (Shift Manager or designee):

- Attachment 106.12-1, Sea Turtle Observation/Capture Report.
- Notification in accordance with Procedures OP-OC-106-101, Significant Event Notification and Reporting, and LS-MA-1253, Exelon Reportability Reference Manual, Event OC-08.

4.3 IF the turtle is observed on the trash rack,

THEN **RECOVER** the animal as follows:

4.3.1 **USE** a long handled dip net for smaller turtles (located at each intake structure).

4.3.2 **USE** the rescue sling for larger turtles (stored in the fish sampling pool at the Circulating Water Intake).

4.3.3 IF the recovered turtle is NOT a sea turtle,

THEN **RELEASE** the turtle to the discharge canal. No additional actions or notifications are required.

CAUTION

Keep clear of the head and front flippers which have claws.

4.4 **PICK UP** the sea turtle by the front and back of the top shell and place the sea turtle in a fiberglass tub (stored in an intake area storage shed).

4.5 **MAINTAIN** the captured sea turtle moist and out of direct sunlight until Environmental personnel arrive.

4.5.1 **ADD** a small amount of intake water to the tub but **do not** cover the mouth or nostrils of the turtle with water.

4.6

NOTE 1

Do not assume an inactive turtle is dead. The onset of rigor mortis is often the only definite indication that a turtle is dead.

NOTE 2

Normally, the activities described in Steps 4.6 and 4.7 would be performed by Environmental personnel; but if not available in a few minutes, the efforts should be initiated by station personnel.

IF a turtle appears to be comatose (unconscious),

AND

intake water temperature is less than 10°C (50°F),

THEN **ASSUME** the turtle to be cold-stunned and perform the following:

- **AUGMENT** blood flow in the turtle by flapping the flippers and rubbing the skin,
- **PLACE** the turtle in a few inches of water that is warmer than the water it was removed from if possible. **Do not** cover the mouth or nostrils with water.
- Gradually, **MOVE** the turtle to warmer area over a period of six hours.

4.7 IF a turtle appears to be comatose (unconscious),

THEN **REVIVE** the turtle by performing the following:

> NOTE
>
> This procedure is designed to void the turtle's lungs of water by active pumping and passive draining. Sea turtles have been known to revive up to 24 hours after this procedure has been complete.

4.7.1 **PLACE** the turtle on its back and gently pump the breastplate.

4.7.2 **PLACE** the turtle on its breastplate and raise its hindquarters. The degree of elevation depends on the size of the turtle; greater elevations are required for larger turtles.

4.7.3 **KEEP** the turtle shaded and moist and observe for 24 hours.

4.8 Complete Attachment 106.12-1 with all required information and send to Environmental.

5.0 RESPONSIBILITIES

5.1 The Shift Manager is responsible for:

5.1.1 The implementation of this procedure on their respective shift.

5.1.2 The completion of notifications in accordance with Exelon Reportability Manual, LS-MA-1253, Event OC-08 for the observation or capture of sea turtles.

5.1.3 The completion of Attachment 106.12-1 for the observation or capture of sea turtles.

5.2 The Nuclear Plant Operators (assigned to the Intake Area Tour) are responsible for:

5.2.1 Inspecting the Intake and Dilution trash racks and area immediately upstream of the trash racks for the presence of sea turtles.

5.2.2 Reporting all observations and captures of sea turtles to the Control Room.

5.2.3 Recovering sea turtles observed on the trash racks.

5.2.4 Maintaining captured sea turtles moist and out of direct sunlight and if required, reviving inactive sea turtles immediately after they are retrieved.

6.0 REFERENCES

6.1 Procedures

- LS-MA-1253, Exelon Reportability Reference Manual, Event #OC-08
- 344, Screen Wash System Evolutions
- OCGS Technical Specifications, Appendix B
- OP-OC-106-101, Significant Event Notification and Reporting

6.2 Assessment of Impact of Oyster Creek Generating Station on Kemp's Ridley (Lepidochelys Kempii) and Loggerhead (Caretta Caretta) Sea Turtles.

6.3 Plant Operations Intake Area Tour Sheet

6.4 Shutdown Intake/Turbine Tour

7.0 ATTACHMENTS

- 106.12-1, Sea Turtle Observation/Capture Report

ATTACHMENT 106.12-1

Sea Turtle Observation/Capture Report

Date: ______________________ Observation / Capture (circle one)

Time: ______________________

Location of Observation/Capture:

Circ Water Intake __________ Dilution Intake __________

(Initials) (Initials)

Intake/Dilution Bay (number/designation): ______________________

Plant Conditions:

Number of Circulating Water Pumps On: __________ Intake level __________ ft.

Number of Dilution Pumps On: ______________

Grass Conditions (circle): Heavy Medium Light

Last inspection of Intake/Dilution Bay where turtle was observed/captured.

____

Date / Time

Intake Temperature______________

Weather Condition (circle): Clear Cloudy Rain

Turtle Condition:

Turtle's head below surface when first observed (circle): YES NO

Condition (circle): ALIVE DEAD NOT SURE

Notifications:

Notification completed in accordance with Procedures OP-OC-106-101, "Significant Event Notification and Reporting", and LS-MA-1253, "Exelon Reportability Reference Manual", Event OC-08.

____

Shift Manager Date / Time

ATTACHMENT 106.12-1
(continued)

Sea Turtle Observation/Capture Report

Personnel Involved:

Name ____________________ Department ____________

____

____

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____

____

Comments:

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SUBMIT report to Environmental (FAX Ext. 2560)