PD II-2 DOCUMENT COVER PAGE

DOCUMENT NAME: G:\PDII-2\St. Lucie\Seaturtles.wpd

SUBJECT: SEA TURTLE ENTRAPMENT STUDY - ST. LUCIE NUCLEAR PLANT, UNITS 1 AND 2 (TAC NOS. MA6374 AND MA6375)

ORIGINATOR: K. Jabbour

SECRETARY: Cheri Nagel

DATE: April 26, 2000

●●● ROUTING LIST ●●●

	NAME	DATE
1.	B. Clayton BAC	4/27/00
x1496 2.	K. Jabbour KNJ	4/28/00
3.	B. Zalcman BZ for	5/1/00
9.	R. Correia RC	5/5/00
5.		/ /00
6.	Secretary/dispatch	/ /00

ADAMS PROCESSING

Enter profile into ADAMS ________

Accession Number ___________

NRR Template Number NRR-064 (Mtg. Not.) _____

NRR-088 (RAI) _____

NRR-028 (Relief) _____

NRR-106 (Letters, Memo, Sholly) _____

NRR- (Other) _____

Dispatch - Enter dates, concurrences, etc. (Secy) ________

QC Electronic copy against hard copy (LA) ________

QC profile and declare Official Record (RC) ________

Can Document be Deleted after Dispatch? _____

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

May 9, 2000

Mr. Robert Hoffman
National Marine Fisheries Service
Southeast Region
Protected Species Division
9721 Executive Center Drive North
St. Petersburg, FL 33702

SUBJECT: SEA TURTLE ENTRAPMENT STUDY - ST. LUCIE NUCLEAR PLANT, UNITS 1 AND 2 (TAC NOS. MA6374 AND MA6375)

Dear Mr. Hoffman:

On November 30, 1999, the U. S. Nuclear Regulatory Commission (NRC) staff formally requested re-initiation of Section 7 consultation with the National Marine Fisheries Service (NMFS) on sea turtles at the St. Lucie Nuclear Plant, Units 1 and 2 (St. Lucie), operated by the Florida Power and Light Company (FPL). At that time, the staff requested an increase in the 1999 incidental take limits for sea turtles at St. Lucie and committed to forward the results of a study required by Terms and Conditions No. 7 of the most recent Biological Opinion for St. Lucie that was to be completed in March 2000. In a letter dated March 22, 2000, FPL transmitted the completed study (Enclosure 1), entitled "Physical and Ecological Factors Influencing Sea Turtle Entrainment Levels at the St. Lucie Nuclear Plant: 1976 - 1998," to the NRC. As agreed in the November 10, 1999, meeting at the St. Lucie site between the NRC, NMFS, Florida Fish and Wildlife Conservation Commission and FPL, we have enclosed (Enclosure 2) a discussion, prepared by FPL, of the alternatives evaluated by FPL over the years to reduce sea turtle entrapment in the intake canal. Enclosure 3 provides material, referenced in Enclosure 2, that was submitted by letter dated April 18, 1985, concerning investigations into methods of modifying sea turtle behavior so that sea turtles would not approach or enter the intake structure.

If you have any questions or comments regarding this information, or wish to set up a meeting or a telephone conference with the licensee, please contact James Wilson at (301) 415-1108 or Kahtan Jabbour at (301) 415-1496.

Sincerely,

Kahtan N. Jabbour

Kahtan N. Jabbour, Senior Project Manager, Section 2
Project Directorate
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-335 and 50-389

Enclosures: As stated

cc w/encl: See next page

Mr. T. F. Plunkett
Florida Power and Light Company

ST. LUCIE PLANT

cc:

Senior Resident Inspector
St. Lucie Plant
U.S. Nuclear Regulatory Commission
P.O. Box 6090
Jensen Beach, Florida 34957

Joe Myers, Director
Division of Emergency Preparedness
Department of Community Affairs
2740 Centerview Drive
Tallahassee, Florida 32399-2100

M. S. Ross, Attorney
Florida Power & Light Company
P.O. Box 14000
Juno Beach, FL 33408-0420

Mr. Douglas Anderson
County Administrator
St. Lucie County
2300 Virginia Avenue
Fort Pierce, Florida 34982

Mr. William A. Passetti, Chief
Department of Health
Bureau of Radiation Control
2020 Capital Circle, SE, Bin #C21
Tallahassee, Florida 32399-1741

Mr. Rajiv S. Kundalkar
Vice President
St. Lucie Nuclear Plant
6351 South Ocean Drive
Jensen Beach, Florida 34957

Mr. R. G. West
Plant General Manager
St. Lucie Nuclear Plant
6351 South Ocean Drive
Jensen Beach, Florida 34957

E. J. Weinkam
Licensing Manager
St. Lucie Nuclear Plant
6351 South Ocean Drive
Jensen Beach, Florida 34957

Mr. John Gianfrancesco
Manager, Administrative Support
and Special Projects
P.O. Box 14000
Juno Beach, FL 33408-0420

Mr. J. A. Stall
Vice President - Nuclear Engineering
Florida Power & Light Company
P.O. Box 14000
Juno Beach, FL 33408-0420

Mr. J. Kammel
Radiological Emergency
Planning Administrator
Department of Public Safety
6000 SE. Tower Drive
Stuart, Florida 34997

PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT LEVELS AT THE ST. LUCIE NUCLEAR PLANT: 1976-1998

Prepared for: *Florida Power & Light Company*
St. Lucie Plant
6501 South Ocean Drive
Jensen Beach, Florida 34957

Prepared by: *Ecological Associates, Inc.*
Post Office Box 405
Jensen Beach, Florida 34958

Enclosure 1

PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT AT THE ST. LUCIE NUCLEAR PLANT: 1976-1998

principal investigators

R. Erik Martin and Robert G. Ernest

Ecological Associates, Inc.
Post Office Box 405
Jensen Beach, Florida 34958

March 2000

TABLE OF CONTENTS

PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT LEVELS AT THE ST. LUCIE NUCLEAR PLANT: 1976-1998

EXECUTIVE SUMMARY

Florida Power & Light Company operates two nuclear power plants on Hutchinson Island, a barrier island in St. Lucie County, Florida. The adjacent marine environment provides foraging and developmental habitat for juvenile loggerhead and green sea turtles, and the adjacent beaches support high density nesting by adult loggerheads.

The St. Lucie Plant obtains its cooling water through a canal system connected to the Atlantic Ocean by underground pipes. Sea turtles, attracted to the offshore structures housing the intake pipes, are frequently entrained with cooling water. After passing through the large-diameter pipes turtles become entrapped in the intake canal. Since the plant began operating in 1976, an evolving program has been implemented to capture and safely return these turtles to the ocean.

Between 1976 and 1998, a total of 6,086 sea turtle captures were documented at the St. Lucie Plant. Although five species and all post-pelagic life history stages were represented, nearly 99 percent of the captures were comprised of loggerhead and green turtles, most of which (80 percent) were juveniles.

Over the life of the plant, the number of annual captures appeared to be rising, with unprecedented capture rates being documented beginning about 1993. As part of a Section 7 Consultation between the Nuclear Regulatory Commission and the National Marine Fisheries Service, FPL agreed to perform an analysis of sea turtle entrapment data to assess the extent to which changes in capture rates may be related to plant operating characteristics and/or extraneous environmental conditions. This report summarizes the findings of that study.

The offshore intake structures resemble a reef system in many aspects. They offer vertical relief in an area where the seafloor is relatively flat and provide suitable attachment sites for a variety of encrusting organisms and marine algae. They also provide unlimited and uncontested space for refuge. Both loggerhead and green turtles are known to utilize natural reefs for foraging and shelter, and loggerheads have been shown to associate with artificial structures. Additionally, nearby hard bottom and worm reefs support many of the same species known to be preferred food items in the diets of both species. These natural systems probably attract turtles to the vicinity of the structures.

The intake structures were designed so they would not entrain sea turtles and other motile marine life (nekton) into the structures from the surrounding environment. These animals must actively enter the structures before they encounter water velocities

sufficiently strong to affect their entrainment. Once within the intake pipes, velocities prevent most turtles from escaping.

Between 1977 and 1998, there were significant increases in the number of juvenile and adult loggerhead and juvenile green turtle captures at the St. Lucie Plant. Captures of adult loggerheads increased gradually and closely corresponded to increases in nesting on Hutchinson Island. Thus, as more adult turtles were present in the nearshore environment, more individuals of this life history stage were entrained with cooling water. A different pattern emerged with juvenile loggerhead and green turtles. Although the number of captures for both species increased significantly over the life of the plant, the changes were not linear. Nearly all of the increases occurred after 1992.

The addition of a second unit at the St. Lucie Plant in 1983, along with a new and larger intake structure, increased the volume of cooling water drawn from the ocean and altered intake velocities. Although the annualized number of captures prior to Unit 2 startup was less than the number after, the addition of a second unit could not account for the dramatic rise in capture rates during the 1990s. Analysis of data following Unit 2 startup indicated that the volume of water entrained each month was not significantly correlated with green turtle entrapment levels, but it did have a weak influence on the number of juvenile loggerhead turtles captured. However, this influence was temporally limited and could not explain the longer-term patterns that were documented. Repairs to the intake structures, completed in 1992, coincided with a substantial increase in the number of juvenile green turtles captured. However, this was probably more coincidental than causal.

Similar to results for plant operating conditions, water temperatures accounted for some of the seasonal variations in capture rates but could not explain long-term changes. Furthermore, seasonal variation in the numbers of juvenile loggerhead and green turtles captured at the plant may be more closely related to migration patterns than to local environmental conditions. There was no correlation between wind velocities (and by extension ocean turbulence) and either short- or long-term sea turtle capture rates. There were no data to discern whether there had been substantive changes in the composition or relative abundance of plants and animals fed upon by loggerhead and green sea turtles in the vicinity of the St. Lucie Plant. Consequently, it was not possible to correlate changes in entrainment rates with changes in biological conditions adjacent to the plant.

A variety of factors affect the entrainment of turtles at the St. Lucie Plant, some related and some unrelated to plant operating conditions. However, none of the factors evaluated during this study provided a convincing explanation for the dramatic increase in captures of juvenile loggerhead and green turtles observed at the plant since the mid 1990s. Increased nesting on Hutchinson Island by both loggerhead and green turtles and recent unprecedented increases in juvenile green turtle captures in other areas of south central Florida suggest that local sea turtle populations may be increasing. This seems to offer the most logical explanation for increased capture rates at the St. Lucie Plant.

LIST OF TABLES

LIST OF FIGURES

PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT LEVELS AT ST. LUCIE NUCLEAR POWER PLANT

INTRODUCTION

Florida Power and Light Company (FPL) operates two nuclear power plants (St. Lucie Plant Units 1 and 2) on Hutchinson Island, Florida (Figure 1). Both plants draw cooling water from the nearshore waters of the Atlantic Ocean through submerged intake pipes. Water flows through the intake pipes into a canal system. In 1976, when the first of the two power plants began operation, it was discovered that sea turtles were being entrained into the intake canal with the cooling water. Once in the canal, water velocities in the intake pipes prevented turtles from returning to the ocean.

A sea turtle capture and release program was instituted in 1976 to remove entrapped turtles from the intake canal and release them safely back into the ocean. Data collected from 1976 through 1998 suggested that the number of sea turtles being entrained with cooling water had increased in recent years. In accordance with a Section 7 consultation under the U.S. Endangered Species Act of 1973, FPL was required to assess sea turtle capture trends at the St. Lucie Plant and to identify factors potentially responsible for recent increases. Ecological Associates, Inc. was contracted by FPL to perform that analysis.

OVERVIEW OF ST. LUCIE PLANT DESIGN AND OPERATION

Site Description

The St. Lucie Plant is located on a 437-hectare site on Hutchinson Island, a 36-km-long barrier island on Florida's East Coast. The island is bounded by the Atlantic Ocean on the east, the Indian River Lagoon on the west, the Ft. Pierce Inlet on the north and the St. Lucie Inlet on the south. The plant is located approximately midway between the two inlets (Figure 1).

The shoreline in the vicinity of the power plant consists of sandy beach with intertidal worm reefs located just south of the intake (Figure 2). Submerged coquinoid rock formations parallel much of the island off the ocean beaches (Gallagher and Hollinger, 1977), though no substantial reef formations have been reported immediately offshore of the plant. The sea bottom adjacent to the power plant is reported to consist of a mixture of sand and shell fragments (Ebasco Servcies, Inc., 1971; Gallagher, 1977).

The continental shelf margin is located approximately 30 km offshore of Hutchinson Island. The Florida Current flows approximately parallel to the margin, but oceanic water associated with the western edge of the current periodically intrudes inshore during the summer (Worth and Hollinger, 1977; Smith, 1982). Seasonal variations in both the Florida Current and coastal winds are apparently responsible for

annually recurring upwelling along Florida's Atlantic coast (Smith, 1982). These upwelling events occur during the summer and result in anomalously low water temperatures. During such events, water temperatures near the power plant may rapidly decrease by as much as 10°C and remain cool for several days to several weeks (ABI, 1977, 1981, 1986, 1990, 1991, 1992; FPL, unpublished data). Ambient water temperatures of the Atlantic Ocean in the vicinity of the power plant range from approximately 14 to 31°C. Water temperatures are typically warmest in September and coolest in January or February.

St. Lucie Plant Description

The St. Lucie Plant consists of two 850 Mwe, nuclear-fueled, electric generating units that draw once-through condenser cooling water from the Atlantic Ocean (Figure 3). Unit 1 went online in May 1976 and Unit 2 went online in June 1983. Three intake structures (one with a 4.9 m diameter opening and two with 3.7 m diameter openings) are located 365 m offshore in approximately 7 m of water. The two smaller intake structures were completed in late-1975 and the larger structure was completed in mid-1983. The configurations of the intake structures are shown in Figures 4 and 5. Each intake structure consists of a large base with a vertical shaft in the center. Numerous columns support a concrete velocity cap approximately two meters above the base of each structure. This configuration was designed to eliminate vertical water entrainment and reduce horizontal intake velocities thereby minimizing incidental entrainment of marine life.

In August 1989, large holes were discovered in the intake structure velocity caps. These holes added a strong vertical component to water entrainment, creating vortices that reached the ocean's surface. In March 1991, a construction project was initiated to repair the damaged caps. A large elevated platform, from which all repairs were conducted, was erected around the three intake structures. The platform remained in place until repairs were completed in February 1992. Repairs resulted in thicker velocity caps and supporting columns with the vertical clearance between the base of the intake structure and the bottom of the velocity cap remaining the same (Figure 6).

Water moves from the vertical shaft of each intake structure to a horizontal intake pipe. Intake pipes pass under the beach and dune system and connect to a 1500 m long intake canal that transports water to the plant. During the history of plant operation several barrier nets have been installed along the intake canal. The locations of these nets are shown in Figure 3. In 1978, a barrier net with a 20.3 cm square mesh was installed across the canal at the Highway A1A bridge. This barrier was intended to keep large debris and sea turtles away from the power plant. Then in January of 1987, an underwater intrusion detection system (UIDS) was installed on the north-south arm of the canal. This security system consists of a 22.9 cm mesh rigid net. And finally, in January 1996, a barrier net with a square mesh of 12.7 cm was installed east of the A1A bridge. This net was intended to better confine turtles to the eastern portion of the intake canal where capture techniques are most effective.

At the power plants, cooling water is drawn from the bottom of the canal into eight separate intake wells (Figures 3 and 7). In the wells, the water first passes through a series of trash racks (vertical bars spaced approximately 7.6 cm apart) and then through a series of traveling screens with a one centimeter mesh. Finally, the water flows through the circulating water pumps and into the plant's condenser system. As the water moves through the plant's condenser system, it gains heat from the condenser and is expelled into the discharge canal.

The discharge canal is 670 m long and leads to two buried discharge pipes at it's eastern terminus (Figure 3). The pipes transport water beneath the beach dune system back into the Atlantic Ocean. One pipe is 3.7 m in diameter, extends approximately 460 m offshore and terminates in a two-port "Y" nozzle. Installation of this discharge pipe was completed in 1975. The other pipe is 4.9 m in diameter and extends 1030 m offshore. Water is discharged into the ocean through a series of 58 ports that rise above the ocean floor along the easternmost 425 m of the pipe. Installation of this structure was completed in 1981.

St. Lucie Plant Intake System Characteristics

From May 1976 through May 1983, St. Lucie Plant Unit 1 drew 32.56 m^3/sec (1150 ft^3/sec) of water through two 3.7-m-diameter intake pipes during normal plant operation. Water velocities at various locations along the intake system are given in the second row of Table 1. When the power plant was shut down for refueling and/or maintenance, the main circulating water pumps were shut down and auxiliary pumps were run. During these periods, velocities due to the auxiliary pumps were approximately three percent of those for periods of normal plant operation (pers. com., N. Whiting). Water velocities along the intake system during periods when only auxiliary pumps were operating are given in the first row of Table 1. Between 1976 and 1983, during periods of normal plant operation, velocities within the 3.7-m intake pipes were between 159 and 178 cm/sec (5.2 – 5.8 ft/sec). Once within the intake canal, water velocities slowed to about 15.2 cm/sec (0.5 ft/sec).

With the addition of Unit 2 and a third (4.9-m-diameter) intake pipe in June 1983, water velocities along the intake system during normal plant operation changed (see the fourth row of Table 1). Velocities within the 4.9-m-diameter intake pipe were greater than those occurring within the 3.7-m-diameter pipes prior to the addition of Unit 2. However, velocities within the 3.7-m-diameter intakes decrease after addition of the larger intake pipe. Between 1983 and 1998, during periods of normal plant operation, velocities within the smaller intake pipes ranged from 127 – 142 cm/sec (4.2 – 4.7 ft/sec) and in the large intake pipe from 180 – 206 cm/sec (5.9 – 6.8 ft/sec). The addition of the second unit doubled current velocities within the intake canal when both units were operational.

The addition of a second power plant also affected velocities along the intake system during maintenance/refueling periods. After June 1983, maintenance and refueling was scheduled such that one plant was always operating while the other was

shut down (with only auxiliary pumps running). So, flow velocities during maintenance/refueling periods were considerably higher after June 1983 than before when only auxiliary pumps were running (see the third row of table 1).

ST. LUCIE PLANT SEA TURTLE CAPTURE PROGRAM

Over the years, most of the turtles entrapped in the St. Lucie Plant were removed by means of large mesh tangle nets. Nets varied in length from 30 to 115 m, were 2.7 to 3.7 m in depth and were usually made of 40.6 cm stretch mesh, multi-strand nylon. Large floats were attached to the surface line and during the first several years the bottom line consisted of hollow braided polypropylene line with lead weights inserted every 61 cm. Since 1982, bottom lines were unweighted. Turtles entangled in the nets generally floated at the water's surface until removed.

Nets were fished at various locations throughout the intake canal, though most netting took place east of the A1A bridge (Figure 3). Throughout the study period, the canal capture program underwent continuous refinement to minimize both entrapment time and any harm to entrained turtles. Prior to April 1990, nets were usually deployed on Monday morning and retrieved Friday afternoon. During deployment, the nets were inspected a minimum of twice per day (once in the morning and again in the afternoon) by biologists. In addition, St. Lucie Plant personnel periodically checked the nets throughout the day and night. Biologists were on call 24 hours per day and were notified immediately if a turtle was observed in the net.

Beginning in April 1990, procedures were revised to decrease response time for removal of entangled turtles from nets and to increase surveillance of the canal for the presence of turtles. Under the new procedures, nets were deployed during daylight hours only (Monday through Friday; approximately eight hours per day) and biologists remained on site during deployment. While on site, biologists were able to assess turtle levels in the canal. Records of daily canal observations were compared with capture data to determine capture efficiencies. Beginning in July 1994, netting effort was increased to seven days per week and 10 to 12 hours per day.

In addition to procedural changes, there were physical changes in the canal that increased the efficiency of the capture program. The A1A barrier net, which was installed in 1978, was constructed to restrict turtles to the easternmost section of the intake canal where netting was most effective. For a number of years after it was installed, the integrity of the barrier net was periodically compromised and turtles were able to move west of A1A. Beginning in January 1987, turtles moving west of A1A were further constrained downstream by the UIDS. Prior to the completion of the UIDS, turtles that breached the A1A barrier net were usually not captured until they reached the power plant's intake wells. The intake wells were inspected throughout the day and night by St. Lucie Plant personnel, and biologists were notified immediately if turtles were observed. Turtles were removed from the intake wells by means of mechanical rakes, dip nets or by hand. Following construction of the UIDS, all but the smallest turtles were

restricted from the intake wells. After improvements were made in 1990, the A1A barrier net was effective in confining all turtles larger than 32.5 cm carapace length (28.7 cm carapace width) to the eastern end of the canal.

In response to a dramatic increase in intake canal captures in 1995, consultation was initiated with FPL, the Nuclear Regulatory Commission (NRC) and the National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act. As a result of that consultation, FPL has designed and constructed a small mesh barrier net east of the A1A barrier net. Construction of the net was completed in January 1996. This net was designed to restrict all turtles with a carapace width greater than 18 cm to the extreme eastern portion of the intake canal. Because capture techniques were most efficient in this portion of the canal, residency times of entrained turtles were further reduced after the installation of this net.

Throughout the history of the canal capture program, the entire intake canal was periodically inspected to determine the numbers, locations and species of turtles present. The effort devoted to surveillance of the canal was increased in 1990, and then again in 1994, concurrent with revised netting procedures during those years. Also, surface observations were augmented with periodic underwater inspections, particularly in the vicinity of the barrier nets. These efforts insured that all turtles that were entrapped in the canal were accounted for.

In addition to tangle nets, several other methods were used to remove turtles from the intake canal. Captures at the intake wells were previously discussed. Another technique involved the use of long handled dip nets from boats, canal banks and headwall structures[1] to capture small turtles (carapace lengths of 30 cm or less). This method was moderately effective. Additionally, divers with snorkels or SCUBA entered the canal and hand-captured turtles. Because this latter technique proved to be highly effective in the capture of turtles of all sizes, it was used extensively from 1990 through 1998. This method was particularly effective in removing less active turtles and undoubtedly helped to reduce residency times for entrapped turtles. Between 1994 and 1998, 12 to 18 percent of the captures that occurred east of the A1A bridge were attributable to hand captures.

Regardless of capture method, all live turtles removed from the canal were identified to species, measured, weighed, tagged and examined for overall condition. Healthy turtles were released into the ocean the same day of capture. Sick or injured turtles were treated and, if necessary, held for observation prior to release. Dead turtles were identified to species, measured and assigned an identity number. Beginning in 1982, necropsies were conducted on dead turtles found in fresh condition.

From 1976 through 1998, 6,086 sea turtles were captured in the St. Lucie Plant intake canal (Table 2). Captures included 3,578 loggerhead turtles, 2,432 green turtles, 21 leatherback turtles, 21 hawksbill turtles and 34 Kemp's ridley turtles. Because the vast majority of the captures consisted of loggerhead (58.8 percent) and green (40.0 percent) turtles, this report will deal only with these two species.

[1] Bulkhead and pier-like structures located at the east end of the intake canal (Figure 3).

The earliest estimates of residency times for turtles in the intake canal were derived from data collected from October 1980 through January 1981 (ABI, 1983). Eleven loggerhead turtles were captured, tagged, released back into the canal and recaptured (ABI, 1983). Recapture occurred one to nine times before individual turtles were released back into the ocean. There were 32 recapture events. The average elapsed time between successive captures was 10.3 days (range: 0.25 to 38 days). Twenty-three of the recaptures (72 percent) occurred within 11 days.

The increased surveillance for turtles in the intake canal that began in April 1990 allowed individual turtles to be identified as they were observed in the canal. As turtles were captured, the date of initial observation was compared to the date of capture and residency times were determined. Data collected for 416 loggerhead turtles from April 1990 through December 1993 indicated that the average residency time was 2.7 days (range: 1 to 50 days; ABI, 1994). Ninety-three percent of these loggerheads were captured within one week of first sighting. Data for 252 green turtles collected during the same period indicated an average residency time of 3.8 days (range: 1 to 61 days). Eighty-six percent of these green turtles were captured within one week of first sighting.

Results of residency time analyses provided the basis for establishing time intervals to be used for analysis of trends in turtle entrainment at the St. Lucie Plant. In this report long-term trends in turtle entrainment are analyzed using annual data. Seasonal trends in entrainment and relationships between turtle entrainment and various environmental and power plant factors are analyzed using monthly data. The latter interval seemed appropriate based on average residency times (time lags between entrainment and capture) of three to ten days. It is recognized that not all turtles captured during a particular month were necessarily entrapped that month. However, overall seasonal trends should be fairly accurately portrayed using monthly data.

Prior to analyzing trends in loggerhead and green turtle captures at the St. Lucie Plant, an overview of pertinent biological characteristics of these two species is warranted. This will aid in interpreting the results of the St. Lucie Plant sea turtle capture program.

BIOLOGY OF LOGGERHEAD AND GREEN TURTLES

Loggerhead Turtles

The loggerhead turtle, *Caretta caretta*, inhabits temperate, subtropical and tropical waters of the Atlantic, Pacific, and Indian Oceans. Most nesting occurs on warm temperate and subtropical beaches (Dodd, 1988). Approximately 50,000 to 70,000 loggerhead turtle nests are deposited on Southeastern US beaches annually, ranking this loggerhead turtle rookery the second largest in the world (NMFS and USFWS, 1991a). The beaches in southeast Florida are especially prolific nesting areas, with Hutchinson Island being a critically important nesting beach (Meylan et al., 1995). Between 5,000

and 8,000 loggerhead nests have been deposited annually on Hutchinson Island during the last ten years (Quantum Resources, 1999).

Most nests on Hutchinson Island hatch within sixty days (Ernest and Martin, 1993; Ecological Associates, Inc., unpublished data). Hatchlings emerge from nests primarily at night. Upon entering the surf, the hatchling swims offshore in a "frenzy" to arrive at floating weed and debris lines (Carr, 1986; Salmon and Wyneken, 1994). Once there, loggerhead turtles feed on various insects, hydrozoans, gelatinous animals, barnacles and other material associated with floating mats of *Sargassum* (Richardson and McGillivary, 1991; Witherington, 1994). Post-hatchling loggerhead turtles from the Florida coast enter the currents of the North Atlantic Gyre that encircles the Sargasso Sea and move toward the eastern Atlantic. They may use magnetic cues to keep them from getting off course and floating into waters too cold for survival (Lohmann and Lohmann, 1996). Bolten et al. (1998) conducted a study of mitochondrial DNA from 131 pelagic juvenile loggerheads captured off the Azores and Madeira in the eastern Atlantic. One hundred and twenty-one of the turtles had known nesting beach haplotypes, and of those, approximately 71 percent were from south Florida, 19 percent from north Florida to North Carolina, and 11 percent from Mexico. The curved carapace length of the turtles from the Azores was 9-71 cm, and for the Madeira turtles 20 to 55 cm. From the eastern Atlantic, some pelagic turtles may enter the Mediterranean Sea, but many drift back around to the shallow coastal waters of the western Atlantic (Bowen et al., 1993; Laurent et al., 1998).

When loggerhead turtles reach the size of approximately 40-60cm straight carapace length (SCL), they leave the pelagic environment and move into various inshore estuaries or reef-system habitats (Carr et al., 1978; Carr, 1986). Most western Atlantic loggerheads are estimated to arrive in coastal waters after five to twelve years of a pelagic existence (National Research Council, 1990; Bjorndal and Bolten, 1994). The nearshore regions where juvenile and subadult loggerheads live and forage have been termed developmental habitats. They may reside in these developmental habitats either seasonally or year round until they reach sexual maturity (Carr et al., 1978). This is estimated to occur between 22 to 26 years of age (Frazer and Ehrhart, 1985; Klinger and Musick, 1995). Few mature adults are found in developmental habitats along the east coast of Florida except during mating or nesting season (National Research Council, 1990).

In the United States, developmental habitats for loggerhead turtles are found from Texas to Nova Scotia (Carr, 1952; Turtle Expert Working Group, 1998). Aerial surveys conducted in summer months indicated that 54 percent of the post-pelagic loggerheads in US coastal waters were found off the southeast coast; 29 percent were off the northeast coast; 12 percent were in the eastern Gulf of Mexico; and 5 percent were in the western Gulf of Mexico (Turtle Expert Working Group, 1998).

While immature loggerhead turtles are found in south Florida waters year round, their occurrence in northern estuaries and bays is seasonal. Generally, the northern habitats are only occupied during the late spring, summer, and early fall (Lutcavage and

Musick, 1985; Keinath et al., 1987; Morreale et al., 1992; Epperly et al., 1995). Over 90 percent of the loggerhead turtles that migrate seasonally to northern waters are sexually immature (Rankin-Baransky, 1997; Coles, 1999).

Coles (1999) reported that loggerhead turtles in the Chesapeake Bay have been found in areas with water temperatures ranging from 13 to 29°C. Most juvenile sea turtles enter the bay in the late spring as temperatures approach 20°C, and they leave in the fall after temperatures fall below 20°C. Many of the turtles entering the bay have migrated from areas south of Cape Hatteras. When they arrive, water temperatures in the bay are still rather cool, and thus the turtles spend proportionately more time near the surface and in deeper areas where temperatures are warmest (19-21°C). This behavior keeps the turtles away from their benthic food supply and exposes them to hazards such as boat collisions. Already weakened from their recent migration, these turtles are also less likely to avoid or survive incidental capture in pound nets and other types of fishing gear (Byles, 1988). Consequently, most dead, ill and injured marine turtles are found in the Chesapeake Bay during the spring (usually May). Loggerhead stranding numbers decrease as bottom temperatures heat up (Keinath et al., 1987; Epperly et al., 1995; Coles, 1999). Klinger and Musick (1995) estimated the age of most loggerheads foraging in the Chesapeake Bay to be between six and ten years old.

Often in the fall, temperatures in the shallower bays along the Atlantic seaboard will drop rapidly before some turtles have migrated south. When water temperatures fall below 8°C, the turtles become hypothermic and float to the surface where many die. This is termed a cold-stunning event. Cold-stunning events have been documented from Cape Cod to the Mosquito Lagoon in the northern region of the Indian River Lagoon system (Witherington and Ehrhart, 1989a; Morreale et al., 1992). Witherington and Ehrhart (1989a) pointed out that these events often occur in estuaries where the outlet to deeper, warmer waters lies to the north – a path opposite to the one that a turtle would instinctively follow to reach warmer waters. Cold-stunning events have also been reported in the Laguna Madre of Texas (Shaver, 1990).

Turtles survive the cold winters in Florida waters by residing in the warmer regions or currents, or by burying themselves into the muddy substrate of deep channels (Ogren and McVea, 1982). Loggerhead turtles are often found buried in the muddy substrates of the Cape Canaveral Ship Channel during the winter. Most of these individuals are subadults or juveniles.

Surveys conducted by trawling vessels in the vicinity of Cape Canaveral, Florida captured immature loggerhead turtles throughout the year, but the majority were caught during the winter months (Henwood, 1987; Bolten et al., 1994). In the central Indian River Lagoon, Ehrhart et al. (1996, 1999) also captured immature loggerhead turtles in tangle nets throughout the year. However, unlike the Canaveral Ship Channel, no seasonal trends in catch per unit effort (CPUE) were apparent.

Since 1989, netting has been conducted on the sabellariid worm reefs just south of Sebastian Inlet, Florida by Ehrhart et al. (1996, 1999). Surprisingly, few loggerhead

turtles have been captured on the reef. Ehrhart et al. (1996) found the paucity of loggerheads over the reefs somewhat perplexing in light of the large number of loggerheads occurring in similar habitat near the St. Lucie Plant. However, Ehrhart et al.'s study site was in water depths of less than 3.5 meters and within 150 meters of shore compared to the St. Lucie Plant intake that is in a water depth of approximately 7 meters and is 365 meters from shore. Additionally, netting on the worm reefs was only performed during the summer months.

Nocturnal SCUBA surveys were conducted from 1986 through 1990 on nearshore hardbottom habitat in Broward County. Turtles encountered by divers were captured by hand. During the period of study, only one loggerhead turtle was captured, compared to 134 juvenile green turtles and 5 juvenile hawksbill turtles (Wershoven and Wershoven, 1990). The loggerhead was captured in the most seaward section of one of the study sites.

Genetic studies performed on immature loggerheads entrapped in the St. Lucie Power Plant intake canal indicate that 70 percent were from South Florida nesting populations, 20 percent from Yucatan nesting populations, and 10 percent were from northern Florida to North Carolina nesting populations (Bass, 1999). The results were similar to a mitochondrial DNA (mtDNA) study of stranded turtles from the northeastern US coast, where 58 percent of the loggerheads originated from south Florida nesting stock, 25 percent were from the north Florida to North Carolina stock, and 17 percent were from Mexico (Rankin-Baransky, 1997). Genetic research has also been done on loggerheads from the Chesapeake Bay, Charleston Harbor, and Kings Bay, Georgia. The genetic origin of these populations seems to be split between north Florida/North Carolina stock and South Florida stock (Sears, 1994; Norrgard, 1995; Sears et al., 1995).

Radioimmunoassay (RIA) analysis of testosterone titer levels on blood serum has allowed researchers to determine the sex of immature sea turtles. The pooled sex ratio of immature loggerhead turtles (40-76 cm SCL) captured at the St. Lucie Plant was 2.1 females for each male (n=218; Wibbels et al., 1991). The sex ratios did not vary by season, or by size class, suggesting that the female bias may be a temporally stable phenomenon, at least within the juvenile stage of the life history. These data are consistent with a previous study done by Wibbels et al. (1984) on immature loggerheads from four locations along the Atlantic Coast of the U. S. in which the ratio of females to males was 1.94:1.0 (female:male). Ehrhart et al. (1999) reported that the juvenile loggerhead population in the Indian River Lagoon also had a female bias (1.6:1.0).

Most of the juvenile loggerhead turtles captured in the Indian River Lagoon and other places along the Atlantic seaboard fall within the size range of 50 to 70 cm straight minimum carapace length (SMCL; Lutcavage and Musick, 1985; Standora et al., 1994; Epperly et al., 1995; Provancha, 1997, 1998; Coles, 1999; Ehrhart et al., 1999). The mean straight carapace length (SCL) for the turtles netted in the central Indian River Lagoon was 62.6 cm (range = 42 – 83 cm; Ehrhart et al., 1999). In the waters around the coast of North Carolina, the mean standard curved carapace length of loggerhead turtles was 66 cm (range = 42 to 105 cm; Epperly et al., 1995). Lutcavage and Musick (1985)

reported SCL means of 68.7 cm for the loggerhead turtles occupying the Chesapeake Bay. Mean SCL for stranded, mainly cold stunned, turtles north of Virginia have been reported to range from 48.2 to 54 cm (Morreale et al., 1992; Rankin-Baransky, 1997). These smaller means may result from the greater physiological susceptibility of younger turtles to hypothermia (Witherington and Ehrhart, 1989a; Morreale et al., 1992).

Loggerhead turtles live in the Florida nearshore waters and lagoons until they approach the size of the smallest females nesting on nearby beaches (Ehrhart et al., 1999). It is not known what cues prompt a subadult to leave developmental habitat or at what time of year departure occurs. However, the average size of loggerhead turtles captured in Florida Bay is 80.1 cm SCL (with a range of 48.9 to 98.7 cm). These turtles appear to comprise an intermediate size class that is nearing maturation (Schroeder et al., 1998). Thus, the larger juvenile loggerhead turtles leaving developmental habitats along the eastern U.S. seaboard may reside in Florida Bay for a period before moving on to join the adult population on distant feeding grounds.

While occupying inshore, developmental habitats, juvenile loggerhead turtles primarily feed on decapod crustaceans, mollusks, and fish (Lutcavage and Musick, 1985). They tend to be opportunistic, often exploiting regionally abundant prey items. The preferred food for loggerheads along the mid-Atlantic coast of the United States is reported to be the horseshoe crab, *Limulus polyphemus* (Keinath et al., 1987; Dodd, 1988; Sauls and Thompson, 1988). On the south Texas coast, Plotkin et al. (1993) reported that sea pens (*Virgularia presbytes*; a soft coral) were a major component of the loggerhead diet. Crabs and mollusks were also present in high quantities within loggerhead diet samples from Texas, along with tube worms, sea pansies, whip corals, and sea anemones.

Carr (1952) wrote that loggerhead dietary items consisted of crabs, shellfish (like clams, oysters and conchs), fish, sponges, jellyfish, and sometimes algae. A loggerhead dietary study conducted in the bays around Long Island, New York, concurred with Carr's food list. Burke et al. (1993) found that approximately 90 percent of the juvenile loggerhead turtles they sampled had consumed crabs (spider crabs *Libinia emarginata*, Atlantic rock crab *Cancer irroratus*, and the lady crab *Ovalipes ocellatus*). These loggerheads had also eaten mussels, whelks, and algae (*Sargassum natans*, *Ulva* sp., and *Fucus* sp.). Similar dietary items were reported for turtles stranded off the coast of Virginia by Bellmund et al. (1987) and off of Georgia by Ruckdeschel and Shoop (1988). A comprehensive list of reported food items of the loggerhead turtle is provided by Dodd (1988).

Adult loggerhead turtles nest mainly in the continental United States from North Carolina to the Florida panhandle, with about 90 percent of the nests being deposited on southern Florida beaches (National Research Council, 1990). The average female loggerhead makes reproductive migrations between her foraging grounds and nesting beach every two or three years and deposits about four clutches of eggs during those years that she nests (Richardson and Richardson, 1982; Murphy and Hopkins, 1984).

In the southeastern United States, the first nests begin to appear in late April and the last usually in September. The months of highest loggerhead turtle nesting are in June and July (NMFS and USFWS, 1991a; Meylan et al., 1995; Ernest and Martin, 1999). The mating season begins in early March, prior to the start of nesting season. Mating activity subsides in mid-June, when it is assumed that most males return to their foraging grounds. Stranding reports coincide with the above mentioned seasonal trends. Most of the adult male loggerhead strandings along the Atlantic seaboard occur just prior to and during the beginning of the nesting season (Turtle Expert Working Group, 1998). Far fewer adult loggerhead strandings (especially male) occur outside of the nesting season. Aerial surveys of turtles in coastal waters of Florida are consistent with the stranding data. The fly-over observations have found highest concentrations of adult loggerheads off the coast of primary nesting beaches during spring and summer, with numbers dramatically dropping off in the fall and winter. The numbers of sighted adults are about 15 times higher in the spring and summer than in the fall and winter (Thompson, 1988; National Research Council, 1990). However, some adult loggerhead turtles are found in Florida waters throughout the year.

Surveys conducted by trawling vessels in the vicinity of the Cape Canaveral Ship Channel between 1978 and 1984 resulted in the capture of over 3,000 individuals (Henwood, 1987). Each age class was dominant at different times of year. Adult males were most abundant in April and May. Adult females were most common from May to July, and juvenile and subadults (<83 cm SCL) constituted over 80 percent of the population during the remainder of the year. Adult females did not seem to stay in the area except while nesting. These seasonal patterns were also documented in a later study by Bolten et al. (1994) in Port Canaveral.

Loggerhead turtles that nest on Hutchinson Island are part of a larger, genetically distinct south Florida nesting population (Bowen et al., 1993). The turtles differ genetically from those turtles that nest in north Florida to North Carolina as well as those found in the Mediterranean. This indicates that there is little to no gene flow between rookeries, supporting the predictions of a natal beach homing hypothesis. This hypothesis contends that hatchlings leaving a particular nesting beach will return to that beach to nest as adults. Thus, from a management standpoint, each subpopulation should be treated as unique and vulnerable to extirpation (Turtle Expert Working Group, 1998).

The adult loggerhead foraging grounds for the south Florida nesting population are thought to be in the Bahamas, Cuba, Dominican Republic, eastern seaboard of the United States, Florida Keys, and the Gulf of Mexico (Meylan et al., 1983; Henwood, 1987; Spotila et al., 1997; Rankin-Baransky, 1997). The habitats used as adult foraging grounds are very diverse, ranging from the muddy bayous of the northern Gulf Coast to continental shelves to the clear, shallow waters of the Bahamas (National Research Council, 1990).

In the southeastern United States, adult loggerheads have a mean SCL of 92 cm and a mean body weight of 113 kg. They rarely exceed 122 cm in length (National Research Council, 1990).

The size used to classify individuals as mature adults is somewhat arbitrary, as loggerhead turtles reach maturity at variable sizes. The adult size range is primarily based on the size of females measured on various nesting beaches. Limpus (1991) reported that the average female begins to breed at a size only slightly smaller than the average size of the entire nesting population.

Ernest et al. (1989) used 85 cm SMCL as a breakpoint separating adults from subadults captured at the St. Lucie Plant. Ehrhart et al. (1996) used 83 cm SCL as the cut off point between subadult and adult females based on the range of measurements from 1,207 females nesting on Brevard County beaches; only four percent of nesting turtles in Brevard County were less than 83 cm. Henwood (1987) used the measurement of 83 cm total (or maximum) carapace length (which equates to 81.5 cm SCL) to delineate between subadults and adults in his trawling study at Cape Canaveral.

Adult loggerhead turtles seem to eat the same general prey as juveniles and subadults. However, more dietary research is needed from various adult foraging grounds. Adults are known to eat horseshoe crabs, decapod and cirriped crustaceans, gastropod and pelecypod mollusks, cnidarians, echinoderms, fish, and algae (Lutcavage and Musick, 1985; Dodd, 1988).

Green Turtles

Green turtles are found in tropical seas throughout the world (Hirth, 1997). Off the east coast of the continental United States, green turtles can be found from Texas to Massachusetts, although nesting only occurs on Florida beaches. The number of nests deposited in Florida is relatively small compared to Costa Rica, Aves Island, Ascension Island, and Surinam. However, many juvenile green turtles utilize shallow U.S. coastal waters and bays as developmental habitat (NMFS & USFWS, 1991b).

Similar to the loggerhead turtle, green turtle hatchlings actively swim offshore to oceanic convergence zones after leaving the beach. Pelagic hatchlings from Florida nests are suspected to enter the North Atlantic Gyre system and eventually make their way back to western Atlantic coastal waters (Witham, 1980). During the pelagic phase, green turtles are presumed to be carnivorous, feeding on small animals like ctenophores and tunicates in the plankton (Booth and Peters, 1972; Bustard, 1976; Hirth, 1997). However, further research is needed on this aspect of their biology. Differences in intestinal length proportions between post-hatchlings and adults, suggest a developmental shift from a predominantly carnivorous to a primarily herbivorous diet (Davenport et al., 1989).

When green turtles reach a size of about 20-25 cm SCL, they leave the pelagic habitat and enter benthic feeding grounds (National Research Council, 1990). The juvenile feeding grounds are usually in warm, shallow, protected waters where benthic vegetation is prevalent (Carr et al., 1978). Foraging habitats most commonly consist of sandy bottoms supporting seagrass or algal beds, but small green turtles are also found on coral reefs, sabellariid worm reefs, or rocky substrate where attached algae is present. Some feeding grounds support only a particular size class of green turtles, while other

feeding areas support a full range of sizes from juveniles to breeding adults (National Research Council, 1990; Wershoven and Wershoven, 1990; Coyne, 1994; Redfoot et al., 1996; Ehrhart et al., 1996).

Many juvenile green turtles use the southeast coast of Florida year-round as developmental habitat. Both inshore lagoons and nearshore sabellariid reefs are considered prime developmental habitat (Ehrhart et al, 1996). Large reefs constructed by polychaete worms of the Family Sabellariidae have been reported from Brevard through Dade County, Florida (Kirtley, 1966). These worm reefs run roughly parallel to the shore and are the primary basis for an elaborate marine community of encrusting, boring and shelter-seeking animals as well as abundant marine flora (Kirtley and Tanner, 1968).

Green turtles appear in coastal developmental habitats at a much smaller size class than loggerhead turtles (Musick and Limpus, 1997). Zug and Glor (1998) used skeletochronology to age juvenile green turtles that died from a cold stunning event in the Mosquito and Northern Indian River Lagoon. The juveniles ranged in size from 28 to 74 cm SCL, and the age estimates for these individuals were 3 to 14 years old. Zug and Glor estimated that most of the juveniles were recruited to the developmental habitat at about 5 or 6 years of age, and would stay in this or other developmental habitats for 6 to 8 years. The individuals would thus leave between the ages of 10 to 14 years old. Mean growth rate estimates were 3.0-5.2 cm per year.

Sabellariid worm reefs are a prime developmental habitat for green turtles in south Florida. The reefs, which can extend from the intertidal zone out to a depth of ten meters, are found along the Atlantic shoreline from Cape Canaveral to Biscayne Bay, Florida. The reefs generally run parallel to the shoreline, and juvenile green turtles feed on the many species of red and green benthic marine algae present on the reef (Ehrhart et al., 1996).

In 1989, Ehrhart et al. (1996) began conducting netting during the summer over a sabellariid worm reef near Sebastian Inlet, Florida. More juvenile green turtles were caught per unit effort (CPUE) on the reef than at a site in the Indian River Lagoon south of the inlet. These data suggests that there may be a higher number of turtles inhabiting the reef than the lagoon, at least during the summer. Alternatively, capture rates on the reef may be higher, because the foraging area is more concentrated over the reef and therefore capture techniques are more effective. The turtles on the reef were similar in size and weight to those captured in the lagoon. Much of the algae consumed by the turtles grows in both locations. However, the juveniles rarely seem to migrate between the two habitats even though an inlet is nearby (Ehrhart et al., 1996, 1999; D. Bagley, unpublished data).

Inside the central Indian River Lagoon, more juvenile green turtles were captured in the winter than in the summer (Ehrhart et al., 1996, 1999). Ehrhart et al. (1996) hypothesized that seasonal increases in drift algae within the lagoon and migrants from northern climates may be responsible for the increased capture frequency during the cooler months.

North of Florida, green turtles are found in smaller numbers than juvenile loggerhead turtles, but there is evidence that many do migrate seasonally as far north as Cape Cod Bay (Lazell, 1980; Henwood, 1987; Morreale et al., 1992; Epperly et al., 1995; Provancha et al., 1998). Like the loggerhead turtle, their migrations seem to be water temperature dependent, and they are quite susceptible to cold water stunning events (Morreale et al., 1992; Coyne, 1994; Epperly et al., 1995).

In Florida, major cold stunning events have been documented as far south as the northern Indian River Lagoon system (Mendonca and Ehrhart, 1982; Witherington and Ehrhart, 1989a; Schroeder et al., 1990). Over 90 percent of the turtles affected by these events were juvenile green turtles; the remaining 10 percent were loggerhead turtles. The body size and physiology of juvenile green turtles may make them more susceptible to hypothermia than loggerhead turtles. The relatively large number of individuals involved in cold-stunning events demonstrates the importance of the Indian River Lagoon as a developmental habitat for green turtles (Witherington and Ehrhart, 1989a).

In a study conducted in the Mosquito Lagoon, Mendonca (1983) noted that green turtles occupied deeper water, would not eat, and took to wandering long distances when water temperatures were between 11 and 18°C, suggesting that they were looking for warmer waters. In Texas, Coyne (1994) reported that green turtles left the study area or became inactive when water temperatures fell below 16°C. Conversely, green turtles also are known to actively thermoregulate when water temperatures get too warm. Both Coyne (1994) and Mendonca (1983) noticed increased activities in the warmer months of the year. When temperatures rose above 32°C the turtles moved to deeper and cooler water (Mendonca, 1983). During hot summer days, turtles often fed in the early morning and late afternoon, when waters temperatures were coolest, and moved into deeper waters to rest during the midday hours (Bjorndal, 1980; Mendonca, 1983).

Bass and Witzell (in press) compared the mtDNA of 62 juvenile green turtles captured at the St. Lucie Power Plant and reported that approximately 42 percent of the turtles originated from Florida or Mexico nesting populations. About 53 percent came from rookeries in Costa Rica, and 4 percent were from Aves Island (Venezuela) and Surinam. The juvenile green turtles residing in developmental habitats in the nearby Bahamas were also tested and found to be primarily (80 percent) from Costa Rican nesting populations. Individuals representing Aves Island and Surinam (14 percent), United States and Mexico (5 percent), and Ascension Island and Guinea Bissau (1 percent) populations were represented as well (Bass and Witzell, in press). These results indicate that the juvenile green turtles utilizing a particular developmental habitat are not of homogenous origin. As for loggerheads, molecular studies support the hypothesis of natal beach homing in green turtles (Bowen et al., 1992).

The sex ratio of juvenile green turtles captured on sabellariid worm reefs and in the central Indian River Lagoon was studied by Ehrhart et al. (1999). Similar to the loggerhead, the green turtle sex ratio was strongly female biased at 2.9:1.0 (female:male). Redfoot et al. (1996) also measured testosterone levels on small green turtles occupying the Trident submarine basin at Cape Canaveral and found the sex ratio to be highly

skewed toward females (10.9:1.0). In the Mosquito Lagoon, the sex ratio of cold stunned green turtles was 1.75:1.0 (Schroeder and Owens, 1994). Only fourteen juvenile green turtles captured in the St. Lucie Plant intake canal have been sexed through blood work. Twelve were females, and two were males, resulting in a 6.0:1.0 ratio (ABI, 1994).

The average size of green turtles netted in the Indian River Lagoon and on the sabellariid worm reef near Sebastian Inlet were 40.7 cm SCL (range = 24 to 72 cm) and 41.1 cm (range = 25 to 67 cm), respectively (Ehrhart et al., 1996). Hand caught green turtles on reefs in Broward County, Florida were similar in size at 43.5 cm mean curved carapace length (CCL; range = 27 to 60 cm; Wershoven and Wershoven, 1990). The mean length of green turtles captured in Florida Bay was recently reported as 46.2 cm SCL (range = 26 to 63 cm; Schroeder et al., 1998). Slightly larger (mean = 52.3 cm SCL; range = 27 to77 cm) turtles were retrieved from the Mosquito Lagoon (northern Indian River Lagoon system) in the cold-stunning event of 1989 (Schroeder et al., 1990). Green turtles netted in the Indian River Lagoon near the Fort Pierce Inlet were of similar size at 53.1cm mean SCL (range = 37 to 75 cm; Bresette et al., 1999). Turtles netted in the Trident Submarine Basin were somewhat smaller averaging about 32.9 cm SCL (range 23 to 48 cm; Redfoot et al., 1996). This was similar to the average size of green turtles (33.8 cm TSCL; range 24 to 68 cm) captured by trawling in the Port Canaveral ship channel (Henwood and Ogren, 1987).

Differences in mean size among study areas may reflect the quantity and quality of food resources available in the habitat. There are some habitats that cannot sustain large individuals because of inadequate food availability (Coyne, 1994; Redfoot et al., 1996). Size class distributions may also be affected by capture methods (Ehrhart et al., 1996). Netting, for example, may undersample very small or large size classes because of mesh size limitations. Net placement at different depths and locations may also influence capture statistics (Ehrhart et al., 1999). Cold stunning may be a very efficient method of sampling turtles. However, as mentioned before, some size groups may be more physiologically susceptible to cooler temperatures than others (Witherington and Ehrhart, 1989a; Morreale et al., 1992).

An extensive list of juvenile and adult green turtle food items from around the globe can be found in Hirth (1997). In many habitats, green turtles are known to exhibit dietary preferences for either algae or seagrass. There are a few places that have populations of turtles that forage primarily on seagrasses within a few kilometers of those that feed primarily on algae (Bjorndal, 1980; Mortimer, 1981a; Coyne, 1994).

Mendonca (1983) found that *Syringodium filiforme* (manatee grass) *and Halodule wrightii* (shoal grass) were the primary food items in the stomachs of juvenile green turtles in the Mosquito Lagoon. These two species of seagrass were also the dominant rooted macrophytes in the lagoon. Although red alga was also abundant, it made up only a small percentage (about 8 percent) of stomach contents. Bjorndal (1980) suggested that switching between a diet high in seagrass to a diet high in algae, or eating both simultaneously, may lead to digestive inefficiency as different fermentative gut microflora are needed to adequately digest each.

The Trident submarine basin at Port Canaveral is about 40km south of the Mosquito Lagoon. Redfoot et al. (1996) studied the diets of juvenile green turtles that inhabited the rock-lined basin. All captured turtles were small (mean = 32.9 SCL), and most of the turtles (58 out of 67) had only algae in their stomachs. Algae and jellyfish were found in 5 of the 67 stomach samples, one sample contained algae and unidentified animal tissue, two samples contained only jellyfish, and one contained only fish. The algae consumed by the turtles were the same species that grew on the rocks in the basin. The researchers suggested that the absence of larger juvenile green turtles (>50cm) was due to limited biomass of the algae growing on the rocks.

In the central portion of the Indian River Lagoon, Ehrhart et al. (1996) found that green turtles were feeding almost exclusively on drift algae instead of nearby seagrasses. The drift algae were comprised of *Gracilaria* spp., *Acanthophora spicifera*, *Bryothamnion seaforthii*, *Hypnea* spp., and *Solieria filiformis*. Ehrhart et al. (1996) also captured turtles on sabellariid worm reefs in the ocean south of Sebastian Inlet. The reefs supported a diverse flora of green, brown, and red algae upon which the turtles foraged. The algae species *Caulerpa prolifera, Ulva lactuca, Bryocladia cuspida, Bryothamnion seaforthii, Gelidium americana, Gigartina acicularis, Hypnea musciformis, Rhodymenia pseudopalmata*, and *Solieria filiformis* were documented on the reef.

In the waters around South Padre Island, Texas, Coyne (1994) studied two populations of juvenile green turtles. The smaller sized turtles (<40 cm SCL) resided near and fed on the algae growing on the large boulders along Brazos Santiago Pass. The larger turtles (>30 cm SCL) were found over the grassbeds of South Bay/Mexiquita Flats. The turtles living near the grassbeds generally fed on *Halodule wrightii*, which was one of the less abundant seagrass species present, indicating that they were selective feeders. Coyne suggested that the algal biomass contained on the boulders in the pass was insufficient to sustain the larger turtles. The study did not determine if the smaller, algae-eating turtles were moving to the grassbeds after leaving the rocky Brazos Santiago Pass.

As noted earlier, green turtles end their pelagic existence and enter shallow coastal waters at an smaller size than loggerhead juveniles. They also leave their developmental habitat at an earlier stage. Unlike loggerhead turtles, green turtles leaving continental US waters are still far from sexual maturity. This is apparent from size range distributions along the coast. The size of most juveniles captured in Florida is between 20 and 65 cm SMCL, while the size of the smallest nesting females on nearby beaches is 83.2 cm SCL (Witherington et al., 1989b).

It has been estimated that juvenile green turtles leave their developmental habitat when they are between 10 and 14 years of age (Zug and Glor, 1998). Estimated age at sexual maturity in Atlantic green turtle populations ranges from 19 to 33 years (Mendonca, 1983; Frazer and Ehrhart, 1985; Frazer and Ladner, 1986; Ehrhardt and Witham, 1992). Thus, there is a period of several years before the juveniles leaving Florida's developmental habitats become part of the adult nesting population. The location and types of habitat supporting subadult green turtles is largely unknown. The Caribbean is one possibility. For example, Ehrhart et al. (1996) had eight remote tag

recoveries from green turtles tagged and released in the central Indian River Lagoon. Four of the tags were recovered from Nicaragua, three were from Cuba and one was from Belize. Nicaragua is known to be a prime subadult and adult foraging ground for green turtles that nest in Costa Rica (Mortimer, 1981a). Thus, many of the green turtles that spend their juvenile days on the east coast of Florida may eventually migrate to the Caribbean to spend the subadult phase of their lives.

Adult green turtles occur relatively infrequently in continental United States coastal waters and nest in relatively low numbers along the Florida coast although the numbers appear to be increasing (Dodd, 1981; NMFS and USFWS, 1991b; Meylan et al., 1995). Green turtle nests have been deposited in Florida from Nassau to Okaloosa Counties, but most are deposited in Brevard, Martin, and Palm Beach Counties.

Witherington and Ehrhart (1989b) measured nesting green turtles on Atlantic beaches in central Florida. The mean carapace length was 101.5 cm SCL and ranged from 83 to 117 cm. At Melbourne Beach, Florida, female green turtles generally deposit 3 to 4 clutches of eggs per season with an average internesting interval of about 12.9 days (Johnson, 1994). The mean distance between consecutive nesting sites was 1.8 miles. Females returned to Melbourne Beach after 2 to 6 years; however, a remigration interval of two years seemed to predominate, and no females were found to nest every nesting season.

The location of foraging grounds used by adult green turtles that nest in Florida has not yet been identified (NMFS and USFWS, 1991b; Johnson, 1994). However, satellite transmitters placed on two females that nested on the central east coast of Florida revealed interesting short term trends. After leaving the vicinity of the nesting beach, these females moved south along the Florida coastline and proceeded west along the Florida Keys, possibly to feed and reside in extensive seagrass meadows and coral reefs surrounding the islands (Schroeder et al., 1996).

Because the exact location of foraging grounds used by adult green turtles nesting in Florida has not been firmly established, the primary food item in the adult turtle's diet is also unidentified. Mortimer (1981b) suggested that adult green turtles graze on seagrass throughout most of their range, but in areas where seagrasses are lacking, algae is the primary dietary component. Also, Mortimer (1981a) suggested that turtles migrating from their foraging ground to their nesting habitat may be more opportunistic feeders than when they remain on their foraging grounds. Adult foraging grounds are typically in quiet, sheltered waters containing lush submarine vegetation. The nesting beaches, however, are typically in high energy surf, which may be devoid of food. During their migration from Nicaraguan foraging grounds to Costa Rican nesting beaches, green turtles stay relatively close to shore and feed on *Syringodium* and red algae. However, on their foraging grounds in Nicaragua, the turtle's diet consists primarily (90 percent) of turtle grass (*Thalassia testudinum*), which is the dominant rooted macrophyte.

Stomach contents from three stranded adult green turtles near Fort Lauderdale consisted of the algae *Sargassum natans*, *Gracilaria cylindrica*, and the hydroid *Bourainvilla carolinensis* (Wershoven and Wershoven, 1990). It is assumed that these turtles were not permanent residents, but rather part of the east coast nesting population.

NEARSHORE ENVIRONMENT AS DEVELOPMENTAL/FORAGING HABITAT

A variety of factors may account for the presence of sea turtles in the vicinity of the St. Lucie Plant. For one, the continental shelf adjacent to the plant is relatively narrow. It decreases in width from about 40 km at the Fort Pierce Inlet, north of the plant, to about 26 km at the St. Lucie Inlet south of the plant (Gallagher and Hollinger, 1977). Aerial surveys have shown that turtle densities are much higher in water depths less than 50 meters (National Research Council, 1990). Thus, a narrow continental shelf would tend to concentrate turtles. Furthermore, Mortimer (1981a) reported that green turtles often stay nearshore when they migrate to nesting areas. Nearshore movements increase the probability of turtles encountering one of the plant's intake structures.

A system of hard bottom substrates and sabellariid worm reefs parallel the shoreline between the Fort Pierce and St. Lucie Inlets. These habitats provide potential foraging and resting areas for turtles moving along the coast. Although the system is not continuous, it does provide intermittent refugia on an otherwise featureless seafloor. Turtles that utilize these natural reefs may be brought into close proximity with the intake structures. The closest sabellariid worm reef is located approximately 450 m southwest of the intake structures.

Documented dietary items of loggerhead turtles were compared to fauna collected during environmental sampling conducted in the vicinity of the St. Lucie power plant by the Florida Department of Natural Resources and Applied Biology, Inc. during the 1970s and early 1980s. Sampling was mostly conducted by trawl or benthic grab.

Crabs are a prevalent item found in most loggerhead dietary studies. Various crabs reportedly consumed by loggerheads have also been collected in the nearshore waters of Hutchinson Island. For example, blue crabs (*Callinectes sapidus*), swimming crabs (*Portunus* spp.), spider crabs (*Libinia* spp.), calico crabs (*Hepatus epheliticus*), speckled crabs (*Arenaeus cribrarius*), purse crabs (*Persephona mediterranea*), box crabs (*Calappa* spp.) and hermit crabs (*Pagurus spp.*) have all been documented as loggerhead turtle food (Mortimer, 1981b; Bellmund et al., 1987; Ruckdeschel and Shoop, 1988; Plotkin et al., 1993; Burke et al., 1993; Godley et al., 1997). Each of these species occurs on the sandy bottoms or sabellariid worm reefs in the vicinity of the power plant (Camp et al., 1977; ABI, 1979). Plotkin et al. (1993) and Ruckdeschel and Shoop (1988) also found barnacles in loggerhead digestive tracts. Several species of barnacles (*Balanus* spp.) have been documented by Camp et al. (1977) and ABI (1981) in the nearshore environment.

Mollusks are a prevalent staple for loggerhead turtles. Mollusks previously documented as food items and found near the St. Lucie Plant include: whelks (*Busycon* spp.; Ruckdeschel and Shoop, 1988; Lyons, 1989; Burke et al., 1993), ceriths (*Cerithium* spp.; Lyons, 1989; Godley et al., 1997), slipper shells (*Crepidula* spp.; ABI, 1981; Lyons, 1989; Burke et al., 1993), tulip shells (*Fasciolaria* spp.; Lyons, 1989; Godley et al., 1997), conchs (*Plueroploca* spp. and *Strombus* spp.; Carr, 1952; Lyons, 1989; Burke et al., 1993; Godley et al., 1997), bonnets (*Phalium* spp.; Lyons, 1989; Godley et al., 1997), and mussels (*Mulinia* spp. and *Mytilus* spp.; ABI, 1981; Lyons, 1989; Burke et al., 1993).

Jellyfish are usually found in low percentages in loggerhead dietary samples, but are probably underrepresented because they are digested so quickly (Plotkin et al., 1993). Jellyfish are often entrained into the St. Lucie Plant intake canal and can become so thick that they clog the plant's cooling system. On occasion the plant has had to reduce power for brief periods because of the massive amounts of jellyfish that were entrained with cooling water (Applied Biology, Inc., unpublished data).

The nearshore environment near the St. Lucie Plant was also evaluated with respect to its suitability as foraging habitat for green turtles. The high-energy environment of the ocean around the St. Lucie Plant precludes the extensive growth of seagrasses. However, both drift and benthic algae are known to occur in the area (Moffler and Van Breedveld, 1979; Bresette et al., 1998).

Gracilaria sp. and *Bryothamnion seaforthii* were the two most abundant food items in immature green turtle dietary samples taken in the summer and fall in the central Indian River Lagoon (Ehrhart et al., 1996). Preliminary observations from a dietary study done on the sabellariid worm reef near the Sebastian Inlet show that immature green turtles feed primarily on algae of the following genera: *Bryothamnion*, *Gracilaria*, *Acanthophora*, *Botryocladia*, and *Solieria* (K. Holloway, pers. com.). All of these genera were included on the list of 119 taxa found in the nearshore area around the St. Lucie Plant (Moffler and Van Breedveld, 1979). Although the sandy-shell hash sediments of the nearshore environment do not support the attachment of larger species of macroscopic algae, a variety of drift algae can often be found near the plant. Additionally, the sabellariid worm reefs along the shoreline support macroscopic algal growth. Moffler and Van Breedveld (1979) estimated that these nearby reefs were the probable source for at least 57 percent of the drift algae species. All of the taxa listed above have been found growing on the sabellariid worm reefs near the St. Lucie Plant.

THE INTAKE STRUCTURES AS TURTLE SHELTER/FORAGING AREAS

In the nearshore environment adjacent to the St. Lucie Plant, where much of the ocean bottom is flat and sandy (Lackey, 1970), the intake and discharge structures provide vertical relief. Both natural and artificial structures attract a variety of marine life, including turtles. For example, divers, NMFS observers, and aerial surveyors have reported that turtles commonly associate with offshore oil platforms in the Gulf of Mexico (National Research Council, 1990). Resting loggerhead turtles are often seen

with their heads, or other body parts tucked under rocky ledges offshore (J. Gorham and E. Martin, pers. com.; Wershoven and Wershoven, 1990). Green turtles have also been documented resting under coral heads and rocky outcroppings at night and during the hottest part of the day (Bjorndal, 1980; Mendonca, 1983; Ogden et al., 1983; Wershoven and Wershoven, 1990; Balazs, 1995). The large opening between the velocity caps and the base of the intake structures may very much resemble a reef ledge and appear to offer an ideal resting site to turtles.

Both Mortimer (1981a) and Mendonca (1983) noted that green turtles seem to occupy a home range while residing on their foraging grounds and may return to the same sleeping place on consecutive nights. Coyne (1994) found that juvenile green turtles living in Brazos Santiago Pass spend more time in and exhibit greater site fidelity to rocky/jetty environments relative to other surrounding habitats. Smaller turtles may also use structure as a refuge from predators (Musick and Limpus, 1997).

In a study conducted at the Miami Seaquarium wooden boxes simulating intake structures were placed in a large tank. Loggerhead and green turtles introduced to the tank readily sought out and utilized these boxes during resting periods (ABI, 1980). One apparent reason for seeking out and wedging themselves within the boxes was to maintain a stationary position while resting instead of being moved by the currents. Often, aggressive interactions would occur between turtles at the boxes indicating competition for available space. Turtles were also observed chasing other turtles away from the boxes or hiding inside as an attack avoidance maneuver.

The St. Lucie Plant intake structures closely resemble large reef outcroppings with one notable exception. They provide practically unlimited habitat. When turtles use the structures as shelter they may be rapidly drawn into the intake pipes. Thus, the shelter effectively remains unoccupied and available to other turtles. Competitive interactions are thereby eliminated.

Another plausible reason for the entrainment of sea turtles at the St. Lucie Plant is that the food supply for both loggerhead and green turtles might be greater on the intake structures than on surrounding sandy areas. Bresette et al. (1998) reported that the intake structures are covered by much of the same green, brown and red algae that Ehrhart (1992) found growing on worm-rock reefs in Indian River County. Based on underwater photographs and videos, the growth on the intake structures resembles that of nearby reefs. All of the surface area is covered with epibiota. Epibiota appear to include hydroids, encrusting sponges, large barnacles, bryozoans, algae (primarily on top of the caps), anemones, and some gorgonian coral. Various species of fish were also observed around the structure. Many of these items were previously shown to be components of loggerhead and green turtle diets.

TRENDS IN LOGGERHEAD CAPTURES AT THE ST. LUCIE PLANT

Size Distribution

When the canal capture program was initiated in May 1976, the sizes of captured turtles were estimated. Beginning in July 1976 the straight minimum carapace length[2] (SMCL) and straight carapace width (SCW) of each turtle was measured with calipers. Weights of captured turtles were recorded beginning in November 1976. Measurement of curved standard carapace length (CSCL) and straight standard carapace length (SSCL) began in April 1981 and November 1987, respectively.

In some cases all measurements could not be taken because gear was not available. In other cases, certain measurements could not be accurately determined due to damage to a turtle's carapace.

Because SMCL measurements were available for more turtles than any other measurement and because it is the recommended length measurement (Bjorndal and Bolten, 1989; Bolten, 1999), it was used for all analyses in this report.

Between 1976 and 1998, SMCL measurements were obtained for 3,479 loggerhead turtle captures at the St. Lucie Plant. The mean size of these turtles was 67.0 cm and sizes ranged from 38.6 to 112.0 cm. This is similar to the size range reported for loggerhead turtles in the central and northern regions of the Indian River Lagoon (Ehrhart, 1983; Ehrhart et al., 1999) and in the Canaveral Ship Channel (Henwood, 1987; Bolten et al., 1994)

The size distribution of loggerhead turtles captured at the St. Lucie Plant is presented in Figure 8. There are several important aspects of this distribution. First, most of the individuals captured were less than 70 cm SMCL. Second, there was a paucity of loggerheads between 70 and 85 cm. And third, a secondary accumulation of adults gives the distribution a bimodal appearance. This distribution is similar to that presented by Ehrhart et al. (1999) for the central Indian River Lagoon and Bolten et al. (1994) for the Canaveral Ship Channel.

The Turtle Expert Working Group (1998) referred to loggerhead turtles less than 70 cm as small benthic immature turtles and those between 70 and 91 cm as large benthic immature turtles. Loggerheads ≥ 92 cm were considered adults. Ehrhart et al. (1996), however, used 83 cm SSCL[3] as the minimum size for adult loggerheads captured in the central Indian River Lagoon.

For the purposes of this report, loggerheads with SMCLs less than 70.0 cm are referred to as juveniles, those between 70.0 and 84.9 cm are considered subadults and those ≥ 85.0 cm are designated adults. These criteria follow the general format used by

[2] See Bolten (1999) for definitions of carapace measurements.

[3] 83 cm SSCL is equivalent to approximately 81.7 cm SMCL based on regression analysis of SMCLs and SSCLs obtained from over 2,000 St. Lucie Plant loggerheads.

Ernest et al. (1989) and ABI (1994) to define size classes/life history stages of loggerhead turtles. Based on the reported sizes of nesting loggerheads, no mature animals should be included in the juvenile size class and few immature animals should be included in the adult size class. The subadult size class, however, undoubtedly contains some small mature animals along with the large immature turtles.

Since most of the analyses in this report were segregated by life history stage, it was important to assign as many turtles as possible to one of the three stages. For this reason, turtles lacking SMCLs were placed in one of the stages based on conversion of other available measurements to SMCL. Equations used to make these conversions are presented in Table 3. After conversions, over 98 percent of the loggerhead turtles captured could be assigned to a life history stage.

The size distribution of loggerhead turtles from the St. Lucie Plant suggests that juvenile loggerheads are using the nearshore waters off Hutchinson Island for developmental habitat but begin to leave the area as subadults. Schroeder et al. (1998) hypothesized that Florida Bay may represent another developmental habitat for turtles nearing maturation (75-85 cm). It may very well be that subadult loggerheads from the Florida East Coast move to Florida Bay to complete maturation. Adult turtles then return to the east coast to mate and nest.

Annual changes in the mean sizes of loggerhead turtles captured at the St. Lucie Plant are illustrated in Figure 9. Linear regression analysis[4] (Zar, 1996) of these data indicated a significant ($r^2 = 0.28$, $P < 0.01$, $n = 23$) increase in the mean size of loggerhead turtles between 1976 and 1998. To further investigate this trend, annual size distributions for loggerhead turtles captured at the St. Lucie Plant were plotted (Figures 10-14). Annual size distributions indicate some year to year fluctuations in the proportion of turtles in each size class. In general, the proportion of adults was relatively low between 1976 and 1983, relatively high during 1989 and 1990, and intermediate during other years. This is more clearly illustrated by examining the annual percentage of captures consisting of adults (Figure 15). These data indicate a significant ($r^2 = 0.48$, $P < 0.001$, $n = 23$) increase in the proportion of adults captured between 1976 and 1998. It appears that the increase in mean size of loggerhead captures at the St. Lucie Plant was a result of an increase in the proportion of adults captured. This is substantiated by the fact that there was no significant trend in the mean size of immature (juvenile + subadult) loggerheads (Figure 16).

[4] Regression analysis is a statistical method for evaluating the relationship of two variables. In a linear regression analysis this relationship is described in terms of variation about a straight line. The extent to which the two variables, x and y, are related to one another is described by the equation $y = bx + a$, where b is the slope of the line (amount of change in y when x increases by one unit) and a is the y intercept (value of y corresponding to $x = 0$). The amount of variation about the line is expressed as the coefficient of determination (r^2). It can range from –1 to +1. A negative value indicates that one variable increases as the other decreases, while a positive value indicates that the two variables increase and decrease in unison. Values of r^2 approaching -1 or +1 indicate a strong relationship. The relationship becomes weaker as values approach 0.

Seasonal Distribution of Juveniles

The seasonal distribution of juvenile loggerhead captures at the St. Lucie Plant is presented in Figure 17. Juvenile loggerheads were captured throughout the year, but, overall, tended to be most abundant from January through April. Juvenile loggerheads were also reported to be present throughout the year in the Canaveral Ship Channel (Henwood, 1987; Bolten et al., 1994) and in the central region of the Indian River Lagoon (Ehrhart et al., 1996, 1999). No seasonal trend was observed in the Indian River Lagoon. However, in the Canaveral Ship Channel the largest concentrations of juvenile loggerheads occurred from October through March.

Bolten et al. (1994) suggested that a sharp increase in juveniles in the Channel in January 1993, probably represented a group of juveniles migrating south away from cooler northern temperatures. These researchers also suggested that the appearance of these migrating loggerheads is determined more by water temperature than by absolute time of year so that peaks may occur in almost any month from late fall to early spring. Other authors have also indicated that temperature was an important factor in regulating the movements of loggerhead turtles (Mendonca, 1983; Keinath et al., 1987; Coles, 1999). Likewise, the seasonal distribution of juvenile loggerheads at the St. Lucie Plant may be influenced by influxes of turtles from northern areas as waters cool.

Examination of seasonal distributions for each year from 1977 through 1998 (Figures 18-22) reveals considerable fluctuation from year to year. These annual fluctuations may in part be explained by variations in water temperatures both in northern areas and locally. No long-term change in the seasonal distribution of juvenile loggerheads is indicated.

Long-term Trends in Juvenile Captures

The number of juvenile loggerhead turtles captured each year from 1977[5] through 1998 at the St. Lucie Plant is presented in Figure 23. Linear regression analysis indicated that there was a significant ($r^2 = 0.33$, $P < 0.01$, $n = 22$) increase in the annual number of juvenile loggerhead captures over that period. However, these data include recaptures (turtles that were captured in the canal, released into the ocean then recaptured in the canal). Analysis of recapture data (Figure 24) indicates that there was also a significant ($r^2 = 0.56$, $P < 0.001$, $n = 22$) increase in recaptures during the same period.

To rule out the possibility that the observed increase in juvenile loggerhead captures was simply due to an increase in the number of individuals captured multiple times, data were reanalyzed with recaptures excluded (Figure 25). Analysis of these data indicated that, even when recaptures were excluded, there was still a significant ($r^2 = 0.28$, $P < 0.05$, $n = 22$) increase in juvenile loggerhead captures from 1977 through 1998. However, most of that increase occurred between 1995 and 1998. In fact, when regression analysis was applied to data from 1977 through 1994, no significant trend was

[5] Data for 1976 are excluded because the power plant did not begin operation until May of that year. A total of 20 juvenile loggerheads were captured in 1976.

indicated. Thus, rather than experiencing a gradual increase in captures over the life of the plant, there was an exponential increase after 1994.

Site Fidelity of Juveniles

The fact that some turtles were captured in the intake canal on more than one occasion is an indication that at least some turtles either remained in the vicinity of the power plant or returned to the plant after moving to other areas. The ability of sea turtles to return to a specific site has been referred to as site fixity, site tenacity and site fidelity. These terms usually refer to a female turtle's tendency to return to a specific nesting beach with a high degree of accuracy (Carr, 1975; Bjorndal et al., 1983; Miller, 1997). The term site fidelity will be used here to describe a turtle's tendency to return to the intake structure (as demonstrated by its recapture in the intake canal).

Approximately five percent of the juvenile loggerhead turtles that were captured in the intake canal were documented returning. However, the extent to which turtles may learn to avoid being entrained while remaining in the vicinity of the intake structures is unknown. Thus, this figure may be conservative. Furthermore, the ability to identify a turtle as a recapture was dependent on the turtle's tag remaining intact. Poor retention of tags has been documented in sea turtles by various authors (Balazs, 1982; Henwood, 1986; Gorham et al., 1998). Considering these factors, it is safe to say that at least five percent of the juvenile loggerhead turtles captured in the canal showed site fidelity to the intake structure.

Some juvenile loggerheads returned to the canal only once while others returned repeatedly (23 times in one case). The time interval between a turtle's first and last capture is an indication of how long a turtle shows site fidelity to the area around the power plant. In some cases a turtle may have remained in the vicinity of the plant between captures, while in others it may have traveled to other areas between captures. In either case, the turtle demonstrated site fidelity to the intake structures. The percentage of recaptures that occurred within each of the various time intervals is presented in Figure 26. Based on these data, approximately 76 percent of the juvenile loggerheads that exhibited site fidelity did so for less than one year. Conversely, only 24 percent of the recaptures showed site fidelity for more than a year. When expressed as a percentage of all juvenile loggerheads entrained, this equates to only 1.2 percent of the juvenile loggerheads captured in the canal returning after one year. Though some juvenile loggerheads returned to the canal over periods of more than seven years, only 0.5 percent returned after two years.

Seasonal Distribution of Subadults

The seasonal distribution of subadult loggerhead turtles at the St. Lucie Plant is presented in Figure 27. As with juveniles, subadults were captured throughout the year. In contrast to the seasonal pattern for juveniles, however, subadults were most abundant during June, July and August. The loggerhead nesting season on Hutchinson Island typically extends from mid-April through mid-September with most nesting usually

occurring in June and July (ABI, 1987, 1994). Therefore, the higher number of subadult captures between June and August suggests that some adults have been included in the subadult life history stage and/or some subadults follow adults to their nesting/mating areas.

Seasonal distributions of subadult loggerheads at the St. Lucie Plant are presented on an annual basis in Figures 28-32. As with juveniles, there were considerable year-to-year fluctuations in seasonal patterns of abundance. In general though, the percentage of subadults captured in June and July was higher during the last ten years than during the previous twelve years. The increase in the proportion of subadults occurring during these two months coincided with a general increase in the mean size of subadults that began in 1989 (Figure 33). This apparent relationship may be accounted for by one or both of the following: 1) as the mean size of subadults increases it becomes more likely that mature animals are included in this size class, and/or 2) as subadults approach adult size they may be more likely than smaller individuals to join with adults in nesting/mating migrations.

Long-term Trends in Subadult Captures

The number of subadult loggerheads captured each year from 1977 through 1998 at the St. Lucie Plant is presented in Figure 34. The long-term trend was not significant. Because so few subadults were recaptured and because there was no significant long-term trend in recapture rates, the annual capture pattern changed little after recaptures were excluded (Figure 35).

Site Fidelity of Subadults

Nine of the loggerhead turtles that were classified as subadults on initial capture were recaptured in the intake canal. Eight were still within the subadult size class when recaptured, but one had grown to adult size prior to recapture. Intervals between first and last capture ranged from nine days to almost seven and a half years (Figure 36). When expressed as a percentage of all subadult loggerheads entrained, approximately two percent of the subadult loggerheads captured in the intake canal were documented returning. Only five (1.1 percent) returned after one year.

Seasonal Distribution of Adults

Adult loggerhead turtles, like juveniles and subadults, were captured in the St. Lucie Plant intake canal throughout the year (Figure 37). However, the most conspicuous aspect of the seasonal distribution of adult loggerhead captures is that it closely corresponded to the seasonal distribution of nesting on Hutchinson Island. Nesting usually begins in mid-April, increases through May, is highest in June and July, decreases in August, and ends in mid-September (ABI, 1987, 1994). Adult loggerhead captures in the intake canal followed this same pattern.

Of the 649 adult loggerhead capture events in the canal, the sex of the turtle was determined in 637 cases. Determination of sex was based on tail length (Wibbels, 1999). A total of 562 of the adult loggerheads were females and 75 were males. Though both sexes were captured during every month of the year, the seasonal distributions of males and females were different (Figure 38). Females were most abundant from May through August while males were most abundant from February through June. Henwood (1987) found a similar pattern in the Canaveral Ship Channel. He suggested that most breeding occurs in April and May with males leaving the area in June while females remain in the area throughout the nesting season (May – August). This probably explains the seasonal patterns documented for the St. Lucie Plant.

As with the other life history stages of loggerhead turtles, adults exhibited considerable year to year fluctuation in seasonal patterns (Figures 39-43). It should be noted, however, that the number of annual captures from 1977 through 1983 was very low. Larger numbers of adults were captured from 1984 through 1998, and during this period seasonal patterns tended to be more consistent (i.e., most adults were captured during the nesting season). This undoubtedly reflects the fact that over 85 percent of the adult captures were females and probably in the area for the purpose of nesting.

Long-term Trends in Adult Captures

The number of adult loggerhead turtles captured each year at the St. Lucie Plant is presented in Figure 44. As with subadults, few adults were recaptured and no significant increase or decrease in recaptures occurred over the period of study. For those reasons, the annual capture pattern changed little after recaptures were excluded (Figure 45). In contrast to subadults, there was a significant increase in the number of adult loggerheads captured between 1977 and 1998 whether recaptures are included or excluded ($r^2 = 0.60$, $P < 0.001$, $n = 22$).

Since the sexes of most adults were determined, long-term trends were reanalyzed for each sex separately. Because the trends including and excluding recaptures are essentially identical, only trends exclusive of recaptures are presented. The numbers of adult female loggerheads captured each year are presented in Figure 46. Since females comprised over 85 percent of the adult captures, it is not surprising that the trend in female captures was very similar to the trend for all adult captures. As for all adults, female captures significantly ($r^2 = 0.61$, $P < 0.001$, $n = 22$) increased from 1977 through 1998.

The fact that seasonal trends in adult captures coincided with seasonal trends in nesting suggests that many of the females captured at the St. Lucie Plant intake may have migrated to the area for the purpose of nesting. To further investigate this possibility, the long-term trend in female captures was compared to the long-term trend in loggerhead nesting on Hutchinson Island (Figure 47). When analyzed, a significant ($r^2 = 0.54$, $P < 0.001$, $n = 18$) positive relationship between capture rates and nesting was indicated (Figure 48). As nesting has increased on Hutchinson Island, so too have the number of adult females entrained into the St. Lucie Plant intake canal. Female turtles may use reef

areas for feeding and/or shelter between nesting episodes and the intake structure may appear to be suitable habitat.

The annual numbers of adult male loggerhead captures are presented in Figure 49. Compared to adult females, the numbers of adult males captured annually were relatively small. However, like females, males exhibited a significant ($r^2 = 0.25$, $P < 0.05$, $n = 22$) increase in numbers from 1977 through 1998.

Site Fidelity of Adults

Seven (six females and one male) of the loggerhead turtles that were classified as adults on initial capture were recaptured in the intake canal. Intervals between first and last capture ranged from three days to over nine years (Figure 50). The male was recaptured 43 days after its initial capture.

When expressed as a percentage of all adult loggerheads entrained, 1.1 percent of the adult loggerheads captured in the intake canal were documented returning. Only four (0.6 percent) returned after one year.

TRENDS IN GREEN TURTLE CAPTURES AT THE ST. LUCIE PLANT

Size Distribution

Between 1976 and 1998, SMCL measurements were obtained for 2,417 green turtle captures at the St. Lucie Plant. The mean size of these turtles was 38.7 cm (range: 20.0 – 108.0 cm). The size distribution of green turtles from the intake canal is presented in Figure 51. Green turtle captures were dominated by juveniles as has been reported on nearshore reefs in Indian River and Broward Counties and in the Indian River and Mosquito Lagoons (Mendonca and Ehrhart, 1982; Wershoven and Wershoven, 1990; Schroeder et al., 1990; Ehrhart et al., 1996, 1999).

Though the mean size of green turtles from the intake canal was similar to that reported by Ehrhart et al. (1996) for green turtles from the central region of the Indian River Lagoon, there was a much higher proportion of very small (< 30 cm) turtles in the intake canal. Only 5.4 percent of the lagoon green turtles, compared to 22.3 percent of those in the intake canal, were less than 30 cm. Though Ehrhart et al. captured a higher proportion (10.0 percent) of these very small turtles at their reef site, the proportion was still less than half of that for the intake canal. These researchers offered two possible explanations for size differences between green turtles captured in the St. Lucie Plant intake canal and those they captured in tangle nets. It was suggested that smaller green turtles could be more susceptible than larger individuals to entrainment by the plant's cooling water system and/or the large mesh of the tangle nets used in their study allowed smaller turtles to escape.

Though differences in capture techniques may contribute to the observed difference in size frequencies, real differences in size structure may exist between green turtles in the nearshore Atlantic and those in the lagoon (Ernest et al., 1988, 1989). This is suggested by the fact that Ehrhart et al. (1996) found a higher proportion of very small green turtles at the reef site versus the lagoon site. This is also suggested by the sizes of green turtles captured in the Canaveral Ship Channel (Henwood and Ogren, 1987) and in the Trident Submarine Basin (Redfoot et al., 1996). The mean sizes of green turtles at these two sites were 33.8 and 32.9 cm, respectively. This is considerably smaller than the mean sizes reported for green turtles in the Indian River Lagoon.

The relatively high proportion of individuals between 20 and 30 cm and the paucity of turtles greater than 50 cm in the St. Lucie Plant intake canal suggests that nearshore coastal waters may be an intermediate developmental habitat for green turtles moving from the pelagic environment to lagoons and estuaries. It has been suggested that the algae available in coastal waters are insufficient to sustain green turtles larger than 50 cm (Coyne, 1994; Redfoot et al., 1996). So, as green turtles in the vicinity of the intake approach this size they may begin to migrate out of coastal waters and into lagoons where algae and seagrasses are more abundant.

Annual changes in mean sizes of green turtles captured at the St. Lucie Plant are shown in Figure 52. Considerable fluctuations in mean sizes exhibited during the early years of the program primarily reflect small sample sizes. After eliminating years in which less than 20 individuals were captured, only two years (1981 and 1988) had means outside of the range of 35 to 41 cm. Consequently, over the period of study, there was no significant increase or decrease in the mean size of green turtles captured in the intake canal. Annual size distributions for green turtles at the St. Lucie Plant are presented in Figures 53-57.

For the purpose of this report, the same size classes/life history stages used for loggerheads were also used for green turtles. Measurements were available for over 99 percent of the green turtle captures, so almost all green turtles could be assigned to a life history stage. Because there were so few green turtles in the subadult and adult life history stages (29 and 28, respectively), subsequent analyses of green turtle captures are limited to juveniles.

Seasonal Distribution of Juveniles

The seasonal distribution of juvenile green turtle captures at the St. Lucie Plant is presented in Figure 58. Though juvenile green turtles were captured during all months of the year, they were most abundant from January through March. Likewise, Ehrhart et al. (1996, 1999) captured more juvenile green turtles in the central Indian River Lagoon in the winter than in the summer. Ehrhart et al. (1996) suggested that increased captures during cooler months may be due to an increase in drift algae in the lagoon and an influx of green turtles from northern climates. No data are available concerning seasonal changes in algae abundance in the vicinity of the intake, so it is unknown whether this factor may affect capture rates. However, it seems likely that higher capture rates during

January through March could be due to seasonal movements of juvenile green turtles from northern areas into the nearshore waters of southeast Florida.

Between 1977 and 1994, the seasonal distribution of juvenile green turtle captures at the St. Lucie Plant exhibited some annual variation, but during most years, captures were greatest during the coolest months (December-March; Figures 59-62). However, beginning in 1995, juvenile green turtle captures tended to be more evenly distributed throughout the year (Figures 62-63). This change in seasonal distribution coincided with an unprecedented increase in juvenile green turtle captures at the St. Lucie Plant.

Prior to 1995, juvenile green turtle captures at the plant were apparently dominated by animals that moved into the area as water temperatures cooled then moved out of the area as water temperatures warmed. These seasonal migrants appeared to make a smaller contribution to annual captures beginning in 1995.

Long-term Trends in Juvenile Captures

The numbers of juvenile green turtles captured annually from 1977 through 1998 at the St. Lucie Plant are presented in Figure 64. Annual captures were relatively low from 1977 through 1992, but increased considerably after 1992. Extraordinarily high numbers of green turtles were captured in 1995 and 1996. Linear regression analysis indicated a significant ($r^2 = 0.43$, $P < 0.001$, $n = 22$) increase in juvenile green turtle captures over the entire period of study. However, analysis of recapture data indicates a similar increase in recaptures during the same period (Figure 65). Likewise, juvenile green turtle recaptures were found to significantly ($r^2 = 0.44$, $P < 0.001$, $n = 22$) increase over the study period.

In order to rule out the possibility that the increase in juvenile green turtle captures was due to an increase in recapture rates, data were reanalyzed after excluding recaptures (Figure 66). Even after recaptures were excluded, juvenile green turtle captures were found to significantly ($r^2 = 0.39$, $P < 0.01$, $n = 22$) increase from 1977 through 1998. However, as with juvenile loggerheads, the increase in captures did not occur gradually over the period of study but rather was limited to the 1990s. A regression analysis indicated no significant trend when applied to data through 1992.

Site Fidelity of Juveniles

Over the period of study, 13.1 percent of the juvenile green turtles that were captured in the intake canal returned. Like juvenile loggerheads, some juvenile green turtles returned on only one occasion while others returned repeatedly (as many as 14 times). Intervals between first and last capture varied from one day to over four years. The percentage of recaptures that occurred within each interval is presented in Figure 67. Based on these data, approximately 67 percent of the juvenile green turtles that exhibited site fidelity, did so for less than one year. Conversely, only 33 percent did so for more than one year. Expressed as a percentage of all juvenile green turtles entrained, this equates to 4.3 percent returning after one year.

Green turtles exhibited a higher incidence of site fidelity than loggerheads. This is consistent with the findings of Mendonca and Ehrhart (1982) in the Mosquito Lagoon. They also found that green turtle recapture rates were higher than those for loggerheads.

Though a higher percentage of juvenile green turtles (4.3 percent) than juvenile loggerheads (1.2 percent) returned to the canal after one year, the longest periods of site fidelity were exhibited by loggerheads. This may be explained by the disproportionately higher percentage of green turtles that were captured, tagged and released during the last five years of the study period. Only 28 percent of the juvenile green turtles captured in the canal had been at large for more than five years at the end of 1998, compared to 63 percent of the juvenile loggerhead turtles.

FACTORS THAT MAY INFLUENCE TURTLE ENTRAINMENT PATTERNS

Power Plant Design and Operating Characteristics

There have been a number of changes to the design of the St. Lucie Plant that may have influenced turtle entrainment. Several changes occurred with the addition of Unit 2 in June 1983. First, another intake structure was installed. This increased the spatial extent of physical structures on the seafloor and may have attracted additional turtles. Second, the addition of another power plant changed flow patterns around the intake structures and within the intake pipes. This may have affected a turtle's likelihood of being entrained when it entered the intake structure. Third, the addition of the second discharge pipe with its 58 ports rising above the ocean surface increased the area of structure just north of the intakes. This may have attracted additional turtles into the general area and eventually resulted in more turtles encountering and entering the intake structures. The second discharge pipe in combination with the second power plant would also be expected to increase the thermal plume in the general area of the intake structures. This might act as an attractant to sea turtles during cooler periods thus increasing the probability of entrainment.

In order to identify changes in entrainment associated with the addition of Unit 2, average annual capture rates for the five-year period prior to construction of the third intake structure (1977-1981) were compared to those for a five-year period after Unit 2 began operating (1984-1988; Table 4). For all loggerhead and green turtle life history stages examined, average capture rates increased after Unit 2 began operation. Juvenile and subadult loggerhead captures increased by 25 and 48 percent, respectively. Average annual captures of juvenile green turtles and adult loggerheads more than tripled. However, when tested with a Mann-Whitney test[6] (Zar, 1996), only the increases for juvenile green turtles and adult loggerheads were statistically significant ($P = 0.05$). Though an increase in entrainment rates was indicated after the addition of the second power plant, this does not necessarily demonstrate that the increase was due to the second

[6] A Mann-Whitney test is a statistical method for determining if two samples have been drawn from the same population. It is used for testing means when the assumptions of the more rigorous t-statistic cannot be met or when sample sizes are relatively small.

plant. For example, the increase in captures of adult loggerheads coincided with a similar increase in loggerhead nesting on Hutchinson Island. So the observed increase in adult loggerhead capture rates may have resulted more from an increase in nesting females in the area than from the addition of the second power plant. Though significantly more juvenile green turtles were captured in the five-year period before, than the five-year period after, Unit 2 went on-line, no significant trend in captures were indicated when all data between 1977 and 1992 were analyzed (see Green Turtles - Long Term Trends in Juvenile Captures and Figure 64). Thus, although the addition of the second unit may have affected capture rates to some extent, it is not clear that this change was responsible for the long-term upward trends in captures of juvenile and adult loggerhead turtles or juvenile green turtles.

Repairs to the velocity caps on the three intake structures also may have affected entrainment rates. The thicker columns and caps may have changed the attractiveness of the structures to turtles and may have affected flow patterns underneath the caps. Since damage to the caps was first observed in August 1989, the period from 1984 through 1988 was used to characterize capture rates for the original three-intake system. Because repairs were completed in February 1992, the period from 1992 through 1996 was used to characterize rates for the modified three-intake system. Average capture rates for each of these five-year periods is presented in Table 5. Though mean capture rates for subadult loggerheads decreased by 21 percent after velocity cap repairs, rates increased for the other groups. Average annual capture rates increased by 31 percent for juvenile loggerheads, 67 percent for adult loggerheads and 851 percent for juvenile green turtles. However, based on a Mann-Whitney test (Zar, 1996) only the change in juvenile green turtle captures was significant ($P = 0.05$).

Whether the increases in juvenile green turtle capture rates were caused by, or simply coincident with, velocity cap repairs is unknown. However, as discussed later, other researchers reported similar increases in the number of juvenile green turtles residing in developmental habitats elsewhere on the east coast of Florida during the 1990s. This would suggest that increases seen at the St. Lucie Plant were part of a larger pattern unrelated to changes in the intake structure.

In addition to changes in power plant design, changes in power plant operations may also affect sea turtle entrainment. In particular, when a power plant is shut down for maintenance or refueling, the circulating-water pumps are also shut down. Though auxiliary pumps are run during these periods, the flow of water through the intake system is considerably reduced. This results in a major reduction in water velocities at the intake structures and within the intake pipes (Table 1). Changes in velocity may affect the probability that a turtle will be entrained into the canal after entering the intake structure. How turtles behave after they enter the structure is unknown, but if they attempt to escape after entering the intake pipe, lower velocities might increase their probability of escape.

Information on maximum swimming speeds of green and loggerhead turtles of the sizes encountered in the canal is fragmentary. However, observations by Ogren et al. (1977) of two adult loggerhead turtles encountering shrimp trawls provides some

pertinent information. In both cases the trawls were towed at about 2.5 knots (129 cm/sec). The first loggerhead was observed swimming leisurely in the same direction that the trawl was being towed. As the trawl began to overtake it, the turtle increased its swimming speed until it equaled that of the trawl. The turtle increased its speed further and was able to outdistance and veer away from the trawl. The encounter lasted approximately two to three minutes. So this turtle was able to maintain and exceed a speed of 129 cm/sec for at least two minutes. A second loggerhead, swimming in the same direction as the tow, kept just ahead or even with the net headrope for two to three minutes then slowed its swimming speed. As the headrope passed over the turtle, it increased its swimming speed, swam 2-3 meters to the headrope then rested momentarily and was overtaken by the net. This pattern of swimming was repeated for 8-10 minutes until the turtle was finally swept further back into the net and ceased swimming. This turtle, then, was able to maintain and occasionally exceed a speed 129 cm/sec for at least ten minutes.

J. Mitchel (pers. com.) also made observations of loggerhead turtles encountering trawls. In this case, two-year-old, captive-reared loggerheads were used to test turtle excluder devices in shrimp trawls. Turtles were placed ahead of trawl nets being towed at 2.5-3.0 knots (129-154 cm/sec). Turtles usually kept swimming at those speeds for the first minute then would slow down.

Additional observations of swimming speeds in sea turtles were made on adult females during the nesting season. Using radio telemetry, Tucker et al. (1996) recorded the internesting movements of female loggerhead turtles in Australia. The maximum swimming rate recorded for these turtles was 3.01 km/hr (84 cm/sec). However, these speeds probably do not reflect the maximum speed that these turtles are capable of. Carr et al. (1974) suggested that adult female green turtles in longshore travel maintain a speed of about 1.5 km/hr (42 cm/sec) for several hours at a time and are capable of brief bursts of 4-7 km/hr (111-194 cm/sec).

Based on these swimming speeds, turtles would be expected to easily escape velocities encountered at the velocity caps of all three intakes and in the vertical sections of the 3.7-m intake structures during any operating condition (Table 1). Though turtles should also be able to escape velocities in the vertical section of the 4.9-m intake when one unit is operating, they may not be capable of escaping when two units are running. During the period when there was only one power plant and two intake structures, turtles would not be expected to be entrained when the plant was shut down. However, when the plant was operating turtles would probably have difficulty swimming against the velocities (159-178 cm/sec) within the intake pipes. The addition of the second power plant and third intake structure changed conditions. With only one plant operating, velocities in the 3.7-m pipes are only 66-73 cm/sec. Turtles should be able to easily escape from the pipes at these velocities. Under the same conditions, velocities in the 4.9-m pipe are 93-106 cm/sec. Turtles should be able to escape at these velocities if they begin swimming against the current shortly after they enter the pipe. However, if they drift with the current for several minutes before beginning to swim against it, then they may have difficulty escaping. With both plants running, velocities in the 3.7-m and 4.9-

m pipes increase to 127-142 cm/sec and 180-206 cm/sec, respectively. At these velocities, turtles entering the pipe would be expected to have difficulty escaping and would likely be entrained into the canal.

In order to determine if the operating status of the power plants affected sea turtle entrainment, capture records were examined on a monthly basis. Only the juvenile stages of the two species provided sufficient numbers to allow meaningful interpretation. The monthly operating status of the power plants was based on available information for periods when each of the plants was shut down for refueling and/or maintenance. Only data for major plant outages were available for the entire study period. So some short periods when a plant (and its circulating pumps) may have been shut down or operating at less than capacity, were not taken into account. For the purpose of this comparison it is assumed that the circulating water pumps for each plant continue to run for two days after the plant is shut down and begin pumping two days before the plant goes back on-line. This is the usual operating procedure (N. Whiting, pers. com.). The monthly operating status of the plant is expressed as days per month that the circulating water pumps for each plant were operating.

The operating status of each plant is compared to monthly captures of juvenile loggerhead turtles in Figures 68-75. It is apparent from these figures that there are considerable fluctuations in monthly capture rates even when the operating status of the plants remains constant. These fluctuations probably reflect natural variation in juvenile loggerhead numbers in the vicinity of the intake structures. Such fluctuations make it difficult to interpret the effects of plant operating status on entrainment. However, there are numerous periods in which fluctuations in capture rates appear to correspond to changes in plant status (February - June 1980, January – June 1983, January - April 1987, September – December 1987, June – September 1988, January - April 1989, January - May 1994 and April - July 1996). In some cases there appears to be a one-month delay in the effect (March – July 1979, August – December 1981, September 1990 – January 1991 and October 1991 – January 1992) which may reflect a delay between entrainment and capture. It appears that the operating status of the power plant often affected entrainment of juvenile loggerhead turtles with captures decreasing during periods of plant outages both before and after Unit 2 went on-line.

Juvenile green turtle captures are compared to power plant operating status in Figures 76-83. As with loggerheads, green turtle captures varied considerably from month to month even when there was no change in the operating status of the power plants. Decreases in captures did coincide with plant outages prior to Unit 2 going on-line, however, these results are difficult to interpret because capture rates were often very low even when the plant was operating. During the first nine years after Unit 2 went on-line, there were few indications that outages affected entrainment rates. In particular, the observed peak in captures during January 1984 (during the March 1983 - April 1984 outage of Unit 1) indicates that seasonal fluctuations in juvenile green turtle numbers around the intake structures had more of an effect on entrainment patterns than plant operational status. However, capture rates generally remained low during this nine-year period. Relatively large numbers of juvenile green turtles were not consistently captured

until after September 1992. From October 1992 through December 1998, there were eight outages. In three cases fluctuations in capture rates appear to correspond to changes in plant status (September 1995 - January 1996, April - July 1996, April - June 1997). There were another four cases in which outages may have contributed to lower capture rates, but the relationship was not as clear (March - June 1993, January - May 1994, October 1997 - January 1998, and October - December 1998). There was one case in which an outage appeared to have no effect on capture rates (September - December 1994). Observed reductions in capture rates during several outages suggests that entrainment of juvenile green turtles was, at least occasionally, affected by power plant operating status.

In an attempt to quantify results of the qualitative analysis presented above, monthly capture data were segregated into periods when only one unit was on line and periods when both units were on line. Only data collected after Unit 2 went on line (June 1993) were used in the analysis so the number of intake structures remained constant. To segregate seasonal effects, two different periods were evaluated: spring (March, April, and May) and fall (October and November). During the spring period, water temperatures in the vicinity of the plant were typically rising following seasonal lows in January or February (Figure 95). During the fall period, temperatures were generally in decline following seasonal highs in September. Spring and fall also represent the periods when most routine plant outages occurred (Table 6).

During the spring between 1994 and 1998, there were 19 months when only one unit was operating and 26 months when both were operating. A t-test[7] applied to these data indicated that the capture of juvenile loggerheads was significantly higher ($t_{0.05(2)(43)} = 3.30$, $P < 0.002$) during months when two units were operating (mean = 18.7/mo $\pm$ 13.58/mo) than during months when only one unit was on line (mean = 7.7/mo $\pm$ 5.71/mo). Similar results were obtained for juvenile green turtles ($t_{0.05(2)(43)} = 2.08$, $P < 0.05$; mean for 2 units = 23.8/mo $\pm$ 36.75/mo; mean for 1 unit = 5.9/mo $\pm$ 7.91/mo). During the fall, there were 17 months when one unit was on line and 15 months when both were operational. The average number of captures for loggerheads during months when only one unit was operating was 5.9/mo ($\pm$ 4.91/mo). That was only slightly higher than the number of monthly captures when both units were on line (mean = 4.7/mo $\pm$ 2.98/mo). Similarly, the capture of juvenile green turtles during the fall was only slightly higher when two units were on line (mean = 12.3/mo $\pm$ 14.99/mo) than when a single unit was operating (mean = 8.7/mo $\pm$ 13.35/mo). Differences in fall capture rates between the two plant operating modes were not statistically significant for either species. Thus, while the number of units on line may affect capture rates during some seasons, the effect is not universal. Furthermore, plant outages have been a regular occurrence over the life of the plant, and there were no trends in outages to explain the long-term increases in the capture of juvenile loggerhead and green sea turtles.

---

[7] A t-test is a statistical method for comparing two sets of samples to infer whether differences exist between the two populations sampled. Sample size and variation of individual values about the mean for each sample are factored into the comparison. A significant t value indicates that the samples were derived from different populations and that the mean values differ because of factors other than random variation.

In a separate analysis of long-term power plant operating trends, the operating status of the plant was determined by calculating the number of days each year that at least one unit was on line (Figure 84). Regression analysis indicated that, over the entire period of study, there was a significant ($r^2 = 0.32$, $P < 0.01$, $n = 22$) increase in the number of days that at least one unit was operating. However, using this criterion, there was no significant trend in the operational status of the plant during the last fifteen years of the study period (1984 – 1998). This was due to the fact that, after Unit 2 went on-line, outages were scheduled so that there was always one unit operating. Thus, the overall trend in operating status was due to the addition of Unit 2 rather than to a gradual increase in plant operating capacity over the period of study.

Because velocities in the intake pipes are proportional to the number of units operating, it was also important to examine periods when both units were on-line. From 1984 through 1998, there was some variation from year to year, but there was no significant long-term trend in the number of days per year that both units were on-line (Figure 85).

Because the operational status of the power plant exhibited no long-term trend between 1984 and 1998, it would not be expected to have been responsible for any increases in turtle entrainment within that period. However, when the entire study period is evaluated it is clear that there was a shift in the operational status of the power plant related to the addition of Unit 2. This shift may have contributed to higher capture rates after Unit 2 went on-line, but if the effect were due strictly to the addition of a second unit, it would be expected to remain constant after 1984. So, for instance, the substantial increases in juvenile loggerhead and green turtle captures that occurred during the 1990s can not be attributed to changes in power plant operating status.

In addition to the duration of outages, the timing of outages could also affect capture rates. Outages would be expected to have a greater effect on annual capture rates if they occurred during months when turtles were more abundant. So a shift in the timing of outages could affect long-term trends in captures. Outage periods for each year are given in Table 6. Throughout the study period, most outages occurred during spring and fall and no long-term shift in timing was indicated. Therefore, the observed increases in loggerhead and green turtle captures can not be attributed to a change in the timing of outages.

More detailed information concerning the operational status of the power plant is available for the period from January 1988 through December 1998. For this eleven-year period actual monthly flow rates are available. These flow rates reflect even short-term outages and periods when circulating water pumps were run at less than capacity. When flow rates were compared to juvenile loggerhead capture rates (Figures 86-87), decreases in capture rates often coincided with decreases in flow rates. The relationship of monthly flow rates to monthly capture rates is shown in Figure 88. Regression analysis indicated a weak but significant ($r^2 = 0.06$, $P < 0.01$, $n = 132$) positive relationship between the two.

When flow rates were compared to monthly juvenile green turtle captures (Figures 89-90), some changes in capture rates seem to coincide with changes in flow rates, but overall there did not appear to be a very strong relationship between the two. This was also indicated when flow rates were plotted against capture rates (Figure 91). Regression analysis indicated no significant relationship between monthly juvenile green turtle captures and monthly flow rates.

These results indicate that flow rates from 1988 through 1998 had a significant but weak effect on juvenile loggerhead entrainment, but no effect on juvenile green turtle entrainment. This may reflect differences in how each species reacts to currents encountered in the intake structures and/or differences in their abilities to escape the velocities encountered.

Regardless of the apparent significant relationship between monthly flow rates and juvenile loggerhead entrainment, flow rates did not appear to be responsible for the considerable increase in juvenile loggerhead captures after 1994. This is indicated by the fact that there was no significant trend in annual flow rates during the period from 1988 to 1998 (Figure 92). When annual juvenile loggerhead captures were compared to annual flow rates during that period (Figure 93), no significant relationship was indicated. Likewise, there was no significant relationship indicated between annual captures of juvenile green turtles and annual flow rates between 1988 and 1998 (Figure 94).

Characteristics of the Nearshore Environment Adjacent to the St. Lucie Plant

Changes in several aspects of the nearshore environment occurring in the vicinity of the St. Lucie Plant during the period that the plant has been operating might affect the numbers of green and loggerhead turtles inhabiting the area. Presumably an increase in the number of turtles near the plant would result in an increase in entrainment rates. For example, changes in the size and structure of nearby worm reefs and coquinoid rock formations might affect the tendency of turtles to utilize these areas. The only data available concerning changes in the dimensions and relief of worm reefs near the St. Lucie Plant were obtained from a study conducted by ABI (1979). Though this study was only conducted between April 1976 and April 1979, the dynamic nature of reef structures was documented. During this study, there was a trend in increasing reef size during the summer with deterioration of the colonies during the winter. Deterioration of the colonies was speculated to be due to increased wave action in fall or natural worm mortality. Major larval settlement resulting in new worm colonies occurred in late fall or early winter. Other rock formations devoid of reef building worms tend to be less dynamic in nature, though some change in relief may occur due to changes in sand levels around the formations.

Changes in the abundance of loggerhead and green turtle food items in the vicinity of the intakes might also affect the abundance of these two species in the area of the intake structures. Changes in the abundance of invertebrates and algae might occur if there were changes in the structure of the nearshore reefs and rock formations or changes

in local environmental conditions. However, there were insufficient data available to assess long-term trends.

One factor for which considerable quantitative data were available was water temperature. Mean monthly water temperatures based on daily temperatures recorded at the power plant's circulating water pumps were available for the period from January 1989 through December 1996. Since water temperatures have been shown to affect loggerhead and green turtle movements and behavior (Mendonca, 1983; Keinath et al., 1987; Coyne, 1994; Epperly et al., 1995; Coles, 1999), the potential effect of water temperature on capture rates was investigated.

Monthly juvenile loggerhead captures are compared to mean monthly water temperatures in Figure 95. In general, peaks in captures coincided with cooler water temperatures. When monthly captures were plotted against mean monthly water temperatures, a negative relationship was indicated (Figure 96). This relationship was found to be statistically significant ($r^2 = 0.23$, $P < 0.001$, $n = 96$).

When monthly juvenile green turtle captures were compared to mean monthly water temperatures a similar relationship was indicated (Figures 97 and 98). Likewise this relationship was found to be statistically significant ($r^2 = 0.06$, $P < 0.05$, $n = 96$).

These results are consistent with suggestions by several authors that increases in juvenile loggerhead and green turtles along the east coast of Florida were associated with decreases in water temperatures (Henwood, 1987; Bolten et al., 1994; Ehrhart et al., 1996). It seems likely that water temperatures influenced seasonal trends in juvenile and loggerhead captures at the St. Lucie Plant.

In order to determine if there was a relationship between long-term trends in turtle captures and water temperatures, average annual water temperatures were compared to annual capture rates of juvenile loggerhead and green turtles (Figures 99 and 100). Though there were differences in average water temperatures among years, correlation analysis indicated no significant relationship between average annual water temperature and annual capture rates of either species.

In addition to differences in average annual water temperatures, there were also differences in the seasonal patterns of water temperature among years. For example, the timing and intensity of cool water intrusions (evidenced by temperature decreases during summer months) varied from year to year. However, no patterns could be detected that would explain long-term trends in turtle captures.

The possibility remains that water temperature may have affected long-term trends in turtle entrainment, but additional data may be necessary to detect the relationship. Increases in turtle numbers along the east coast of Florida during the winter have been partially attributed to seasonal migrants from northern climates. Therefore, water temperature patterns in these northern areas may be just as important as local temperatures in influencing trends in turtle abundance in the vicinity of the St. Lucie

Plant. Investigation of temperature patterns in these northern areas was beyond the scope of the present study.

Another characteristic of the nearshore environment that was investigated related to meteorological conditions (i.e., storms/high winds). The wave action that is often associated with high winds might affect a turtle's tendency to enter the intake structures. For example, turtles might seek refuge in the structures from the turbulence created by increased wave action. Conversely, turtles may leave the area around the intake and move to offshore areas to escape the turbulence.

High wind conditions associated with storms often increase wave activity near shore. This is particularly true if the wind is directed towards the coastline. Since no quantitative data on wave conditions near the St. Lucie Plant were available, wind conditions were used as a gauge of wave activity. Data on wind velocity and direction at the St. Lucie Plant were available for the period from January 1995 through December 1998. Wind data were collected hourly at a height of 10 meters just north of the plant's discharge canal. For the purpose of this analysis, winds with bearings of 0-140° and velocities greater than or equal to 10 mph (16.1 km/hr) were considered to be wave generating. In order to compare wind/wave conditions to monthly capture rates, the percentage of wind readings meeting the above criteria was calculated for each month. Occasionally instruments malfunctioned and readings could not be recorded for a period of time. If more than 24 readings (the equivalent of one day's readings) were missing during a month, then that month was excluded from analysis.

Monthly juvenile loggerhead captures are compared to wind conditions in Figure 101. No consistent relationship between captures and wind conditions were apparent. When capture rates were plotted against wind conditions, there did not appear to be a correlation between the two (Figure 102). Likewise, correlation analysis indicated no significant relationship between wind conditions and juvenile loggerhead captures. As with loggerheads, juvenile green turtle captures did not appear to be influenced by wind conditions (Figures 103 and 104). Again, correlation analysis indicated no significant relationship between wind conditions and juvenile green turtle captures. Based on the lack of any relationship between monthly wind conditions and turtle capture rates, it is unlikely that storms influenced long-term trends in loggerhead or green turtle entrainment at the St. Lucie Plant.

Population Trends

One possible explanation for the observed long-term increases in captures of loggerheads and green turtles at the St. Lucie Plant is that the populations of these two species have increased during the study period. Unfortunately, due to their wide and unpredictable distribution among various developmental and foraging habitats, sea turtle populations are particularly difficult to census (Meylan, 1982).

In fact, the Turtle Expert Working Group (1998) stated that results of studies conducted at the St. Lucie Plant provided one of the very few unbiased indices of

abundance for benthic immature and adult loggerheads. The only other in-water studies that provide long-term trends in the abundance of loggerhead turtles along the east coast of Florida were conducted in the Indian River Lagoon system.

Ehrhart et al. (1999) analyzed trends in loggerhead population density in the central region of the Indian River Lagoon. They analyzed June and July CPUE (catch per unit effort) data for the years 1983-85, 1988-90, 1993-95 and 1998. The results indicated that loggerhead population density had not changed over the 15-year span of the study.

Provancha et al. (1998) evaluated the relative abundance of loggerhead turtles in the Mosquito Lagoon. Data that they collected in 1994-1996 were compared to data collected in 1977-1979 by Mendonca and Ehrhart (1982). Provancha et al. found that loggerhead CPUE declined from 0.16 to 0.06 between the two periods. Additional studies were conducted during 1997 and 1998 (Provancha, 1997, 1998). Loggerhead CPUEs for these two years (0.09 and 0.12) remained below the 0.16 CPUE for 1977-1979.

Differences among trends in the central Indian River Lagoon (no trend), the Mosquito Lagoon (negative trend), and the St. Lucie Plant (positive trend) may be due to differences in local environmental conditions. Conditions may be quite different between the lagoonal habitats and the coastal habitat near the St. Lucie Plant. Local availability of food items may also affect turtle abundance. Provancha et al. (1998) found the decline in loggerhead numbers coincided with a decline in horseshoe crabs in the Mosquito Lagoon.

Because of the limited number of studies that provide information on population trends for immature sea turtles, indices of population size and stability often rely on estimates of nesting females (see Meylan, 1982; NMFS and USFWS, 1991a). The Turtle Expert Working Group (1998) found that nesting data collected on index nesting beaches represented the best dataset available to index the population size of loggerhead sea turtles. This group also found that annual nesting from Hutchinson Island predicted annual nesting on all Florida index beaches well and may accurately reflect nesting trends for the total South Florida Subpopulation.

The National Research Council (1990) found a possible rising trend in numbers of loggerhead nests on Hutchinson Island from 1973 through 1989. They concluded that there was no decline or a possible increase in the loggerhead assemblage nesting south of Cape Canaveral. The Turtle Expert Working Group (1998) found a significant increase on Hutchinson Island during the period 1971-1994 as well as a significant increase for a composite of eight Florida beaches from 1983 through 1994. Witherington and Koeppel (in press) analyzed loggerhead nesting for the thirty index beach sites throughout Florida and concluded that loggerhead nesting appeared to be stable or increasing between 1989 and 1998.

When loggerhead nesting data for Hutchinson Island were analyzed for the period from 1981 through 1998, a significant increase in nesting was indicated ($r^2 = 0.75$, $P < 0.001$, $n = 18$; Figure 105). It has already been shown that there was a significant

positive correlation between adult female loggerhead captures in the St. Lucie Plant intake canal and nesting on Hutchinson Island. However, based on estimates of time spent in the pelagic stage, increases in nesting would not be expected to begin affecting juvenile loggerhead captures for five to twelve years. Consequently, it is difficult to directly correlate changes in juvenile captures with changes in the adult population.

If trends in loggerhead nesting on Hutchinson Island do accurately reflect nesting trends for the total South Florida Subpopulation, then nesting for that subpopulation apparently increased from 1981 through 1998. Based on results of genetic analysis by Bass (1999), the majority (70 percent) of juvenile loggerhead captures from the St. Lucie Plant originated from the south Florida nesting population. So it would be reasonable to conclude that the increase in juvenile loggerhead captures at the plant reflects the increase in this population.

Like loggerheads, in-water studies of green turtles along the Atlantic coast of Florida are limited. The only studies that provide information on long-term trends in abundance were conducted in the Indian River Lagoon system and on worm reefs just south of the Sebastian Inlet.

Ehrhart et al. (1999) analyzed trends in green turtle population density in the central region of the Indian River Lagoon. They analyzed June and July CPUE data for the years 1983-85, 1988-90, 1993-95 and 1998 and found that the 1998 CPUE was significantly greater than CPUE for the other three time periods. These results supported speculation by Ehrhart et al. (1996) that the extraordinary increase in green turtle CPUE that occurred in the winter and spring of 1995-96 may have been an indication of a stepwise increase in the relative population density of the lagoonal green turtle population. Ehrhart et al. (1996) also found that green turtle CPUE during the periods 1988-90 and 1993-95 were significantly greater than the CPUE during 1983-1985.

Ehrhart et al. (1999) also studied green turtles on worm reefs just south of the Sebastian Inlet from 1989 through 1998. Though statistical differences in CPUE were found between years, the fluctuations did not follow any discernible pattern. The researchers suggested that differences among years might reflect changes in surf conditions and water clarity, which affect netting success, or fluctuations in the availability of algae utilized by green turtles as food.

Provancha et al. (1998) evaluated the relative abundance of green turtles in the Mosquito Lagoon. Data that they collected in 1994-1996 were compared to data collected in 1977-1979 by Mendonca and Ehrhart (1982). Provancha et al. found that green turtle CPUE increased from 0.21 to 0.36 between the two periods. Additional studies were conducted during 1997 and 1998 (Provancha, 1997, 1998). Green turtle CPUEs for these two years (0.28 and 0.32) remained above the 0.21 CPUE for 1977-1979.

Recent evidence that a large portion (53 percent) of the juvenile green turtles from the St. Lucie Plant originate from Costa Rican nesting populations (Bass and Witzell, in

press) complicates the use of nesting data as an index of overall population status. Trends in the abundance of juvenile green turtles near the plant may be affected by trends in nesting in Costa Rica as well as Florida (42 percent of the juveniles are from the Florida/Mexico nesting population).

Bjorndal et al. (1999) analyzed nesting data for Tortuguero, Costa Rica, during the period from 1971 through 1996. The green turtle population that nests at Tortuguero is the largest in the Atlantic by at least an order of magnitude. Evaluation of the trend in nesting indicated a relatively consistent increase from 1971 to the mid-1980s, constant or decreasing nesting during the late 1980s, and then continuation of an upward trend in the 1990s. Overall, for the entire period, the trend was upward.

Dodd (1981) reviewed available records of green turtle nesting in Florida from 1959 through 1981 and speculated that the nesting population of green turtles in Florida was increasing. Dodd did point out, though, that better surveillance undoubtedly accounted for some of the increase in reported nests.

The National Research Council (1990) reported that the numbers of green turtle nests increased on Hutchinson Island over the period 1971-1989. Considerable nesting was reported to occur on Melbourne Beach, Florida, but nesting surveys had not been conducted for a long enough period to confirm a trend. Wide year to year fluctuations in numbers of nesting green turtles made statistical analysis of trends for this species particularly difficult.

NMFS and USFWS (1991b) reported that the number of green turtle nests in Florida appeared to be increasing. However, it was uncertain whether the upward trend was due to an increase in the number of nests or a result of more thorough monitoring of nesting beaches.

Meylan et al. (1995) reviewed green turtle nesting data throughout Florida from 1979 through 1992 and found an overall upward trend in nesting. These researchers, like others, cautioned that increased survey effort was partially responsible for the observed increase in numbers of nests.

Witherington and Koeppel (in press) evaluated green turtle nesting from 1989 through 1998 on thirty beach sites that are part of the Florida Index Nesting Beach program. They concluded that, over the ten-year period of study, green turtle nesting in Florida appears to be stable or increasing.

Changes in the annual numbers of green turtle nests on Hutchinson Island from 1981 through 1998 are shown in Figure 106. The drastic year-to-year fluctuations in nests numbers observed on Hutchinson Island have been documented at other green turtle nesting beaches and make analysis of trends difficult. However, regression analysis indicated a significant increase in nesting during this period ($r^2 = 0.28$, $P < 0.05$, $n = 18$).

There appears to be evidence that the green turtle nesting populations in Costa Rica and Florida increased between the 1970s and the 1990s. It seems reasonable to conclude that such an increase would result in an increase in juvenile green turtles in the vicinity of the St. Lucie Plant.

CONCLUSIONS

Immature loggerhead and green turtles apparently use the nearshore ocean environment in the vicinity of the St. Lucie Plant as developmental/foraging habitat. This appears to be related to the water depth in the area, the presence of hard bottom substrates and worm reefs, and the occurrence of preferred food items. Based on recapture data it appears that some turtles reside in the area throughout the year, while others transmigrate seasonally. The area is apparently also used as internesting habitat by large numbers of female loggerhead turtles that nest on Hutchinson Island every year.

Turtles migrating along the coast and/or utilizing hardbottom substrates and worm reefs in the vicinity of the plant would be brought into close proximity with the plant's intake structures. Turtles may enter the intake structures to rest or avoid attack from predators and/or competition from other turtles. Green and loggerhead turtles may also be attracted to the intakes for the purpose of foraging, since the structures resemble reefs, important foraging habitat for both species.

The majority of the loggerhead and green turtles entrained into the St. Lucie Plant intake canal between 1977 and 1998 were juveniles. However, loggerhead captures included a higher proportion of subadults and adults than green turtle captures. This probably reflects the fact that the loggerhead nesting population is considerably larger than the green turtle nesting population in the Hutchinson Island area.

There were significant increases in the numbers of juvenile and adult loggerhead captures and juvenile green turtle captures at the St. Lucie Plant from 1977 through 1998. The increase in adult loggerhead captures was more or less continuous and was significantly correlated with increases in nesting on Hutchinson Island. The upward trends in juvenile loggerhead and green turtle captures were primarily due to increases that occurred in the 1990s.

On average, more turtles were captured each year after Unit 2 was placed on line than before, suggesting that the addition of a second unit affected capture rates to some extent. However, this change could not account for the dramatic increases in capture rates of juvenile loggerhead and green turtles that only occurred after Unit 2 had been operating for ten years.

Changes in the physical appearance of the intake structure velocity caps following their repair coincided with substantial increases in juvenile green turtle captures at the plant. However, the extent to which the two are causally related is unclear.

Power plant outages over the life of the plant, at times, appeared to affect short-term trends in juvenile loggerhead and green turtle captures. However, plant outages could not explain the substantial increases in captures of either species that occurred during the 1990s. Flow rates from 1988 through 1998 appeared to have a weak but significant affect on short-term juvenile loggerhead entrainment rates. Again, however, flow rates were not responsible for the long-term increases in juvenile loggerhead captures occurring during this period. Flow rates had no affect on either short- or long-term captures of juvenile green turtles.

Changes in the nearshore environment near the St. Lucie Plant might be expected to affect long-term trends in turtle entrainment. Unfortunately, data relating to the relative size and relief of nearby worm reefs and hard bottom or to changes in the abundance of food items in the area were lacking. One environmental factor that was shown to be significantly correlated with monthly captures of juvenile green and loggerhead turtles was water temperature. However, no relationship between local water temperatures and long-term trends in capture rates could be demonstrated. The frequency of high, wave-producing winds also did not appear to affect entrainment of turtles. Seasonal increases in the number of juvenile loggerhead and green turtles in the vicinity of the plant may be more closely related to the migration patterns of turtles from more northern areas than to local conditions.

There is evidence (mainly from nesting beach surveys) that the adult populations of both green and loggerhead turtles that provide juveniles to the Hutchinson Island area increased during the study period. It would logically follow that the juvenile component of those populations also increased. The number of juvenile green turtles captured at the St. Lucie Plant increased dramatically in the 1990s. A similar increase was documented in the central Indian River Lagoon in an area well beyond the influence of the St. Lucie Plant. Unfortunately, there are relatively few other study sites for which long-term quantitative data are available for juvenile loggerheads. However, the strong correlation between adult loggerhead captures at the St. Lucie Plant and nesting on Hutchinson Island elucidates the relationship between canal capture rates and the relative numbers of individuals in the nearshore environment.

Even though changes in physical plant design and operating characteristics have occurred over the life of the plant, these changes do not appear to be responsible for the long-term increases in the numbers of juvenile and adult loggerhead and juvenile green turtles captured at the St. Lucie Plant. The most logical explanation for these increases is that there are more individuals of these life history stages present in the vicinity of the plant.

LITERATURE CITED

ABI (Applied Biology, Inc.). 1977. Ecological monitoring at the Florida Power & Light Co. St. Lucie Plant. Annual Report 1976. Volume 1. AB-44. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

ABI (Applied Biology, Inc.). 1979. Worm reef monitoring at the Florida Power & Light Company St. Lucie Plant: April 1976 – April 1979. AB-209. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1980. Turtle entrainment deterrent study. AB-290. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1981. Florida Power & Light Co., St. Lucie Plant annual non-radiological environmental monitoring report 1980. Volumes II and III, Biotic monitoring. AB-324. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1983. Florida Power & Light Co., St. Lucie Plant annual non-radiological environmental monitoring report 1982. Volumes I and II, Biotic monitoring. AB-442. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1986. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1985. AB-563. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1987. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1986. AB-579. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1990. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1989. Volume 1. AB-603. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1991. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1990. Volume 1. AB-610. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1992. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1991. Volume 1. AB-617. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

__________. 1994. Florida Power & Light Co., St. Lucie Unit 2 annual environmental operating report 1993. Volume 1. AB-631. Prepared by Applied Biology, Inc. for Florida Power & Light Co.

Balazs, G.H. 1982. Factors affecting the retention of metal tags on sea turtles. Marine Turtle Newsletter 20:11-14.

__________. 1995. Behavioral changes within the recovering Hawaiian green turtle population. Pages 16-20 in Proceedings of the Fifteenth Annual Symposium on

Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387. Pp16-20.

Bass, A. L. 1999. Genetic analysis of juvenile loggerheads captured at the St. Lucie Power Plant. A Report to National Marine Fisheries Service and Quantum Resources, Inc.

__________ and W. N. Witzell. In press. Demographic composition of immature green turtles (*Chelonia mydas*) from the east central Florida coast: evidence from mtDNA markers. Herpetologica.

Bellmund, S.A., J.A. Musick, R.E.C. Klinger, R. A. Byles, J. A. Keinath, and D. E. Barnard. 1987. Ecology of sea turtles in Virginia. The Virginia Institute of Marine Science, School of Marine Science, College of William and May, Gloucester Point, Virginia. 48pp.

Bjorndal, K.A. 1980. Nutrition and grazing behavior of the green turtle Chelonia mydas. Marine Biol. 56:147-154.

__________ and A.B. Bolten. 1989. Comparison of straight-line and over-the-curve measurements for growth rates of green turtles, *Chelonia mydas*. Bull. Mar. Sci. 45(1):189-192.

__________ and __________. 1994. *Caretta caretta* growth and pelagic movement. Herp. Rev. 25(1):23-24.

__________, A.B. Meylan and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida, I. Size, growth and reproductive biology. Biological Conservation 26:65-77.

__________, J.A. Wetherall, A.B. Bolten, and J.A. Mortimer. 1999. Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. Conservation Biol. 13(1):126-134.

Bolten, A.B. 1999. Techniques for measuring turtles. Pages 110-114 in Eckert, K.L., K.A. Bjorndal, F.A. Abreu-Grobois, and M. Donnelly (eds.). Research and management techniques for the conservation of sea turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4. 235pp.

__________, K.A. Bjorndal, P.J. Eliazar, and L.F. Gregory. 1994. Seasonal abundance, size distribution, and blood biochemical values of loggerheads (*Caretta caretta*) in Port Canaveral ship channel, Florida. NOAA Tech. Memo. NMFS-SEFSC-353.

__________, K.A. Bjorndal, H.R. Martins, T. Dellinger, M.J. Biscoito, S.E. Encalada, and B.W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. Ecol. Apps. 8(1):1-7.

Booth, J. and J. A. Peters. 1972. Behavioral studies on the green turtle (*Chelonia mydas*) in the sea. Animal Behav. 20:808-812.

Bowen, B., J.C. Avise, J.I. Richardson, A.B. Meylan, D. Margaritoulis, and S.R. Hopkins-Murphy. 1993. Population structure of the Loggerhead turtles (*Caretta caretta*) in the Northwestern Atlantic Ocean and Mediterranean Sea. Cons. Biol. 7(4):835-844.

__________, A.B. Meylan, J.P. Ross, C.J. Limpus, G.H. Balazs, and J.C. Avise. 1992. Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. Evolution 46(4):865-881.

Bresette, M., J. Gorham, and B. Peery. 1998. Site fidelity and size frequencies of juvenile green turtles (*Chelonia mydas*) utilizing near shore reefs in St. Lucie County, Florida. Marine Turtle Newsletter. 82:5-7.

__________, B. Peery and J. Gorham. 1999. Assessment of green turtles in an area of the southern Indian River Lagoon System, Florida: September 1998 – June 1999. Report submitted to National Marine Fisheries Service. 22pp.

Bustard, H.R. 1976. Turtles of coral reefs and coral islands. Pages 343-368 in Jones, O.A. and R. Endern (eds.). Biology and Geology of Coral Reefs, Biology 2, Volume III. Academic Press, New York.

Burke, V. J., E. A. Standora and S.J. Morreale. 1993. Diet of Juvenile Kemp's Ridley and loggerhead sea turtles from Long Island, New York. Copeia 4:1176-1180.

Byles, R. A. 1988. The behavior and ecology of sea turtles in Virginia. Unpub. Ph.D. Dissertation. VA Institute of Marine Science, College of William and Mary, Gloucester Point, VA. 112pp.

Camp, D.K., N.H. Whiting, and R.E. Martin. 1977. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. V. Arthropods. Florida Marine Research Publications. 25:1-63.

Carr, A. 1952. Handbook of turtles: the turtles of the United States, Canada, and Baja California. Cornell University Press, Ithica, NY.

__________. 1975. The Ascension Island green turtle colony. Copeia 1975(3):547-555.

__________. 1986. Rips, FADs, and little loggerheads. Bioscience 36:92-100.

__________, M.H. Carr, and A.B. Meylan. 1978. The Ecology and migrations of sea turtles, 7. The West Caribbean green turtle colony. Bull. Am. Museum of Nat. Hist. 162(1):1-46.

Carr, A., P. Ross, and S. Carr. 1974. Internesting behavior of the green turtle, *Chelonia mydas*, at a mid-ocean island breeding ground. Copeia 3:703-706.

Coles, W. C. 1999. Aspects of the biology of sea turtles in the Mid-Atlantic Bight. Ph.D. Dissertation, School of Marine Science, The College of William and Mary. 149pp.

Coyne, M. 1994. Feeding ecology of subadult green sea turtles in south Texas waters. M.S. thesis, Texas A & M University. 76pp.

Davenport, J., S. Antipas and E. Blake. 1989. Observations of gut function in young green turtles *Chelonia mydas* L. Herpetological Journal 1(8):336-342.

Dodd, C.K. Jr. 1981. Nesting of the green turtle (*Chelonia mydas*) in Florida: historic review and present trends. Brimleyana 7:39-54.

__________. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). US Fish and Wildl. Serv. Biol. Rep. 88(14). 110pp.

Ebasco Services, Inc. 1971. Hutchinson Island – Unit No. 1. Cooling water discharge report. Report prepared by Ebasco Services, Inc. for Florida Power & Light Co.

Ehrhardt, N. and R. Witham. 1992. Analysis of growth of the green sea turtle (*Chelonia mydas*) in the Western Atlantic. Bulletin of Marine Science 50(2):275-281.

Ehrhart, L.M. 1983. Marine turtles of the Indian River Lagoon System. Florida Sci. 46(3/4):337-346.

__________. 1992. Turtles of the worm-rock reefs. The Florida Naturalist (Summer 1992):9-11.

__________, W.E. Redfoot, and D.A. Bagley. 1996. A study of the population ecology of in-water marine turtle populations on the east-central coast of Florida. Comprehensive final report to NOAA, The National Marine Fisheries Service. 164pp.

__________, D.A. Bagley, and W.E. Redfoot. 1999. A study of the population ecology of in-water marine turtle populations on the east-central Florida coast, in 1997-98. Final report to NOAA & National Marine Fisheries Service. 56pp.

Epperly, S.P., J. Braun, and A. Veishlow. 1995. Sea turtles in North Carolina waters. Conservation Biology 9(2):384-394.

Ernest, R.G. and R.E. Martin. 1993. Sea turtle protection program performed in support of velocity cap repairs, Florida Power & Light Company St. Lucie Plant, 1991. Prepared by Applied Biology, Inc. for Florida Powr & Light Co.

Ernest, R.G. and R.E. Martin. 1999. Martin County Beach Nourishment Project: sea turtle monitoring and studies 1997. Annual report and final assessment. Ecological Associates, Jensen Beach, Florida.

__________, __________, B.D. Peery, D.G. Strom, J.R. Wilcox and N.W. Walls. 1988. Sea turtles entrapment at a coastal power plant. Pages 270-301 in Mahadevan, K., R. Evans, P. Behrens, T. Biffar and L. Olsen (eds.). Proceedings of the southeastern workshop on aquatic ecological effects of power generation. Mote Marine Laboratory, Report No. 124.

__________, __________, N. Williams-Walls, and J.R. Wilcox. 1989. Population dynamics of sea turtles utilzing shallow coastal waters off Hutchinson Island, Florida. Pages 57-59 in Eckert, S.A., K.J. Eckert, and T.J. Richardson (compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-232.

Frazer, N. B. and L. M. Ehrhart. 1985. Preliminary growth models for green, (*Chelonia mydas*), and loggerhead, (*Caretta caretta*), turtles in the wild. Copeia 1985(1):73-79.

__________ and R. C. Ladner. 1986. A growth curve for green sea turtles, *Chelonia mydas*, in the U.S. Virgin Islands, 1913-1914. Copeia 1986 (3):798-802.

Gallagher, R.M. 1977. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. II. Sediments. Florida Marine Research Publications 23:6-24.

__________ and M.L. Hollinger. 1977. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. I. Introduction and Rationale. Florida Marine Research Publications 23:1-5.

Godley, B.J., S.M. Smith, P.F. Clark, and J.D. Taylor. 1997. Molluscan and crustacean items in the diet of the loggerhead turtle, *Caretta caretta* (Linnaeus, 1758) [Testudines:Chelonidae] in the eastern Mediterranean. J. Moll. Stud. 63:474-476.

Gorham, Jonathan. Quantum Resources, Inc. Personal communication.

Gorham, J.C., M.J. Bresette and B.D. Peery. 1998. Comparative tag retention rates for two styles of flipper tags. Pages 179-182 in Epperly, S.P. and J. Braun (compilers). Proceedings of the seventeenth annual sea turtle symposium. NOAA Technical Memorandum NMFS-SEFSC-415.

Henwood, T.A. 1986. Losses of monel flipper tags from loggerhead sea turtles, Caretta caretta. Journal of Herpetology 20(20):276-279.

Henwood, T.A. 1987. Movements and seasonal changes in loggerhead turtle *Caretta caretta* aggregations in the vicinity of Cape Canaveral, Florida (1978-84). Biological Conservation 40:191-202.

__________ and L.H. Ogren. 1987. Distribution and migrations of immature Kemp's ridley turtles (*Lepidochelys kempi*) and green turtles (*Chelonia mydas*) off Florida, Georgia, and South Carolina. Northeast Gulf Science 9(2):153-159.

Hirth, H.F. 1997. Synopsis of the biological data on the green turtle *Chelonia mydas*. Fish and Wildlife Service Biological Report 97(1):1-120.

Holloway, Karen. University of Central Florida. Personal communication.

Johnson, S.A. 1994. Reproductive ecology of the Florida green turtle (*Chelonia mydas*). M.S. thesis, University of Central Florida. 108pp.

Keinath, J.A., J.A. Musick, and R.A. Byles. 1987. Aspects of the biology of Virginia's sea turtles: 1979-1986. Virginia Journal of Science, 38(4):329-336.

Klinger, R.E. and J.A. Musick. 1995. Age and growth of loggerhead turtles (*Caretta caretta*) from Chesapeake Bay. Copeia 1995(1):204-208.

Lackey, J.B. 1970. Hutchinson Island ecological surveys. Appendix 3 in Florida Power & Light Company, Hutchinson Island Plant. Environmental Report Vol. 1.

Laurent, L., P. Casale, M.N. Bradai, B.J. Godley, G. Gerosa, A.C. Broderick, W. Schroth, B. Schrierater, A.M. Levy, D. Freggi, E.M. Abd El-Mawla, D.A. Hadaud, H. El-Gomati, M. Domingo, M. Hadjichristophorou, L. Kornaraki, F. Demirayak, and C. Gautier. 1998. Molecular resolution of marine turtle stock composition in fishery bycatch: a case study in the Mediterranean. Molec. Ecol. 7(11):1529-1542.

Lazell, Jr., J. D. 1980. New England waters: critical habitat for marine turtles. Copeia 2:290-295.

Limpus, C. J. 1991. Puberty and first breeding in *Caretta caretta*. Pages 81-83 in Richardson, T.H., J.I. Richardson and M. Donnelly (compilers). Proceedings of the tenth annual symposium for biology and conservation of sea turtles. NOAA Tech. Memo. NMFS-SEFC-278.

Lohmann, K.J., and C.M.F. Lohmann. 1996. Detection of magnetic field intensity by sea turtles. Nature 380:59-61.

Lutcavage, M. and J.A. Musick. 1985. Aspects of the biology of sea turtles in Virginia. Copeia 2:449-456.

Lyons, W. G. 1989. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. XI. Mollusks. Florida Marine Research Publications. 47:1-131.

Martin, Erik. Ecological Associates, Inc. Personal communication.

Mendonca, M.T. 1983. Movements and feeding ecology of immature green turtles (*Chelonia mydas*) in a Florida lagoon. Copiea. 1983(4):1013-1023.

__________ and L.M. Ehrhart. 1982. Activity, population size, and structure of immature *Chelonia mydas* and *Caretta caretta* in the Mosquito Lagoon, Florida. Copeia 1982(1):161-167.

Meylan, A. B. 1982. Behavioral ecology of the West Caribbean green turtle *(Chelonia mydas*) in the internesting habitat. Pages 67-89 in Bjorndal, K. (editor). Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

__________, K.A. Bjorndal and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida, II. Post-nesting movements of *Caretta caretta.* Biological Conservation 26:79-90.

__________, B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida: 1979-1992. Florida Marine Research Publication 52:1-51.

Miller, J.D. 1997. Reproduction in sea turtles. Pages51-81 in Lutz, P.L. and J.A. Musick (eds.). The biology of sea turtles. CRC Press, Inc. Boca Raton, Florida.

Mitchel, John. National Marine Fisheries Service, Pascagoula Lab. Personal communication.

Moffler, M.D. and J. F. Van Breedveld, 1979. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. X. Benthic algae species list. Florida Marine Research Publications 34:118-122.

Morreale, S.J., and A.B. Meylan, S.S. Sadove, and E.R. Standora. 1992. Annual occurrence and winter mortality of marine turtles in New York waters. J. Herp. 26(3):301-308.

Mortimer, J.A. 1981a. The feeding ecology of the West Caribbean green turtle (*Chelonia mydas*) in Nicaragua. Biotropica 13(1):49-58.

__________. 1981b. Feeding ecology of sea turtles. Pages 103-109 in Bjorndal, K. (ed.). Biology and Conservation of Sea Turtles. Smithsonian Institution Press. Washington, D.C.

Murphy, T.M. and S.R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region, U.S. Final Report to National Marine Fisheries Service. 73pp.

Musick, J.A. and C.J. Limpus. 1997. Habitat utilization and migration in juvenile sea turtles. Pages 137-163 in Lutz, P.L. and J.A. Musick (editors). The Biology of Sea Turtles. CRC Press, Inc. Boca Raton, Florida.

NMFS (National Marine Fisheries Service) and USFWS (U.S. Fish and Wildlife Service) 1991a. Recovery plan for the US population of the loggerhead turtle. National Marine Fisheries Service, Washington, D.C. 64pp.

__________ and __________ 1991b. Recovery Plan for the US population of Atlantic green turtle. National Marine Fisheries Service, Washington, D.C. 52pp.

National Research Council. 1990. Decline of the sea turtle. National Academy Press. Washington, DC:1-259.

Norrgard, J. 1995. Determination of stock composition and natal origin of a juvenile loggerhead population (*Caretta caretta*) in Chesapeake Bay using mitochondrial DNA analysis. M.S. thesis, Virginia Institute of Marine Science.

Ogden, J.C., L. Robinson, K. Whitlock, H. Daganhardt, and R. Cebula. 1983. Diel foraging patterns in juvenile green turtles (*Chelonia mydas*) in St. Croix, U.S. Virgin Islands. J. Exp. Mar. Biol. Ecol. 66(3): 199-206.

Ogren, L. and C. McVea, Jr. 1982. Apparent hibernation by sea turtles in North American Waters. Pages 127-132 in Bjorndal, K. (ed.). Biology and Conservation of Sea Turtles. Smithsonian Institution Press. Washington, D.C.

__________, J.W. Watson, Jr., and D.A. Wickham. 1977. Loggerhead sea turtles, Caretta caretta, encountering shrimp trawls. Marine Fisheries Review 39(11):15-17.

Plotkin, P.T., M.K. Wicksten, and A.F. Amos. 1993. Feeding ecology of the loggerhead sea turtle (*Caretta caretta*) in the Northwestern Gulf of Mexico. Marine Biol. 115:1-15.

Provancha, J. 1997. Annual report for sea turtle netting in Mosquito Lagoon. Kennedy Space Center, Florida.

__________. 1998. Annual report for sea turtle netting in Mosquito Lagoon. Kennedy Space Center, Florida.

__________, M.J. Mota, R.H. Lowers, D.M. Scheidt, and M.A. Corsello. 1998. Relative abundance and distribution of marine turtles inhabiting Mosquito Lagoon,

Florida, USA. Pages 78-79 in Epperly, S.P. and J. Braun (compilers). Proceedings of the seventeenth annual sea turtle symposium. NOAA Tech. Memo. NMFS-SEFSC 415.

Quantum Resources. 1999. Florida Power & Light Company St. Lucie Unit 2 annual environmental operating report. 1998. Prepared by Quantum Resources, Inc. for Florida Power & Light Co. 40pp.

Rankin-Baransky, K. C. 1997. Origin of loggerhead turtles (*Caretta caretta*) in the Western North Atlantic Ocean as determined by mtDNA analysis. M.S. thesis, Drexel University. Pp. 48.

Redfoot, W.E., L.M. Ehrhart, D.A. Nelson. 1996. A population of juvenile green turtles utilizing the Trident Submarine Basin, Port Canaveral, Florida. Pages 258-259 in Keinath, J.A., D.E. Barnard, J.A. Musick, and B.A. Bell (compilers). Proceedings of the fifteenth annual symposium on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-387.

Richardson, J. I. and P. McGillivary. 1991. Post-hatchling loggerhead turtles eat insects in Sargassum community. Marine Turtle Newsletter, 55:2.

__________, and T.H. Richardson. 1982. An experimental model for the loggerhead sea turtle (*Caretta caretta*). Pages 189-195 in Bjordal, K.A. (ed.) Biology and conservation of sea turtles. Smithsonian Institution Press. Washington, D.C.

Ruckdeschel, C. and C.R. Shoop. 1988. Gut contents of loggerheads: findings, problems, and new questions. Pages 97-98 in Schroeder, B.A. (compiler). Proceedings of the Eighth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFC-214.

Salmon, M. and J. Wyneken. 1994. Orientation by hatchling sea turtles: mechanisms and implications. Herp. Nat. Hist. 2(1):13-24.

Sauls, B. and M. Thompson. 1994. Observations of a loggerhead turtle feeding in the wild. Marine Turtle Newsletter. 67:28-29.

Schroeder, B.A., L.M. Ehrhart, J.L. Guseman, R.D. Owens, and W.E. Redfoot. 1990. Cold stunning of marine turtles in the Indian River Lagoon System, Florida, December, 1989. Pages 67-69 in Richardson, T. H., J. I. Richardson and M. Donnelly (compilers). Proceedings of the tenth annual workshop on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-278.

__________, __________, and G.H. Balazs. 1996. Post nesting movements of Florida green turtles: preliminary results from satellite telemetry. Page 289 in Keinath, J.A., D.E. Barnard, J.A. Musick, and B.A. Bell (compilers). Proceedings of the

fifteenth annual symposium on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-387.

Schroeder, B.A., A.M. Foley, B.E. Witherington, and A.E. Mosier. 1998. Ecology of marine turtles in Florida Bay: population structure, distribution, and occurrence of fibropapilloma. Pages 265-267 in Epperly, S.P. and J. Braun (compilers). Proceedings of the seventeenth annual sea turtle symposium. NOAA Technical Memorandum NMFS-SEFSC-415.

__________, and D.W. Owens. 1994. Sex ratio of immature green turtles in an east central Florida developmental habitat. Pages 157-160 in Schroeder, B.A. and B.E. Witherington (compilers). Proceedings of the thirteenth annual symposium on sea turtle biology and conservation. NOAA Tech. Memo. NMFS-SEFSC-341.

Sears, C.J. 1994. The genetic structure of a local loggerhead sea turtle population based on mtDNA analysis. Pages 163-165 in Schroeder, B.A. and B.E. Witherington (compilers). Proceedings of the thirteenth annual symposium on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-341.

__________, B.W. Bowen, R.W. Chapman, S.B. Galloway, S.R. Hopkins-Murphy, and C. M. Woody. 1995. Demographic composition of the feeding population of juvenile loggerhead sea turtles (*Caretta caretta*) off Charleston, South Carolina: evidence from mitochondrial DNA markers. Marine Biology 123:869-874

Shaver, D.J. 1990. Hypothermic stunning of sea turtles in Texas. Marine Turtle Newsletter 48:25-27.

Smith, N.P. 1982. Upwelling in Atlantic shelf waters of South Florida. Florida Sci. 45(2):125-138.

Spotila, J.R., P.T. Plotkin, and J.A. Keinath. 1998. In water population survey of sea turtles of Delaware Bay. Final report to NMFS Office of Protected Resources. Contract 43AANF600211. 17pp

Standora, E.A., S.J. Morreale, A.B. Bolten, M.D. Eberle, J.M. Edbauer, T.S. Ryder, and K.L. Williams. 1994. Diving behavior and vertical distribution of loggerheads, and a preliminary assessment of trawling efficiency for censusing. Pages 194-197 in Schroeder, B.A. and B.E. Witherington (compilers). Proceedings of the thirteenth annual symposium on sea turtle biology and conservation. NOAA Tech. Memo. NMFS-SEFSC-341.

Thompson, N.B. 1988. The status of loggerhead, *Caretta caretta*; Kemp's ridley, *Lepidochelys kempi*; and green, *Chelonia mydas*, sea turtles in U.S. waters. Marine Fisheries Review 50(3):16-23.

Tucker, A.D., N.N. Fitzsimmons, and C.J. Limpus. 1996. Conservative implications of internesting habitat use by loggerhead turtles *Caretta caretta* in Woongarra Marine Park, Queensland, Australia. Pacific Conservation Biology 2:157-166.

Turtle Expert Working Group. 1998. An assessment of the Kemp's ridley (*Lepidochelys kempi*) and loggerhead (*Caretta caretta*) sea turtle populations in the western North Atlantic. NOAA Technical Memorandum, NMFS-SEFSC-409:1-96.

Wershoven, R. and J. Wershoven. 1990. Assessment of juvenile green turtles and their habitat in Broward County, Florida waters: Data summary, 1986-1990. Report to Florida Department of Natural Resources, Division of Marine Resources. 23pp.

Whiting, Nick. Florida Power & Light Co. St. Lucie Plant. Personal communication.

Wibbles, T. 1999. Diagnosing the sex of sea turtles in foraging habitats. Pages 139-143 in Eckert, K.L., K.A. Bjorndal, F.A. Abreu-Grobois and M. Donnelly (eds.). Research and management techniques for the conservation of sea turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4. 235pp.

__________, R.E. Martin, D.W. Owens, and M.S. Amoss, Jr. 1991. Female-biased sex ratio of immature loggerhead sea turtles inhabiting the Atlantic coastal waters of Florida. Can. J. Zool. 69:2973-2977.

__________, D. Owens, Y. Morris and M. Amos. 1984. Sex ratio of immature loggerhead sea turtles captured along the Atlantic coast of the United States. Final report to the National Marine Fisheries Service, Contract No. NA81-GA-C-00039.

Witham, R. 1980. The "Lost Year" question in young sea turtles. Amer. Zool. 20:525-530.

Witherington, B.E. 1994. Some "lost year" turtles found. Pages 194-197 in Schroeder, B.A. and B.E. Witherington (compilers). Proceedings of the thirteenth annual symposium on sea turtle biology and conservation. NOAA Tech. Memo. NMFS-SEFSC-341.

__________, and L.M. Ehrhart. 1989a. Hypothermic stunning and mortality of marine turtles in the Indian River Lagoon System, Florida. Copeia 1989(3):696-703.

__________, and __________. 1989b. Status and reproductive characteristics of green turtles (*Chelonia mydas*) nesting in Florida. Pages 351-352 in Ogren, L., F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham (eds.). Proceedings of the second Western Atlantic turtle symposium. NOAA Tech. Memo. NMFS-SEFC-226. 401pp.

Witherington, B.E. and C.M. Koeppel. In press. Sea turtle nesting in Florida, USA, during the decade 1989-1998: an analysis of trends. Proceedings of the nineteenth annual sea turtle symposium.

Worth, D.F. and M.L. Hollinger. 1977. Nearshore marine ecology at Hutchinson Island, Florida: 1971-1974. III. Physical and chemical environment. Florida Marine Research Publications 23:25-85.

Zar, J.H. 1996. Biostatistical analysis. Third Edition. Prentice Hall. Upper Saddle River, New Jersey.

Zug, G.A. and R.E. Glor. 1998. Estimates of age and growth in a population of green sea turtles (*Chelonia mydas*) from the Indian River lagoon system Florida: a skeletochronological analysis. Can. J. Zool. 76:1497-1506.

Table 1. Calculated flow velocities along the intake system. Values for two power plants operating with three intakes are from Bellmund, 1982 (see Table 3). All other values were based on these values and the assumption that changes in velocities are proportional to changes in flow rates and the assumption that the 4.9-m pipe conveys 60 percent of the total flow (see p. 36, Bellmund et al., 1982).

Time Period	Number of power plants operating	Number of Intakes	Velocity Cap Flow Velocity (cm/sec)		Vertical Section Flow Velocity (cm/sec)		Pipe Flow Velocity (cm/sec)		Canal Flow Velocity (cm/sec)
			3.7-m	4.9-m	3.7-m	4.9-m	3.7-m	4.9-m	
May76-May83	None[1]	Two	0.4-0.5		1.3-1.5		4.8-5.3		0.46
May76-May83	One[2]	Two	14.0-15.8		44.9-50.2		159-178		15.24
Jun83-Dec98	One[3]	Three	5.8-6.5	14.4-15.7	18.5-20.7	97-106	66-73	93-106	15.70
Jun83-Dec98	Two[4]	Three	11.2-12.6	27.9-30.5	35.9-40.2	188-206	127-142	180-206	30.48

[1] Only auxiliary pumps for one unit operating
[2] Main pumps for one unit operating
[3] Main pumps for one unit and auxiliary pumps for the other unit operating
[4] Main pumps for both units operating

Table 2. Annual numbers of turtle captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

Year	Loggerhead	Green Turtle	Leatherback	Hawksbill	Kemp's Ridley	Total
1976	33	0	0	0	0	33
1977	80	5	1	0	0	86
1978	138	6	3	1	0	148
1979	172	3	0	0	0	175
1980	116	10	0	0	0	126
1981	62	32	2	0	1	97
1982	101	8	1	0	0	110
1983	119	23	0	0	0	142
1984	148	69	0	1	2	220
1985	157	14	0	1	0	172
1986	195	22	1	1	1	220
1987	175	35	0	2	6	218
1988	134	42	0	0	5	181
1989	111	17	1	2	2	133
1990	112	20	0	0	0	132
1991	107	12	0	1	1	121
1992	123	61	1	2	0	187
1993	147	179	5	2	4	337
1994	164	193	2	0	2	361
1995	254	673	1	0	5	933
1996	349	549	0	5	3	906
1997	188	191	2	1	0	382
1998	393	268	1	2	2	666
Total	3578	2432	21	21	34	6086
Annual Mean[1]	162.6	110.5	1.0	1.0	1.5	275.1

[1] Data from 1976 are excluded since the power plant did not begin operation until May of that year.

Table 3. Equations used to convert straight standard carapace length (SSCL) and curved standard carapace length (CSCL) to straight minimum carapace length (SMCL) for loggerhead turtles.

Conversion	Equation	R^2	P	SE	N
SSCL to SMCL	$y = 0.9923x - 0.6948$	0.9986	<0.001	0.57	2061
CSCL to SMCL	$y = 0.9363x - 1.7437$	0.9925	<0.001	1.28	2901

Table 4. Average annual numbers of sea turtle captures for a five-year period before construction of the third intake (1977-1981) and for a five-year period after Unit II began operation (1984-1988), St. Lucie Plant intake canal, Hutchinson Island, Florida.

Species	Life History Stage	Mean Annual Capture Rate	
		1977-1981	1984-1988
Loggerhead Turtle	Juvenile	84.8	105.8
Loggerhead Turtle	Subadult	17.4	25.8
Loggerhead Turtle	Adult	7.8	29.0
Green Turtle	Juvenile	10.2	34.2

Table 5. Average annual numbers of sea turtle captures for a five-year period before velocity caps were damaged (1984-1988) and a five-year period after velocity caps were repaired (1992-1996), St. Lucie Plant intake canal, Hutchinson Island, Florida.

Species	Life History Stage	Mean Annual Capture Rate	
		1984-1988	1992-1996
Loggerhead Turtle	Juvenile	105.8	138.4
Loggerhead Turtle	Subadult	25.8	20.4
Loggerhead Turtle	Adult	29.0	48.4
Green Turtle	Juvenile	34.2	325.2

Table 6. Maintenance/refueling outage periods for each of the St. Lucie Plant units. Unit I outages are designated by vertical shading and Unit II outages are designated by black areas. Outages were assigned to months in which circulating water pumps operated for less than 25 days. The asterisks indicate the month (June 1983) in which Unit II went on-line.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977												
1978												
1979												
1980												
1981												
1982												
1983						******						
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												

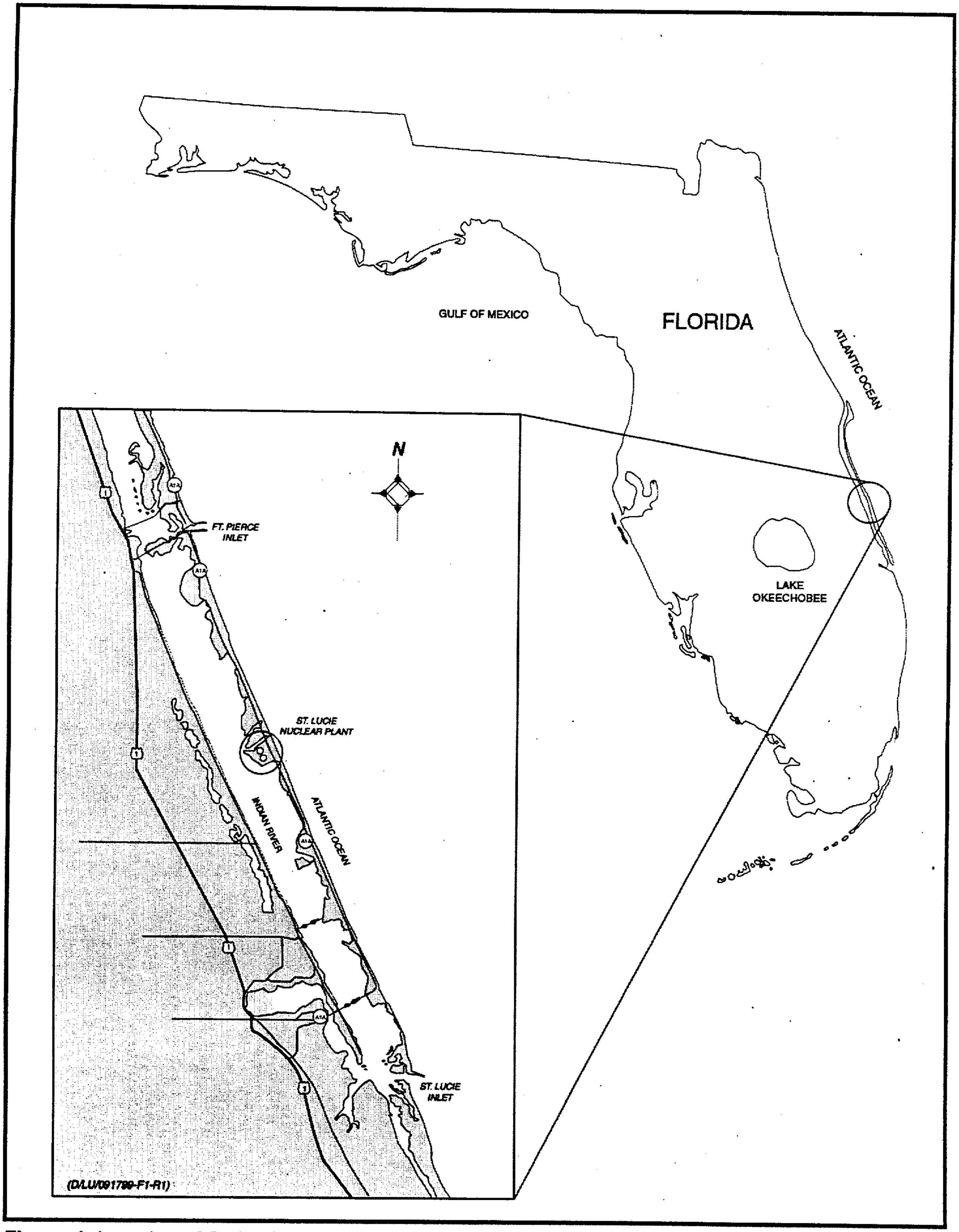


Figure 1. Location of St. Lucie Plant, Hutchinson Island, Florida.

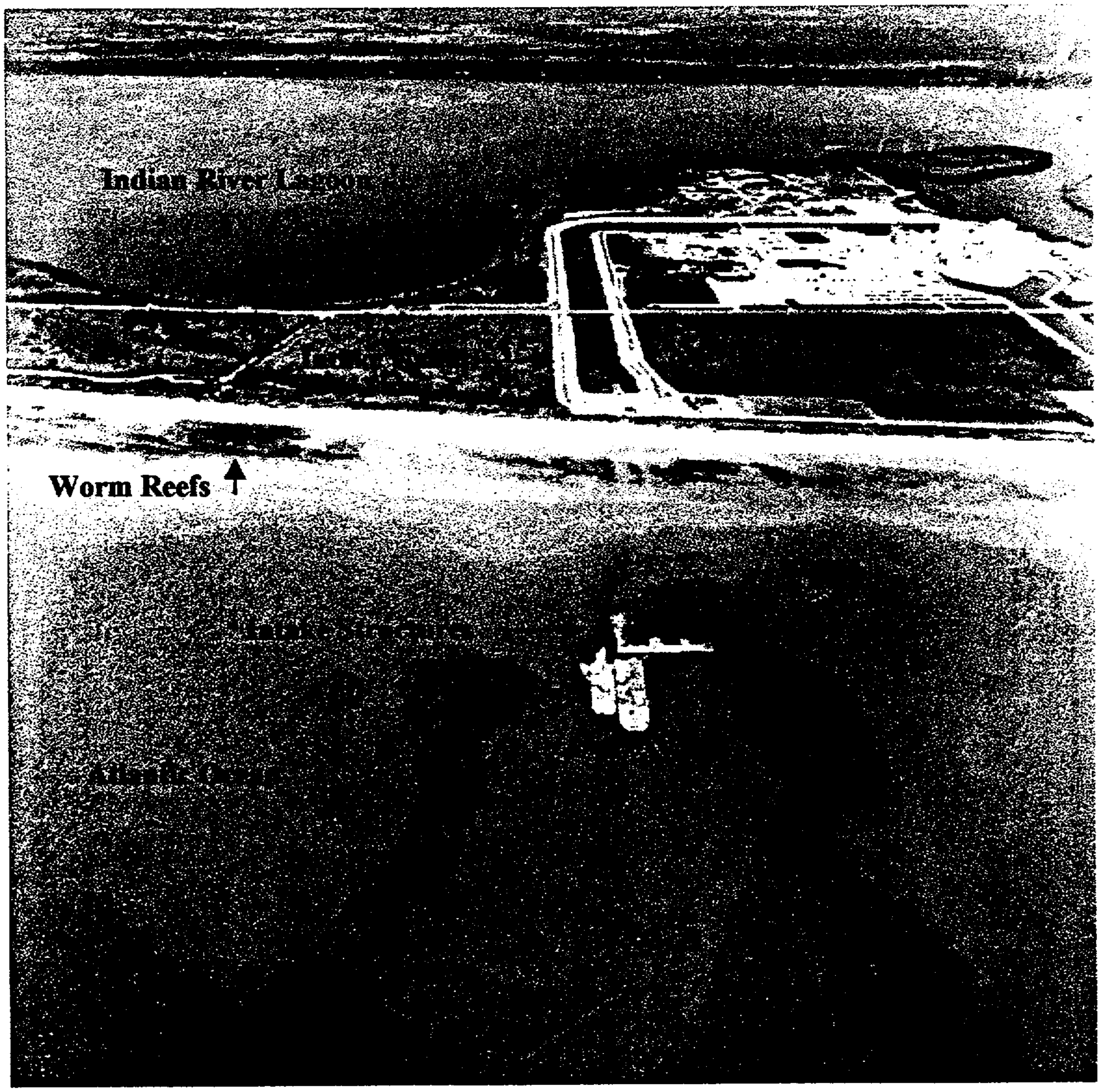


Figure 2. Aerial view of the St. Lucie Plant, Hutchinson Island, Florida. The above-water structures and barges in the vicinity of the intake structures were only present during velocity cap repairs during 1991 and 1992.

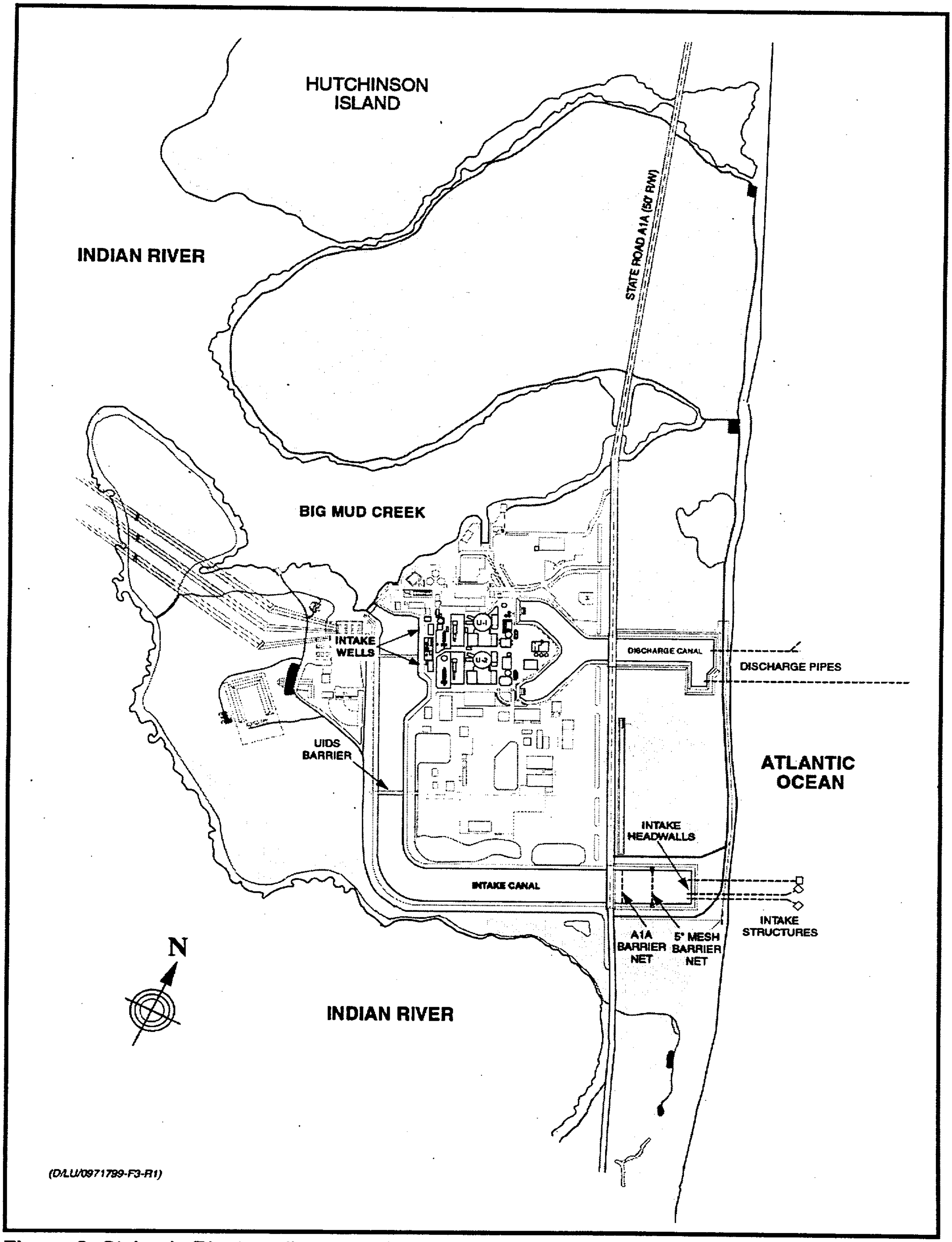


Figure 3. St. Lucie Plant cooling water intake and discharge system.

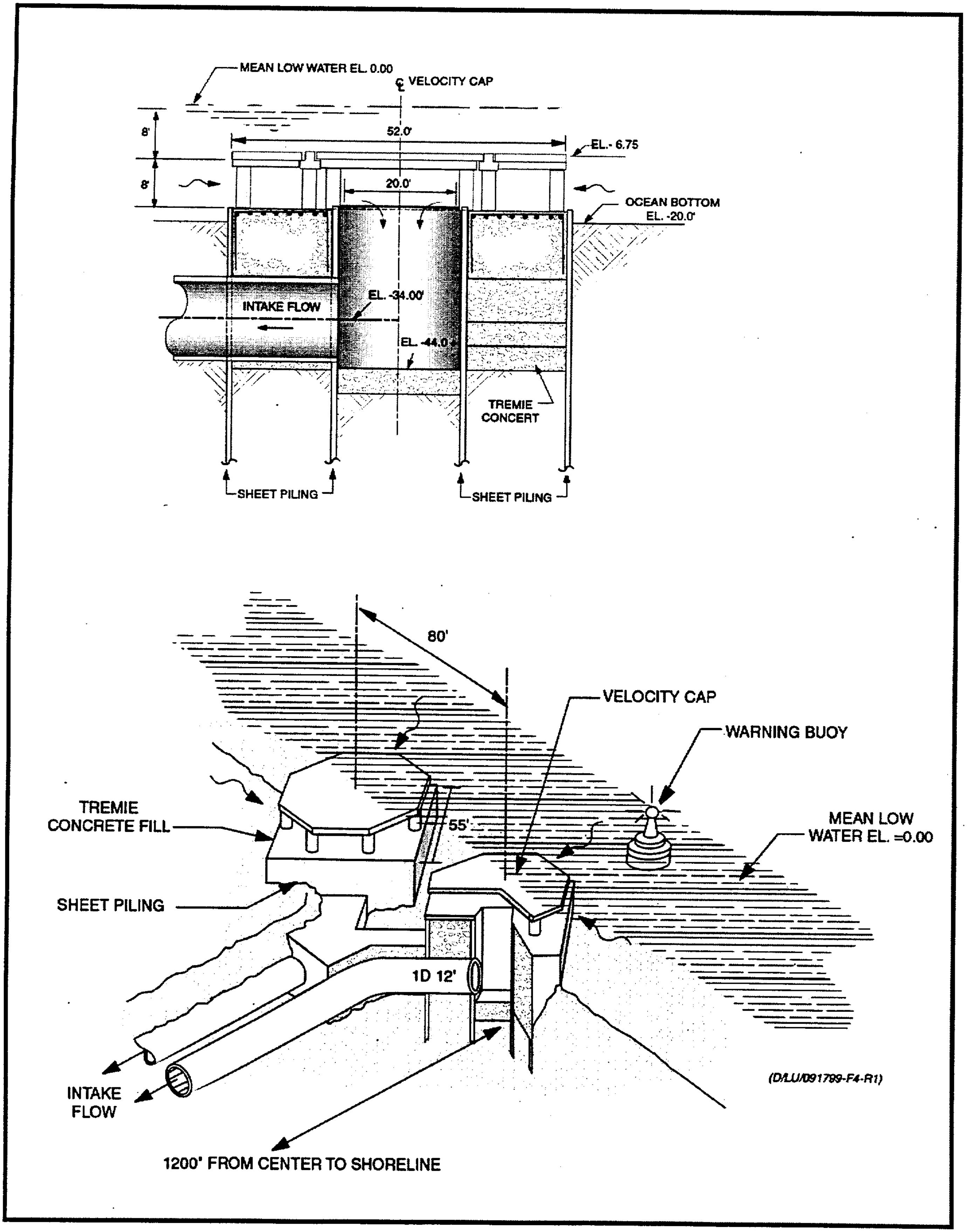


Figure 4. Configuration of the two 3.7-meter-diameter intake structures, St. Lucie Plant, Hutchinson Island, Florida.

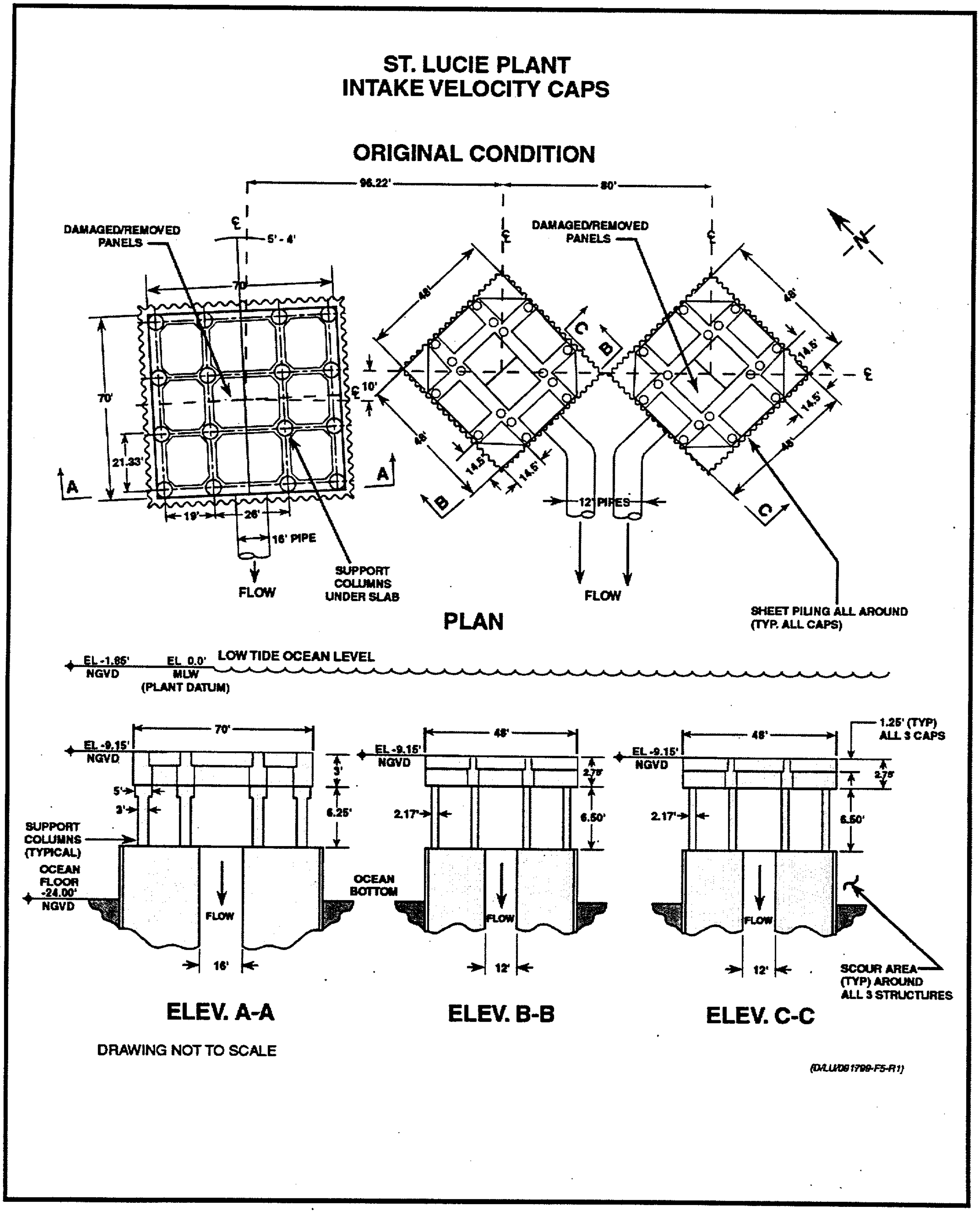


Figure 5. Diagram of the three intake structures located 1200 feet (365 m) offshore of the shoreline at the St. Lucie Plant, Hutchinson Island, Florida. Dimensions represent conditions prior to velocity cap repairs completed in February 1992.

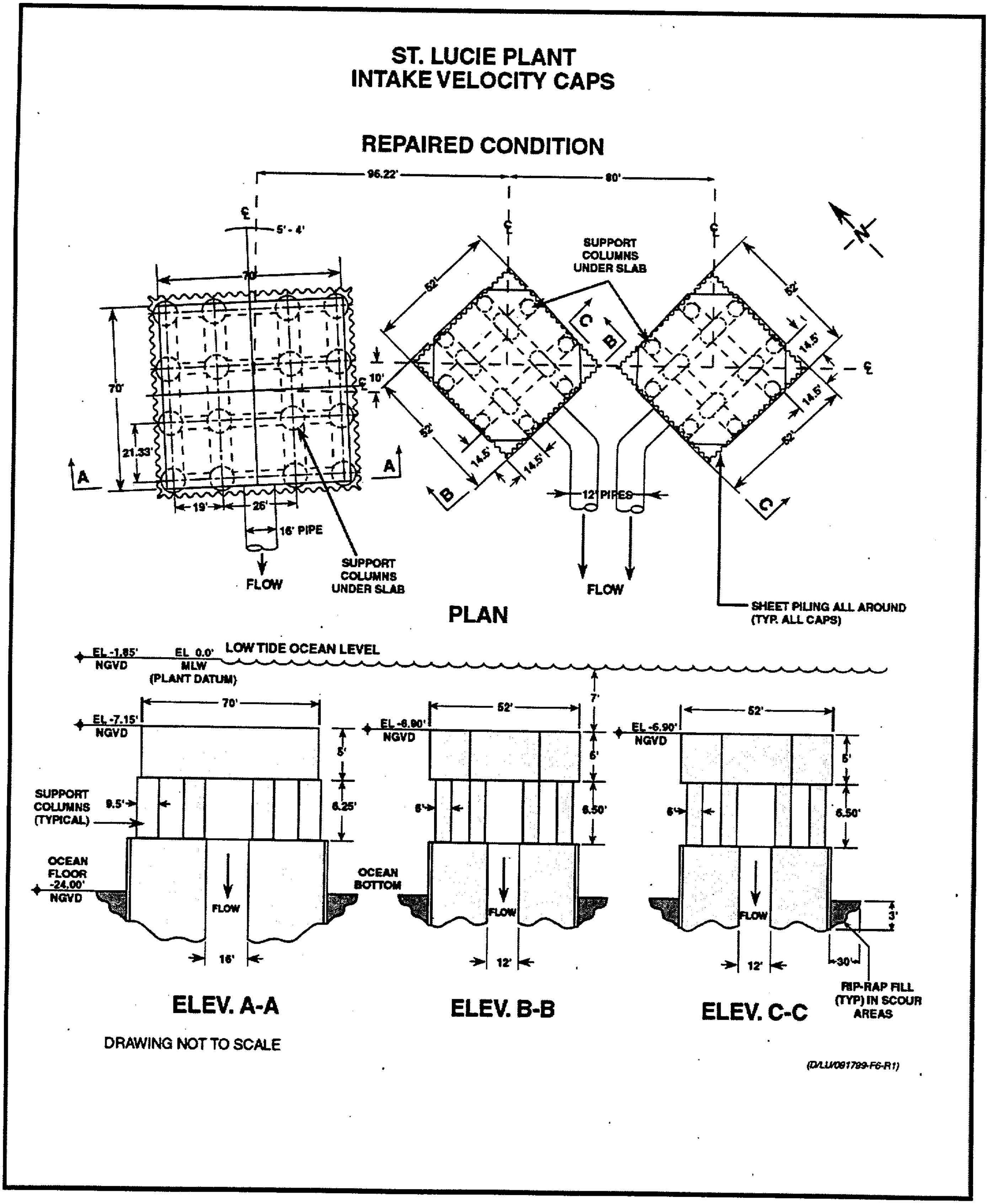


Figure 6. Diagram of the three intake structures located 1200 feet (365 m) offshore of the shoreline at the St. Lucie Plant, Hutchinson Island, Florida. Dimensions represent conditions after velocity cap repairs completed in February 1992.

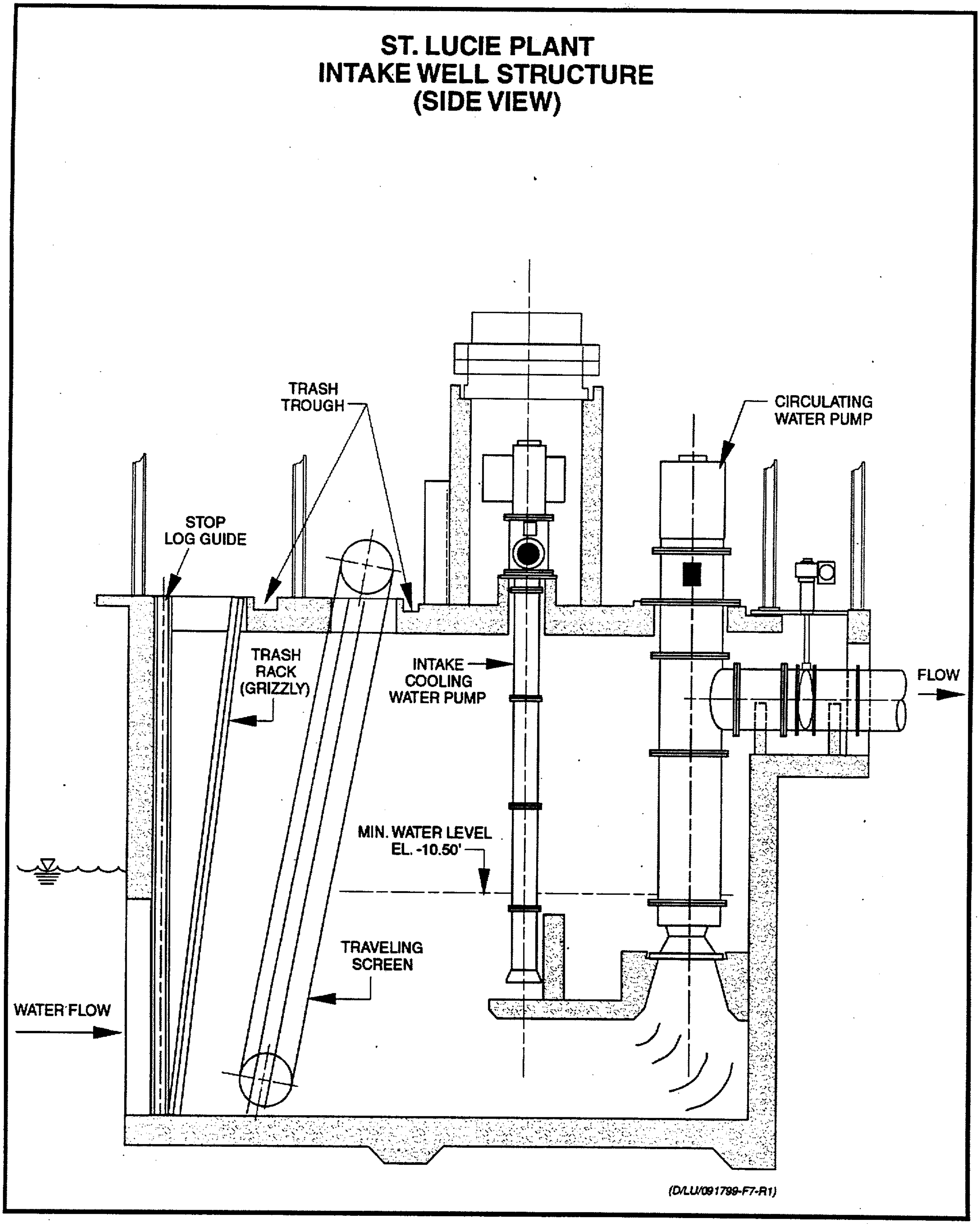


Figure 7. Diagram of an intake well at the St. Lucie Plant, Hutchinson Island, Florida.

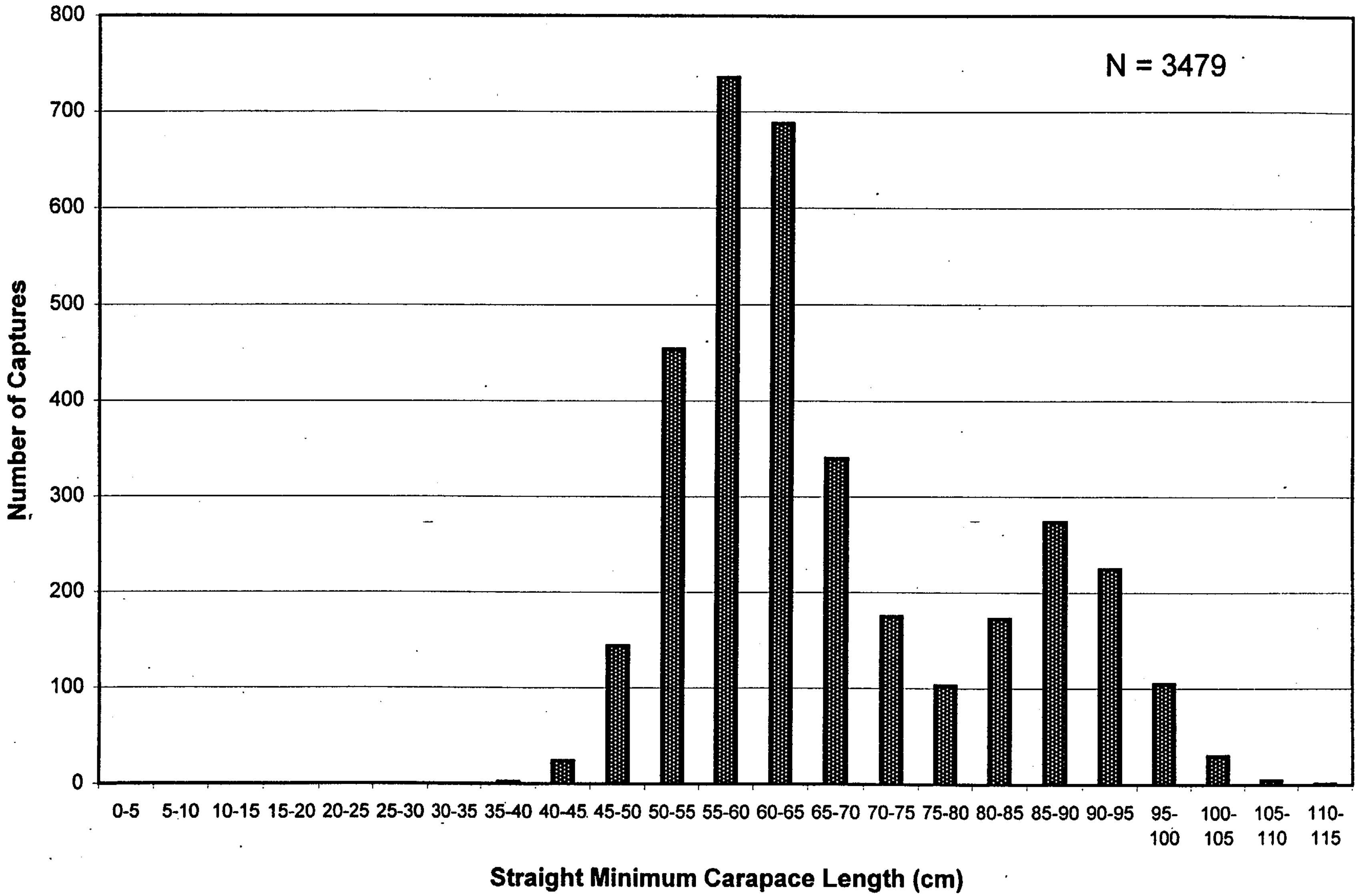


Figure 8. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

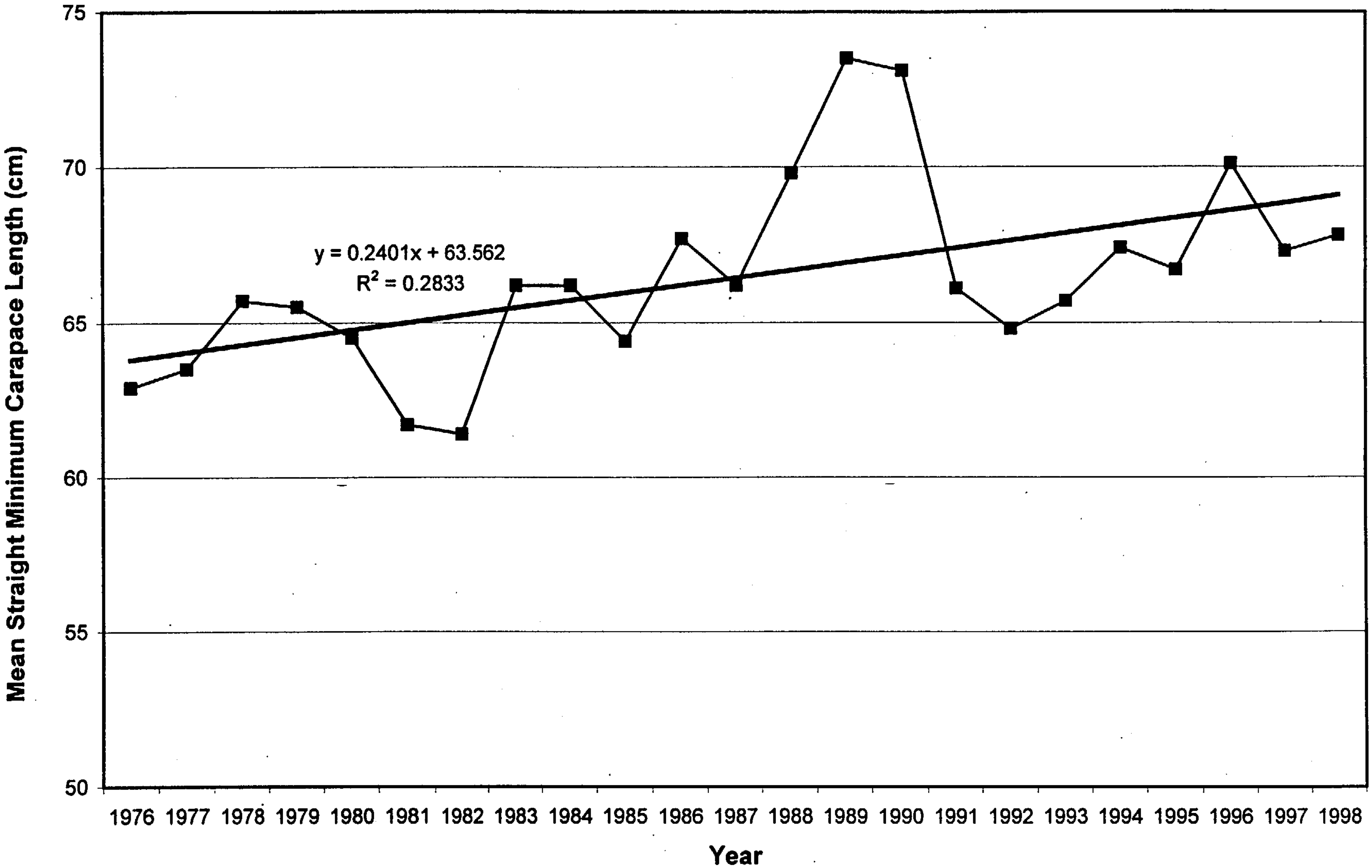


Figure 9. Mean size (straight minimum carapace length) of all loggerhead turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

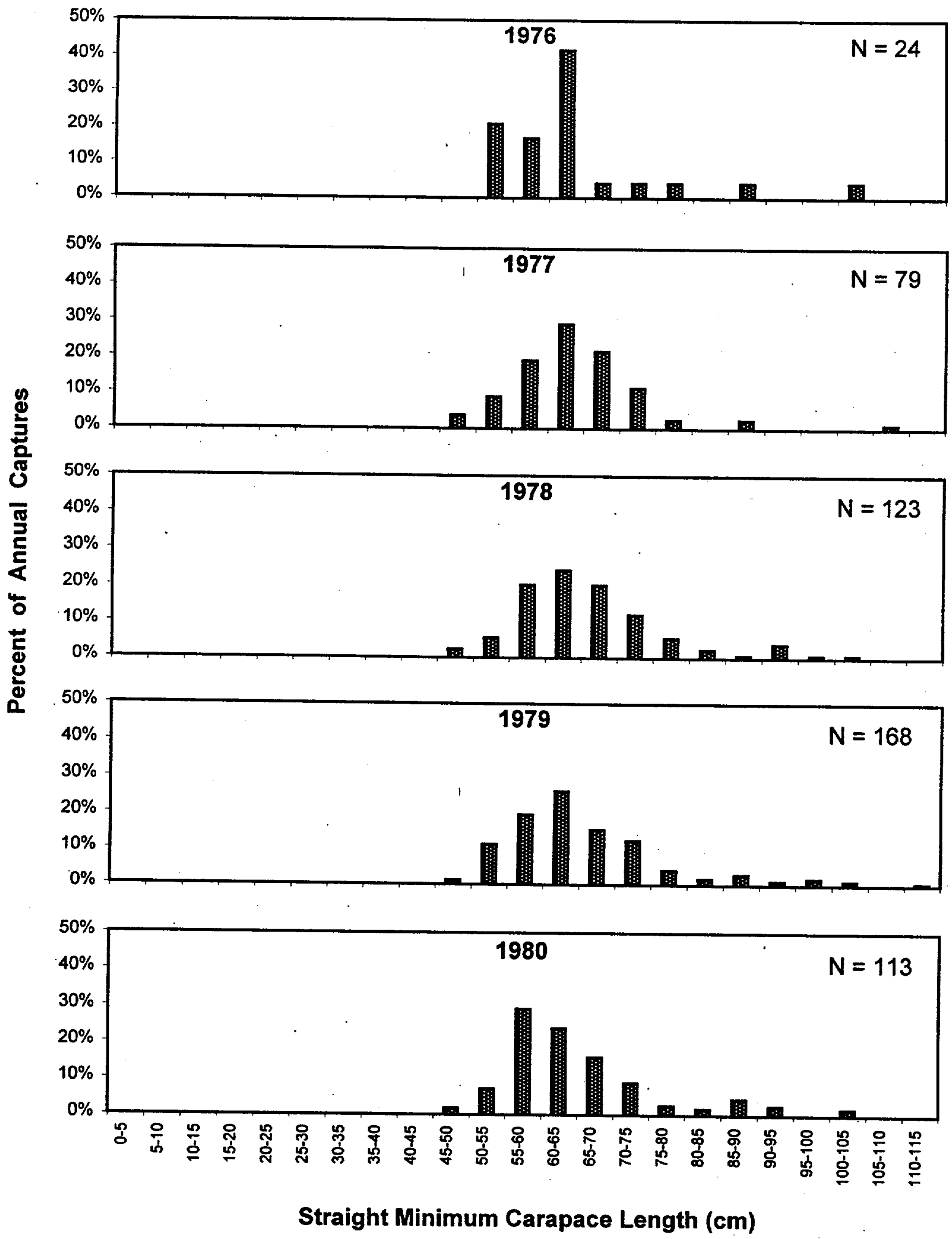


Figure 10. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1980.

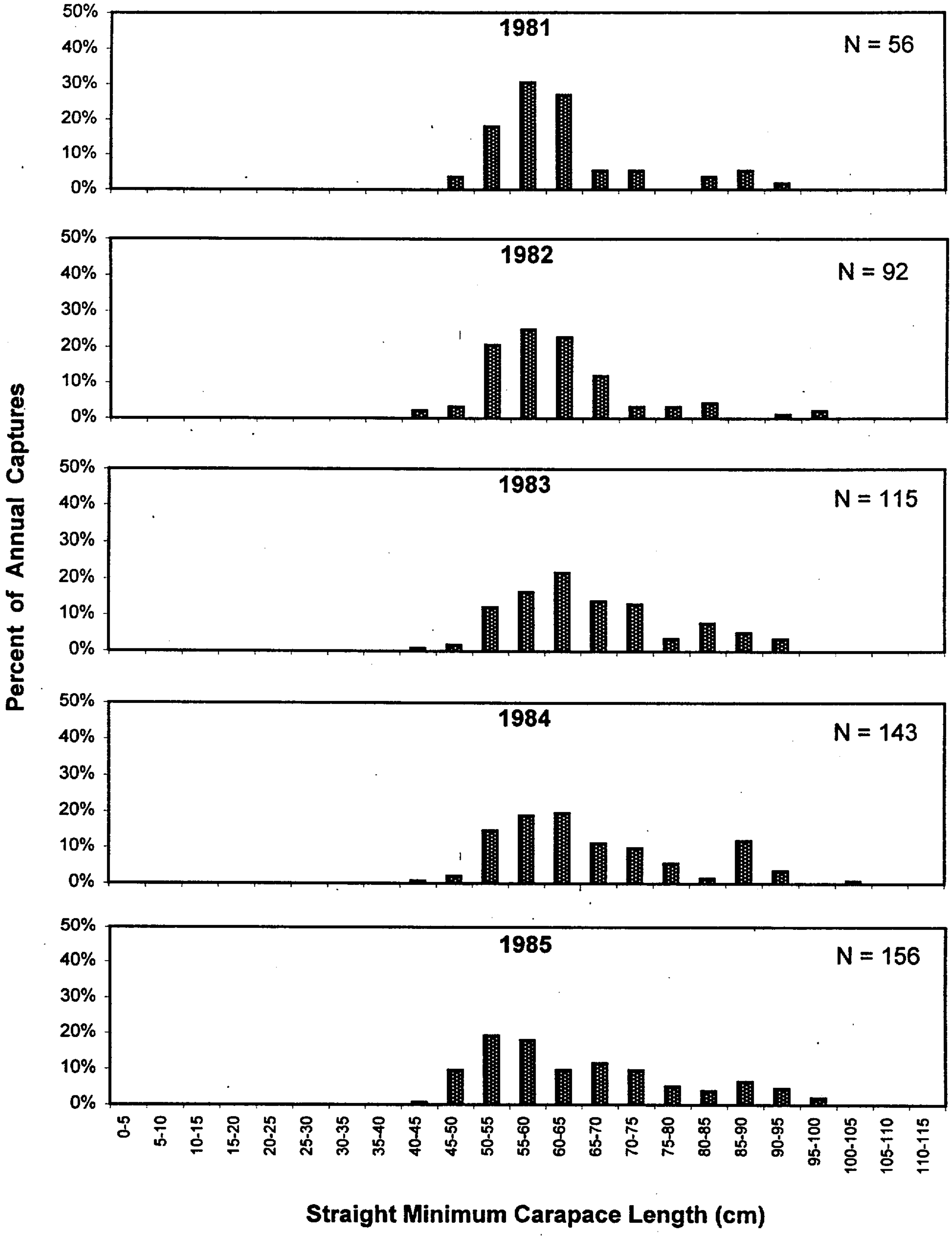


Figure 11. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1981-1985.

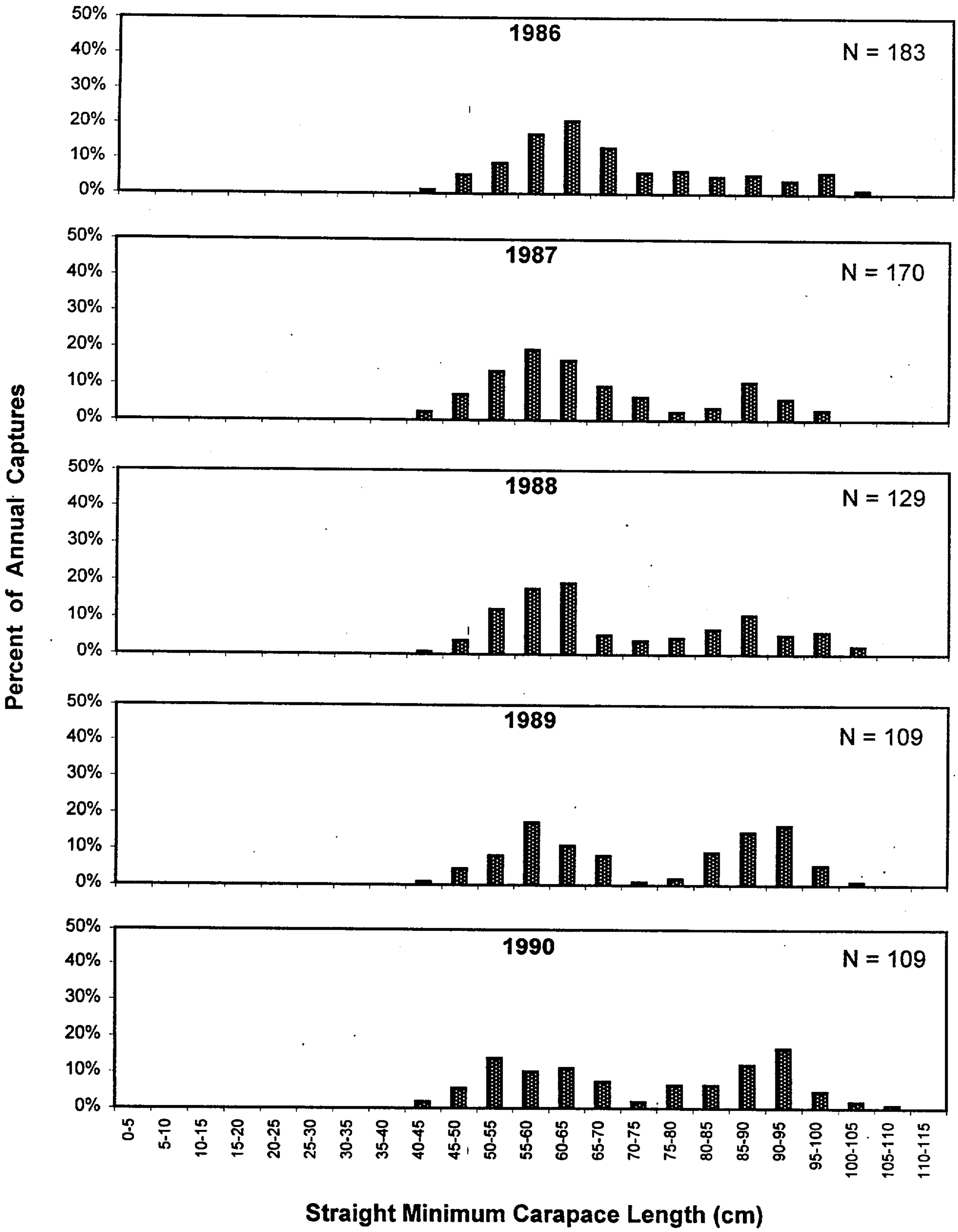


Figure 12. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1986-1990.

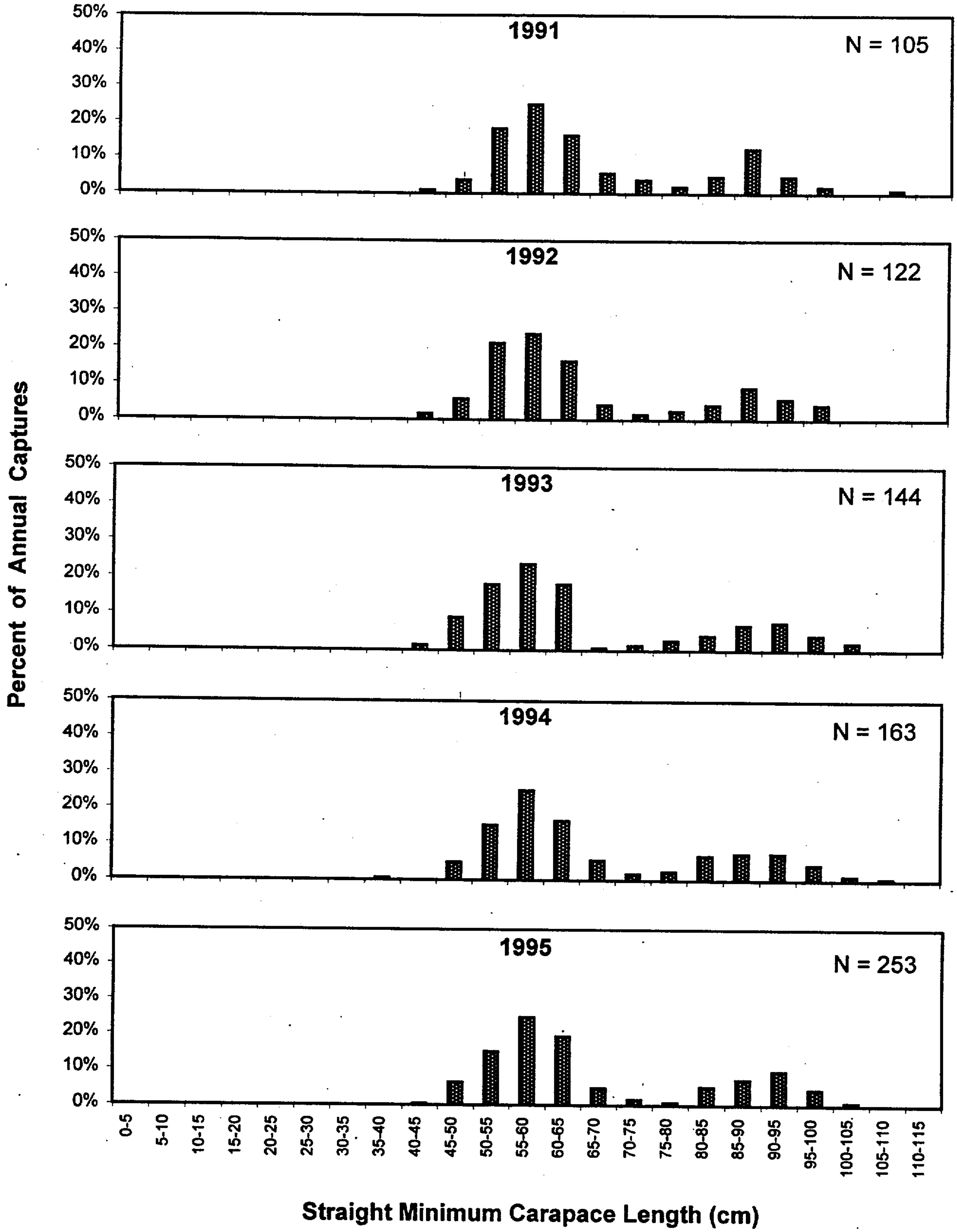


Figure 13. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1991-1995.

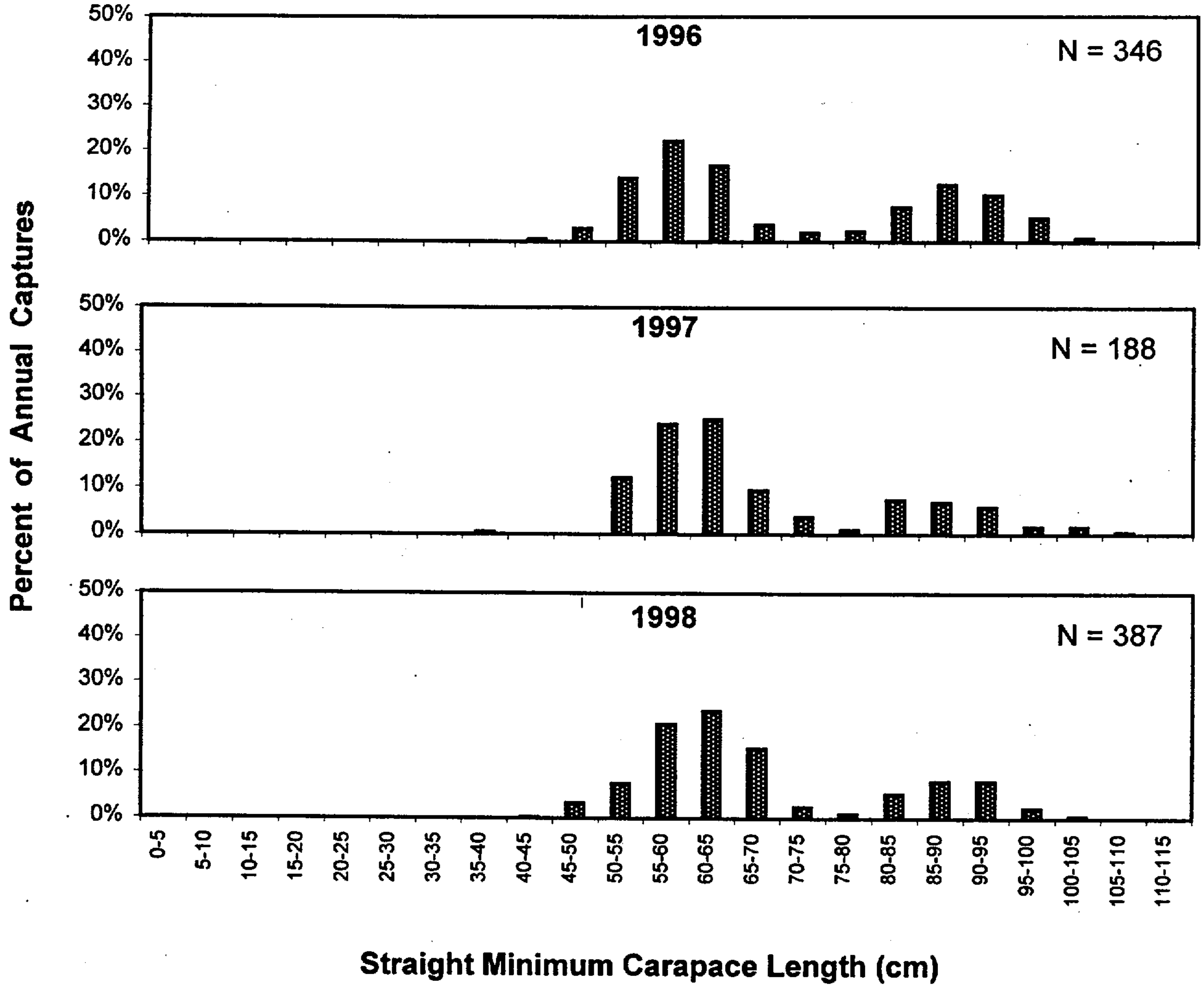


Figure 14. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1996-1998.

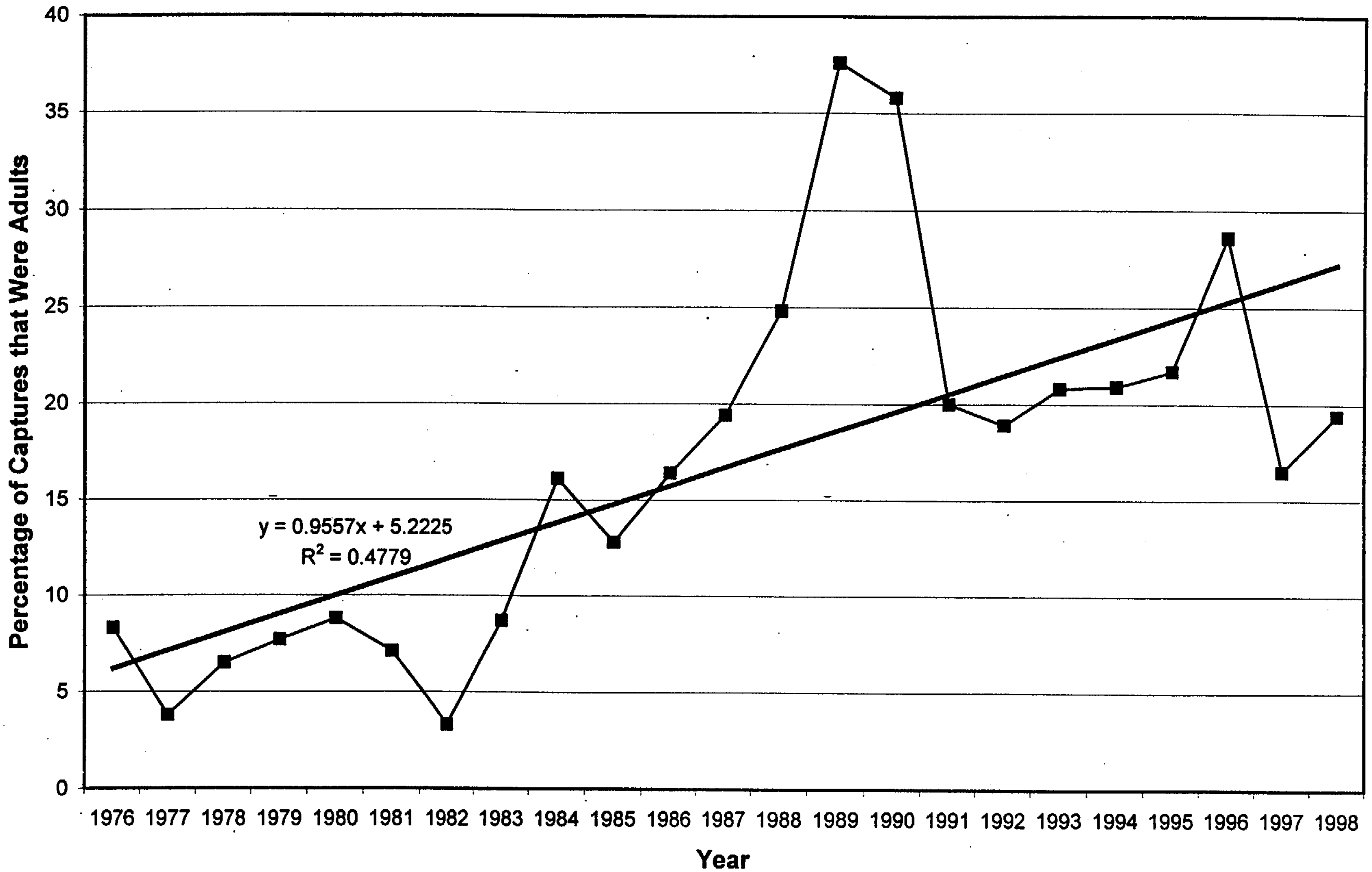


Figure 15. Percentage of annual loggerhead captures that were adults, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

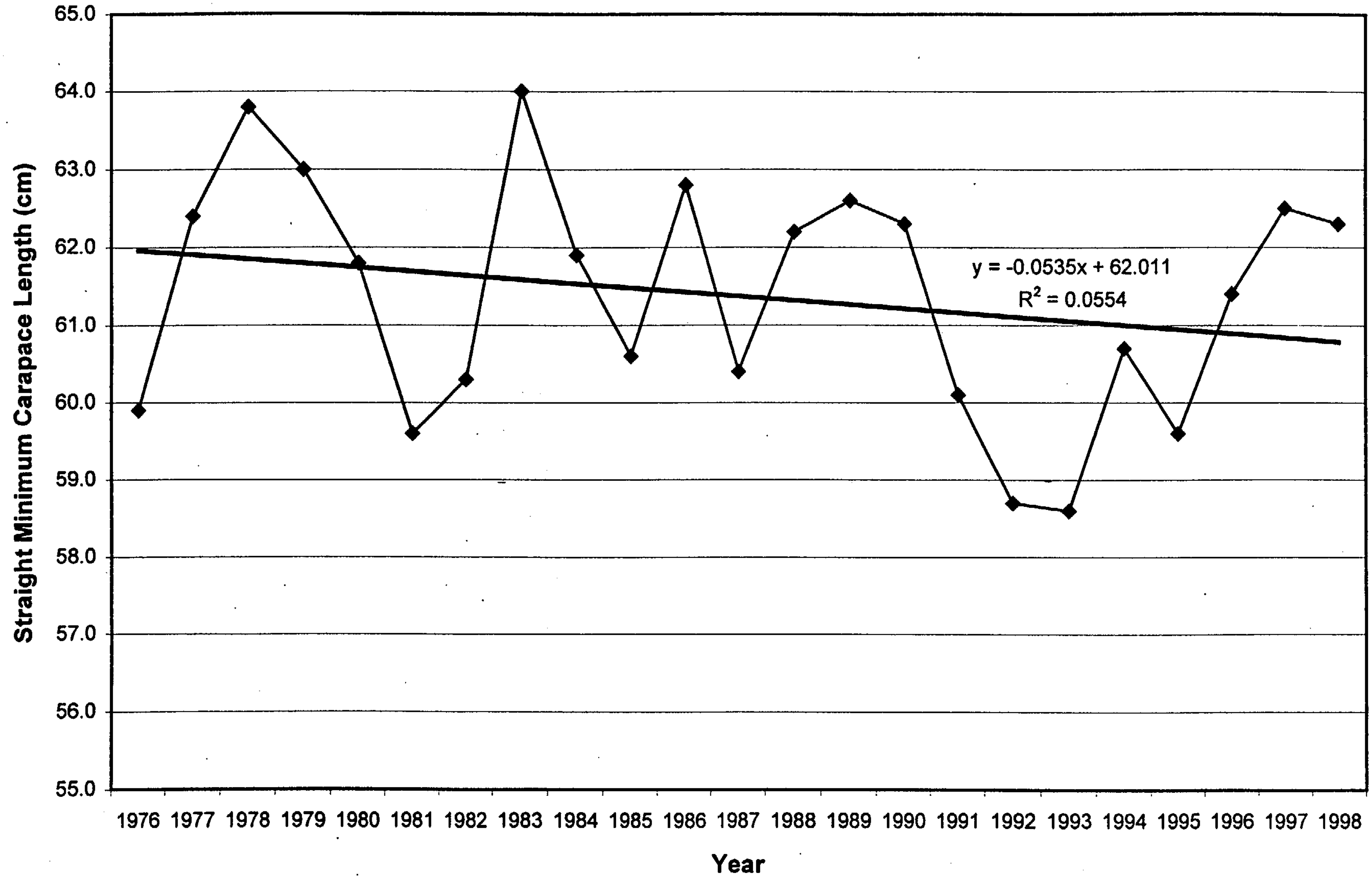


Figure 16. Mean size (straight minimum carapace length) of immature loggerhead turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

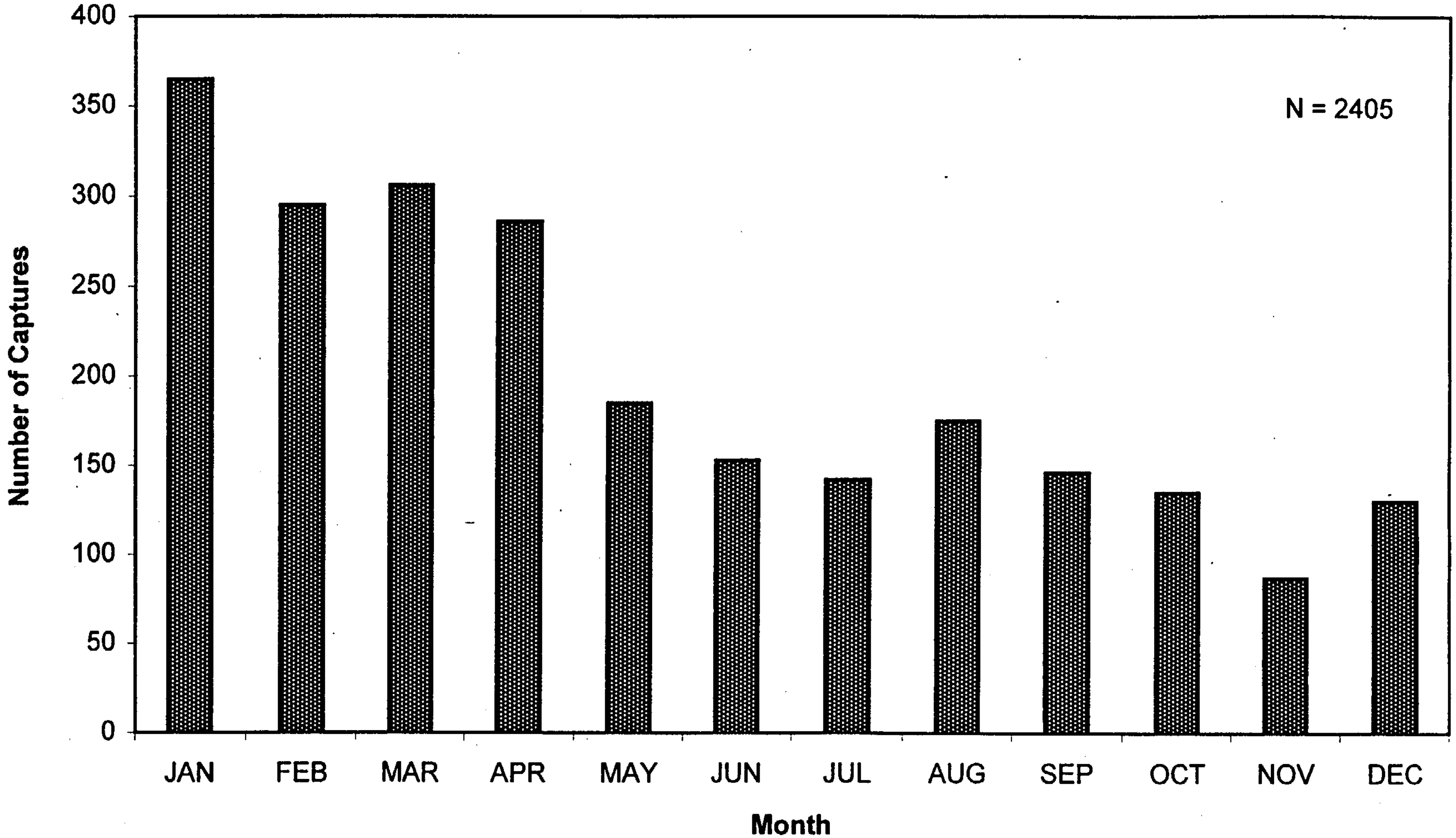


Figure 17. Number of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

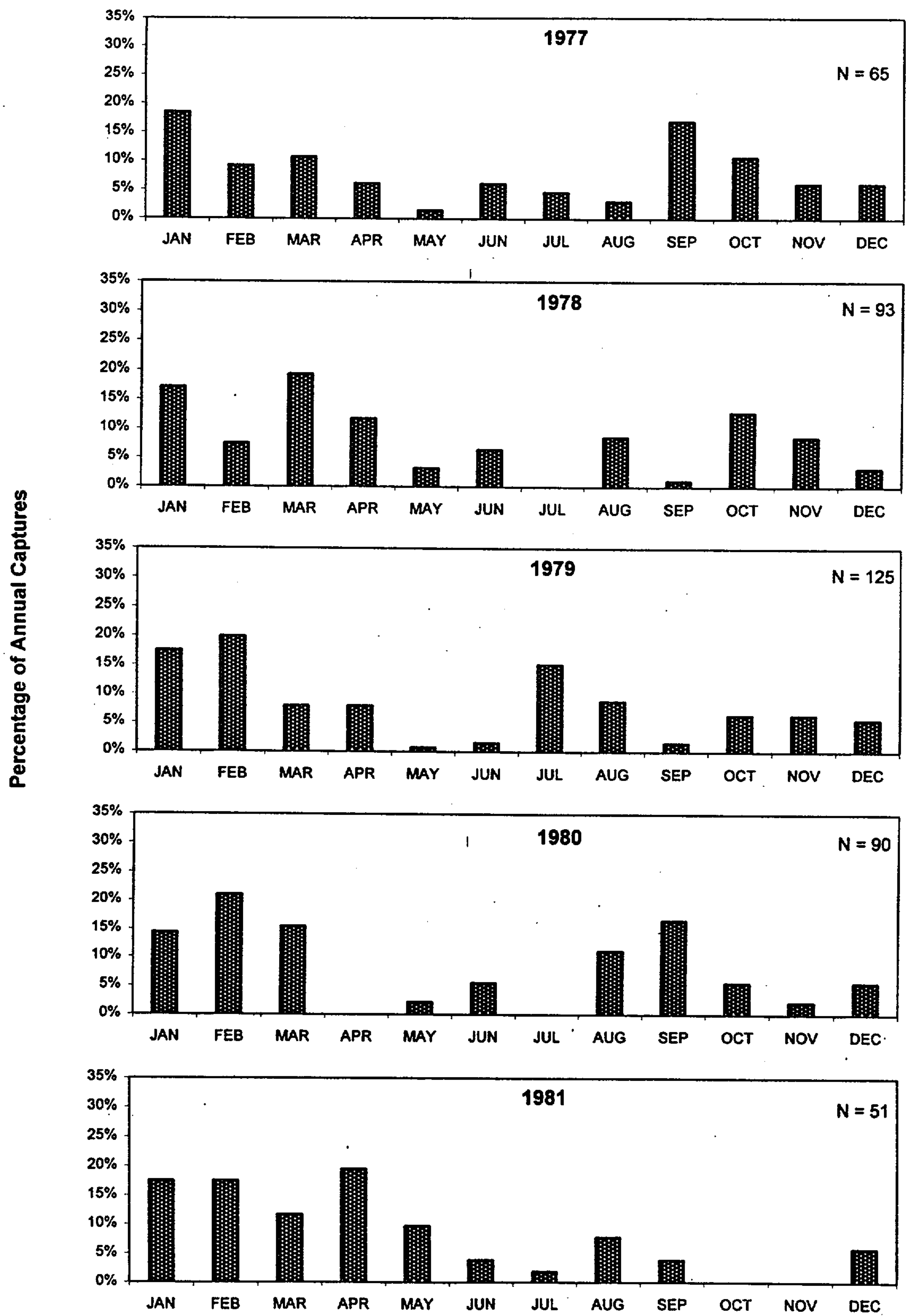


Figure 18. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

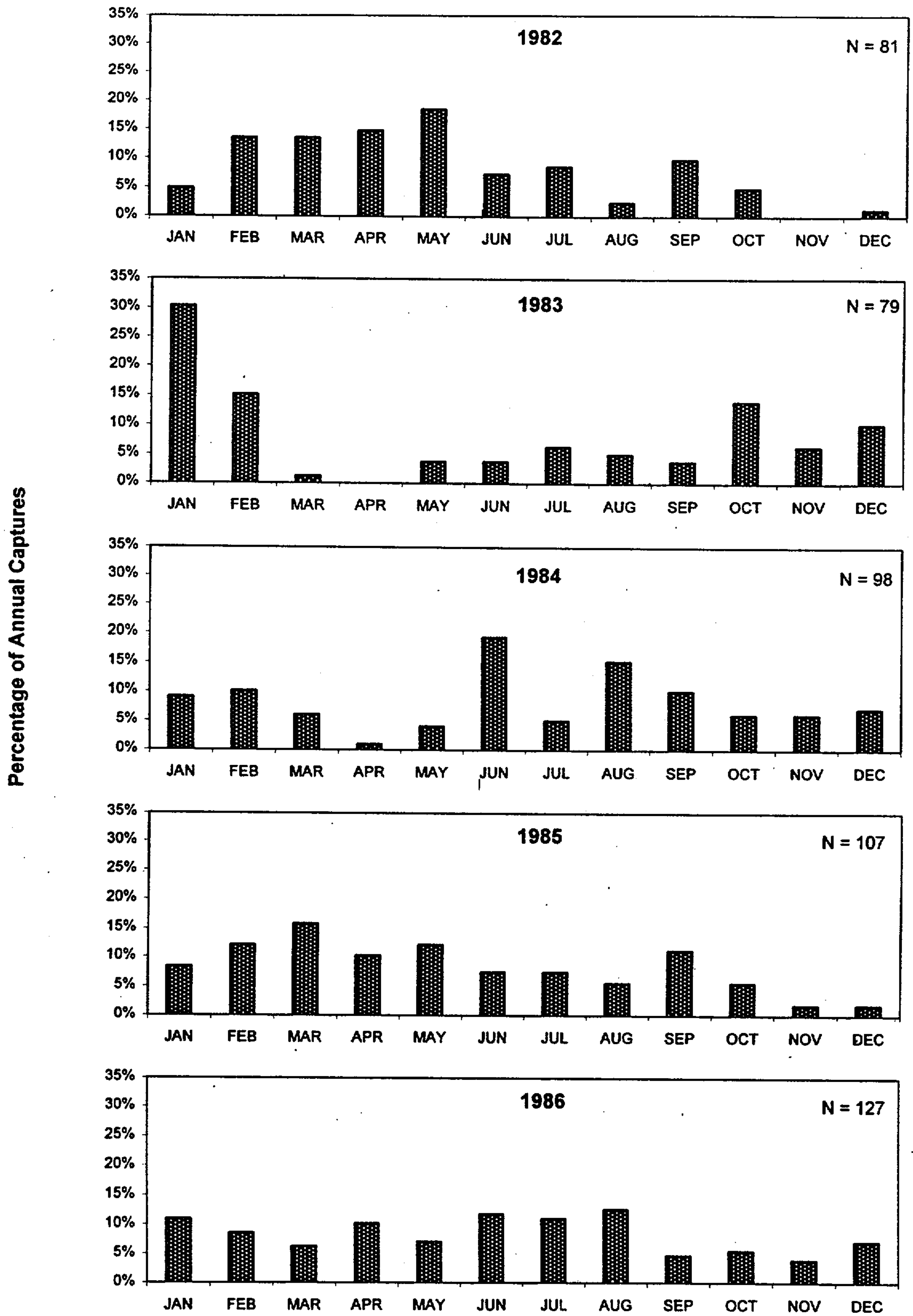


Figure 19. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

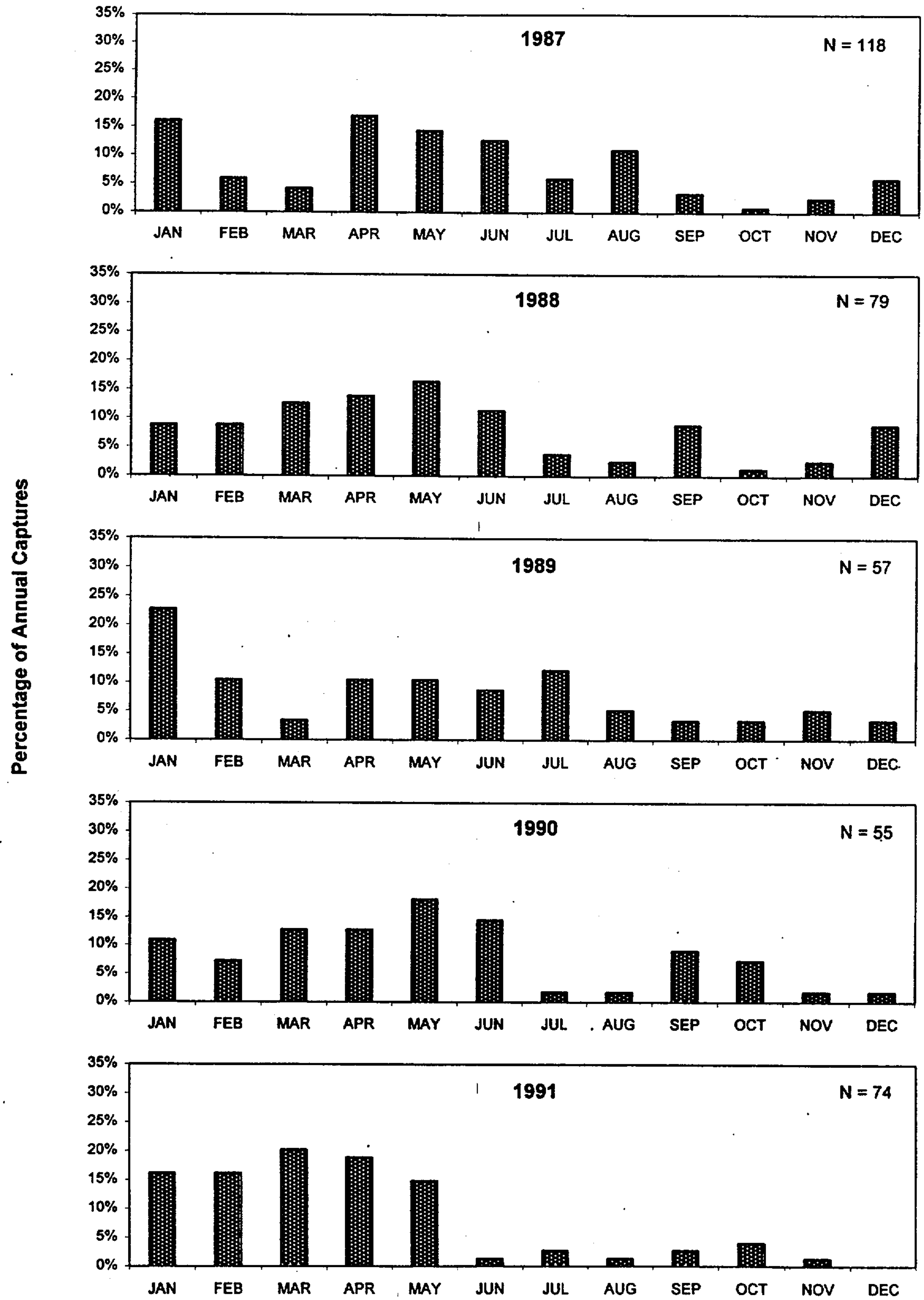


Figure 20. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

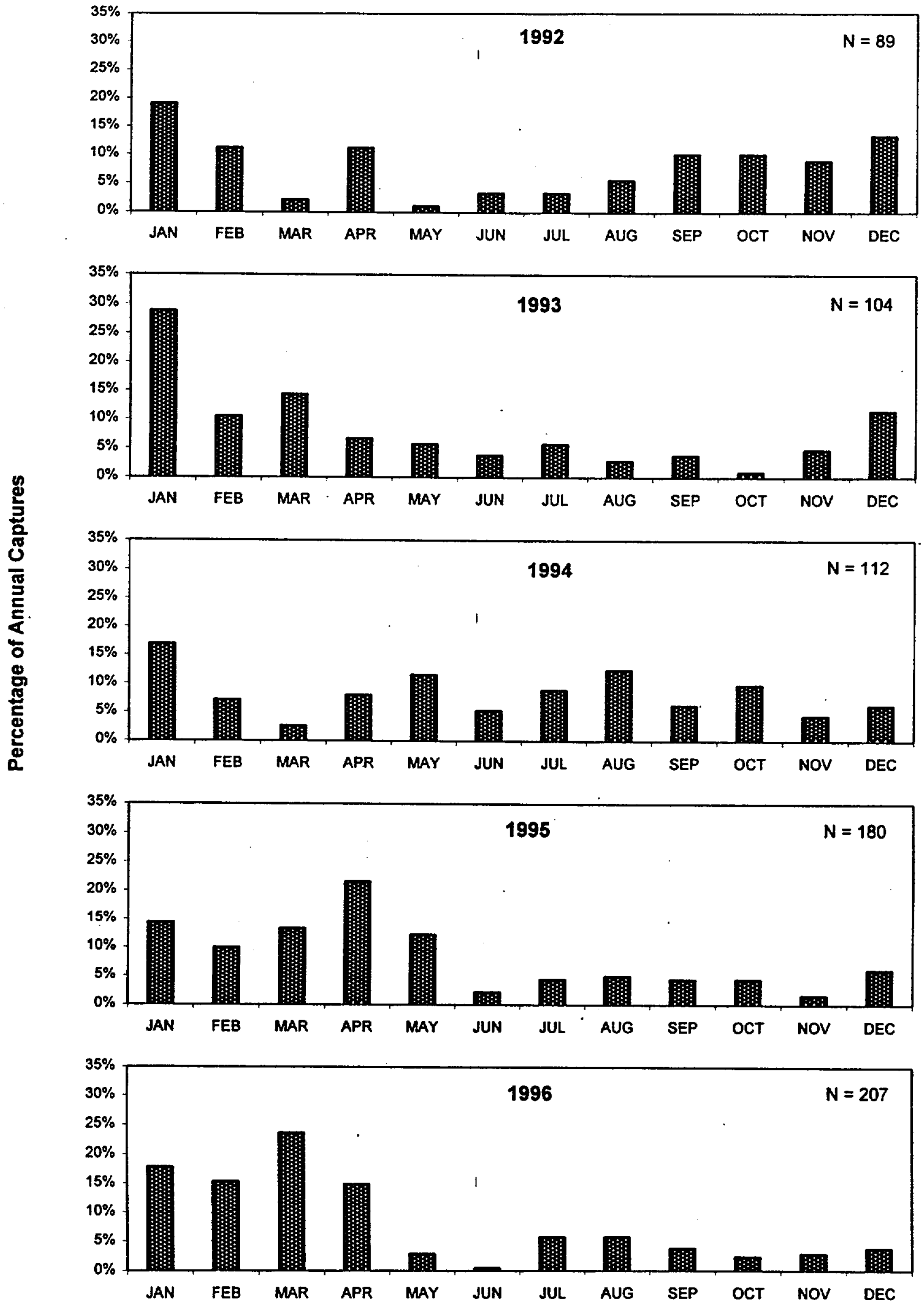


Figure 21. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

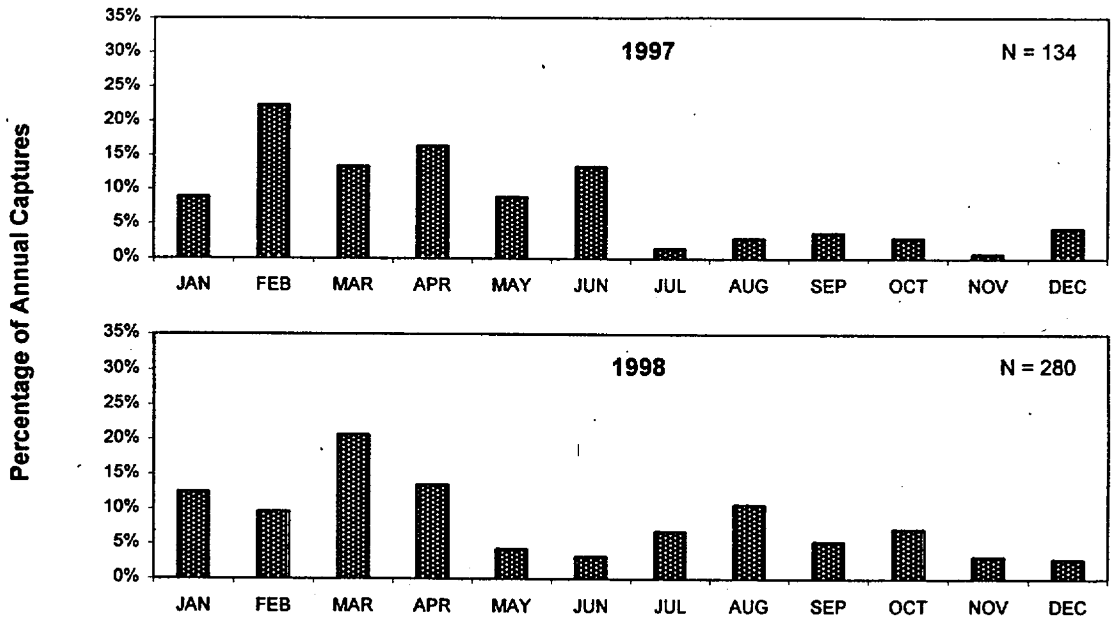


Figure 22. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

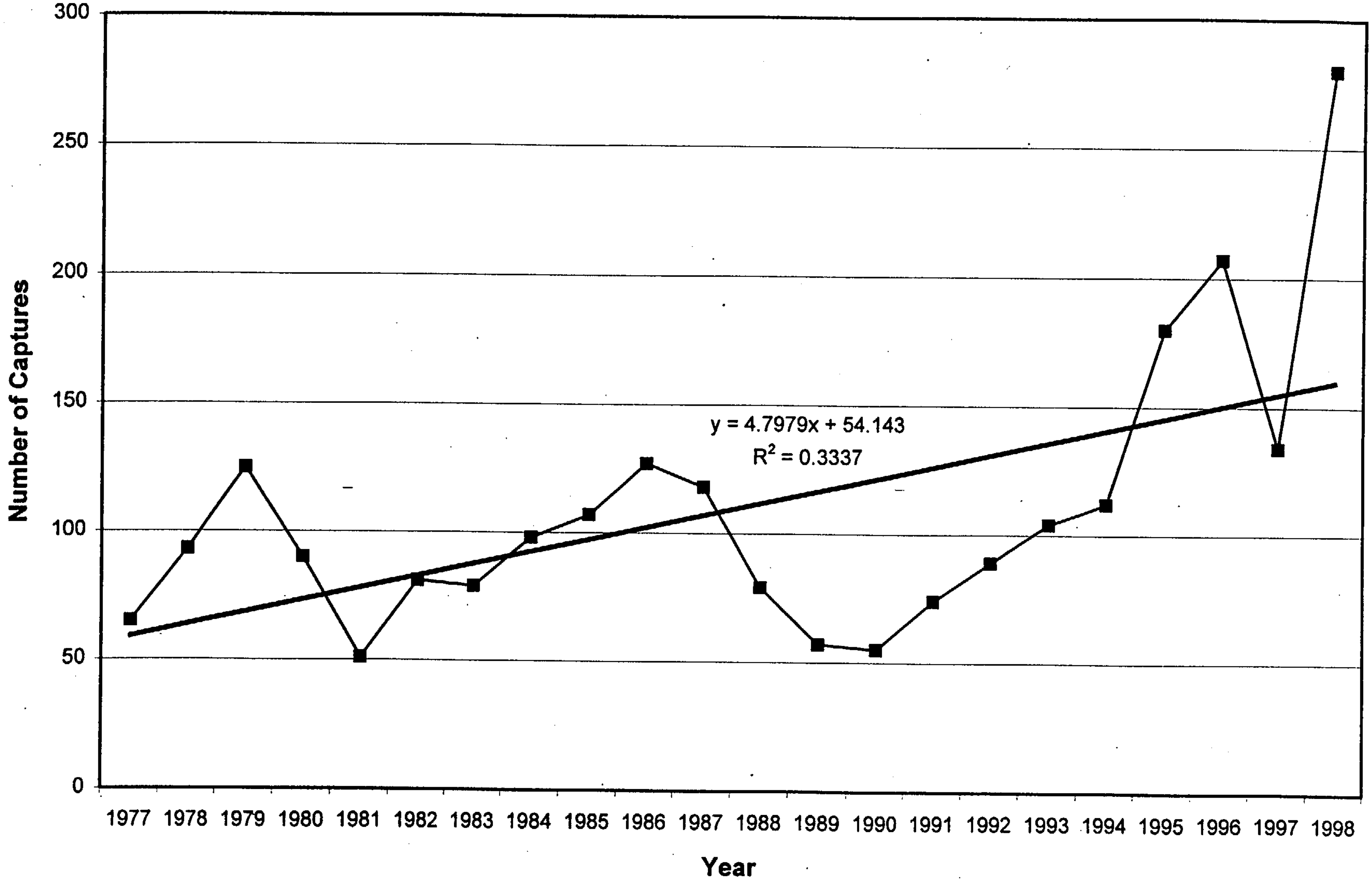


Figure 23. Annual number of juvenile loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

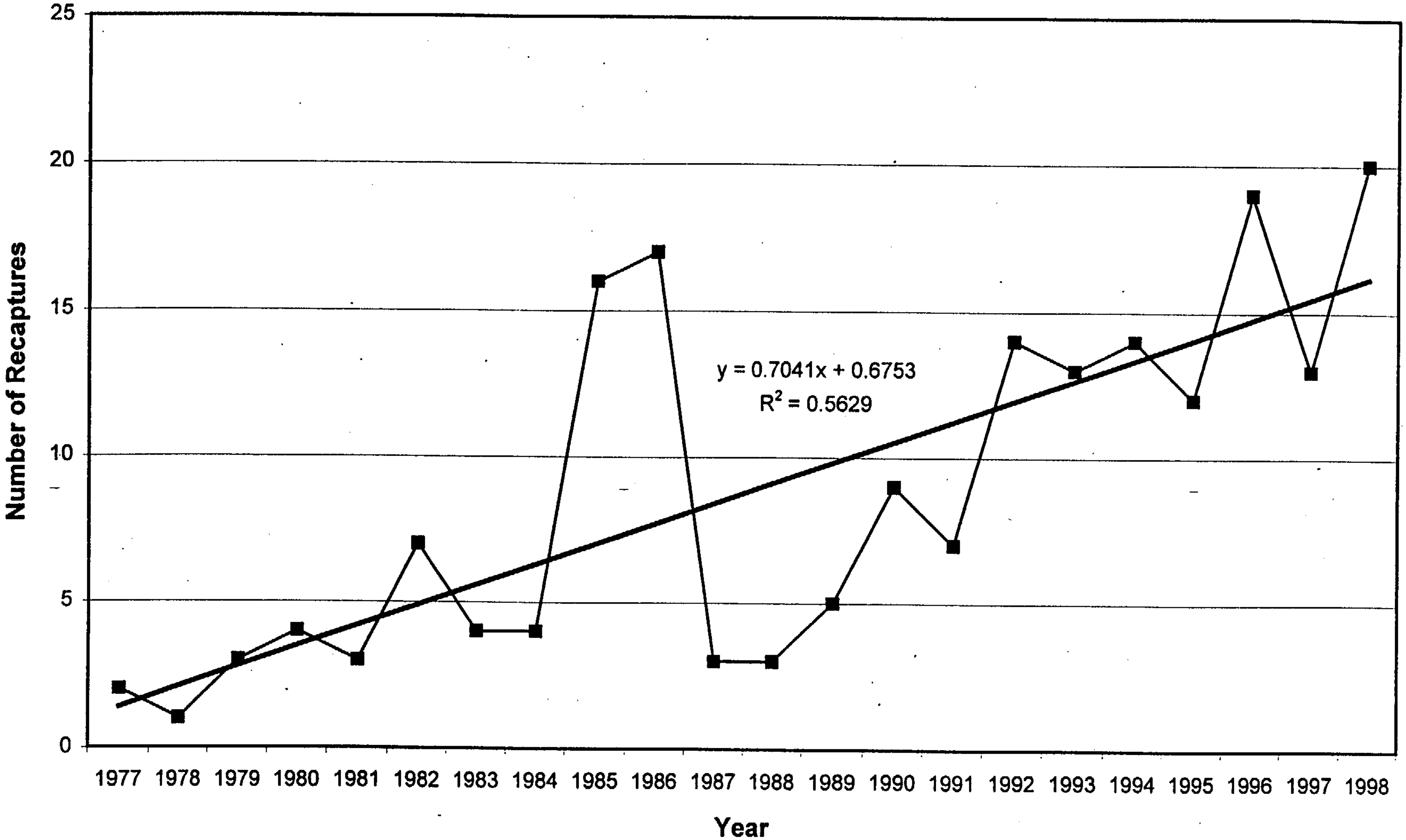


Figure 24. Annual number of juvenile loggerhead recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

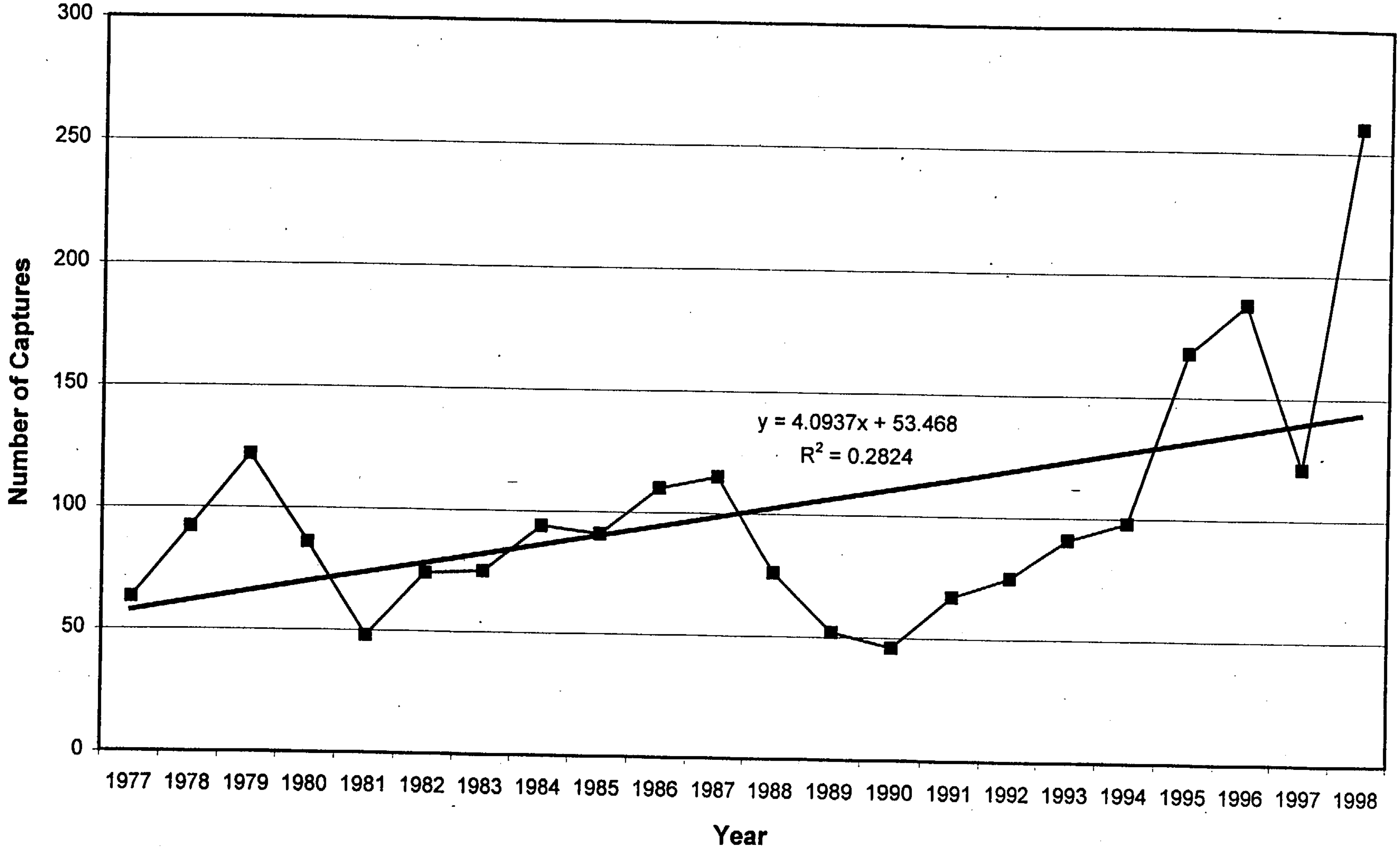


Figure 25. Annual number of juvenile loggerhead captures excluding recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

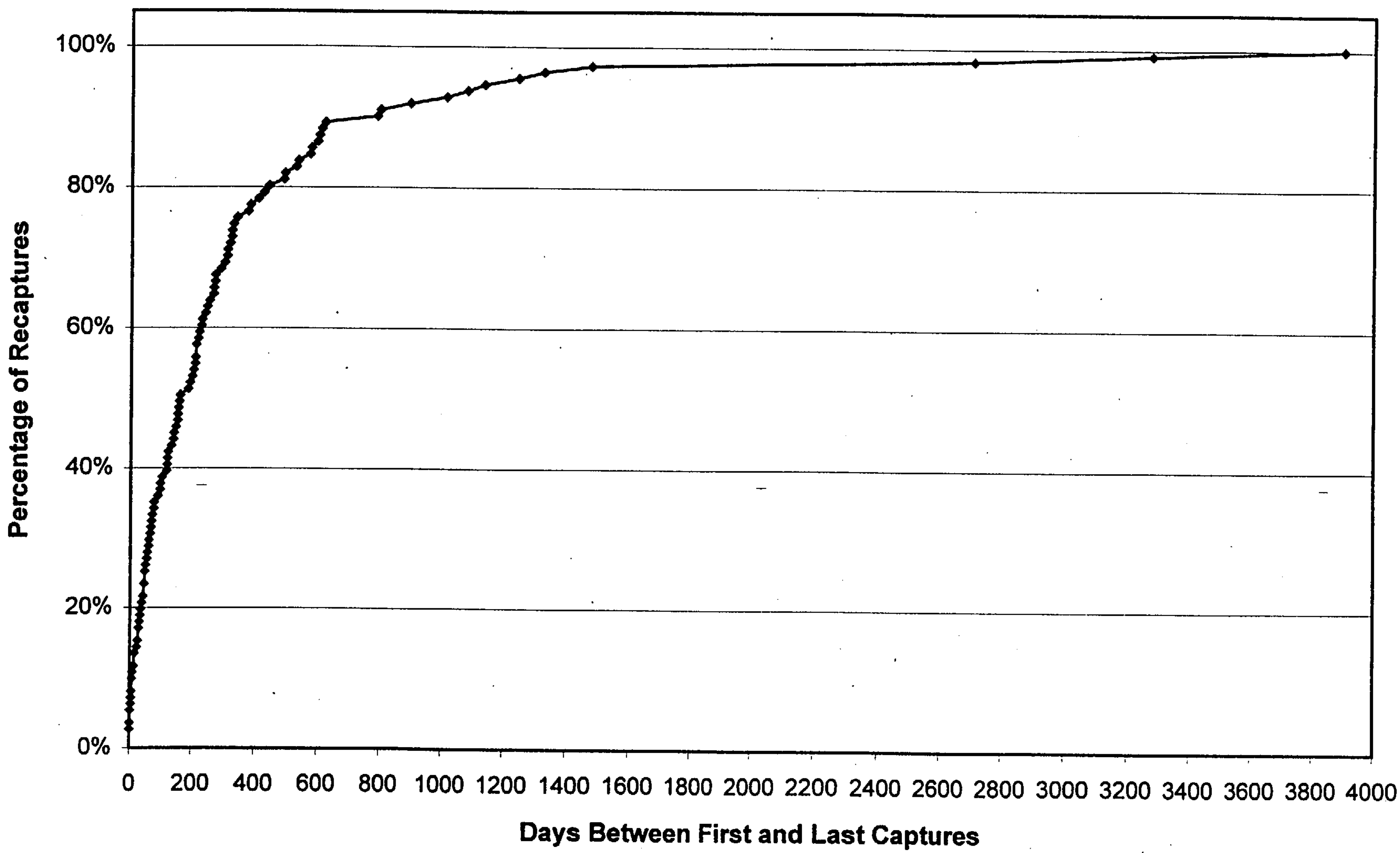


Figure 26. The percentage of juvenile loggerhead recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

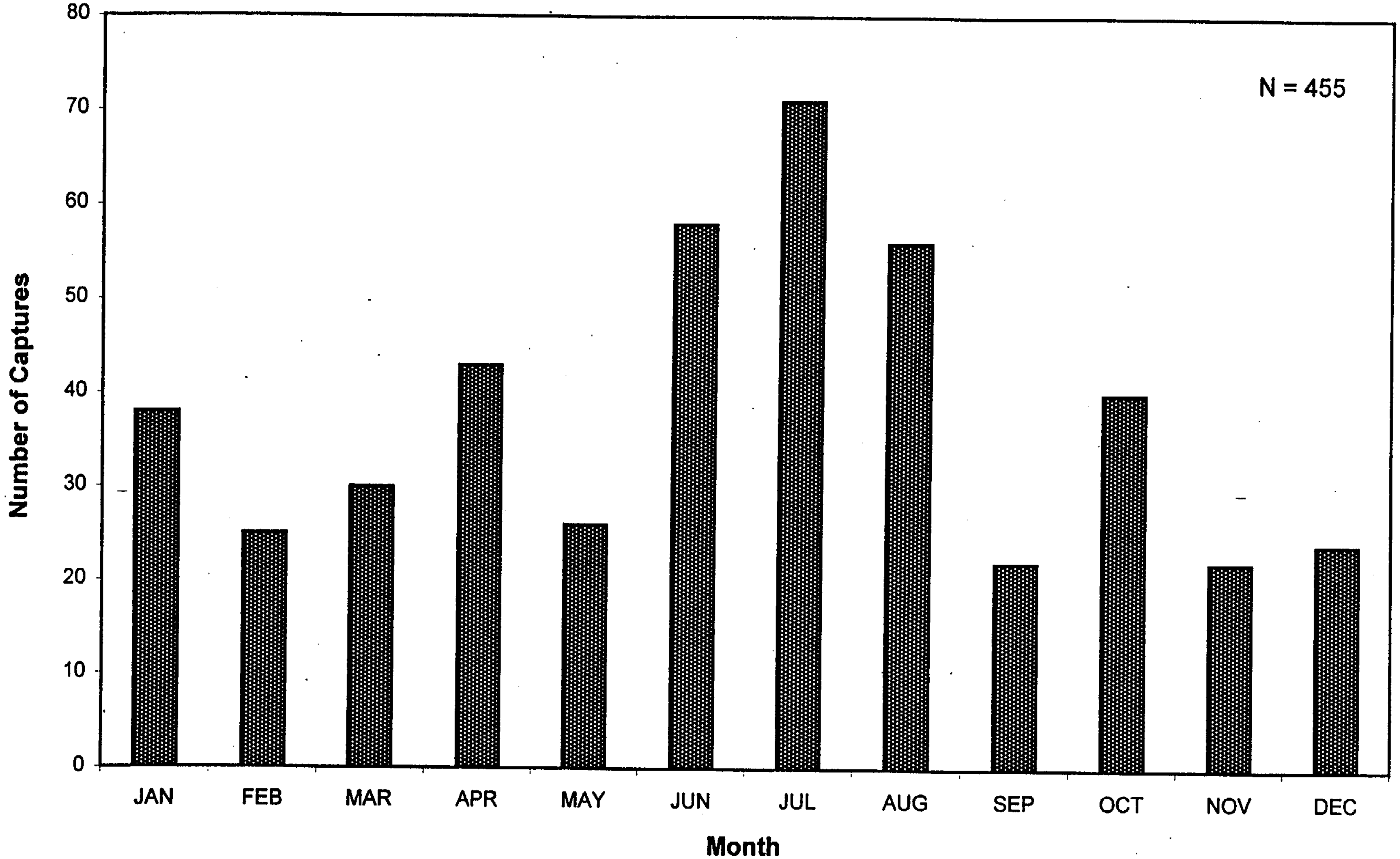


Figure 27. Number of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

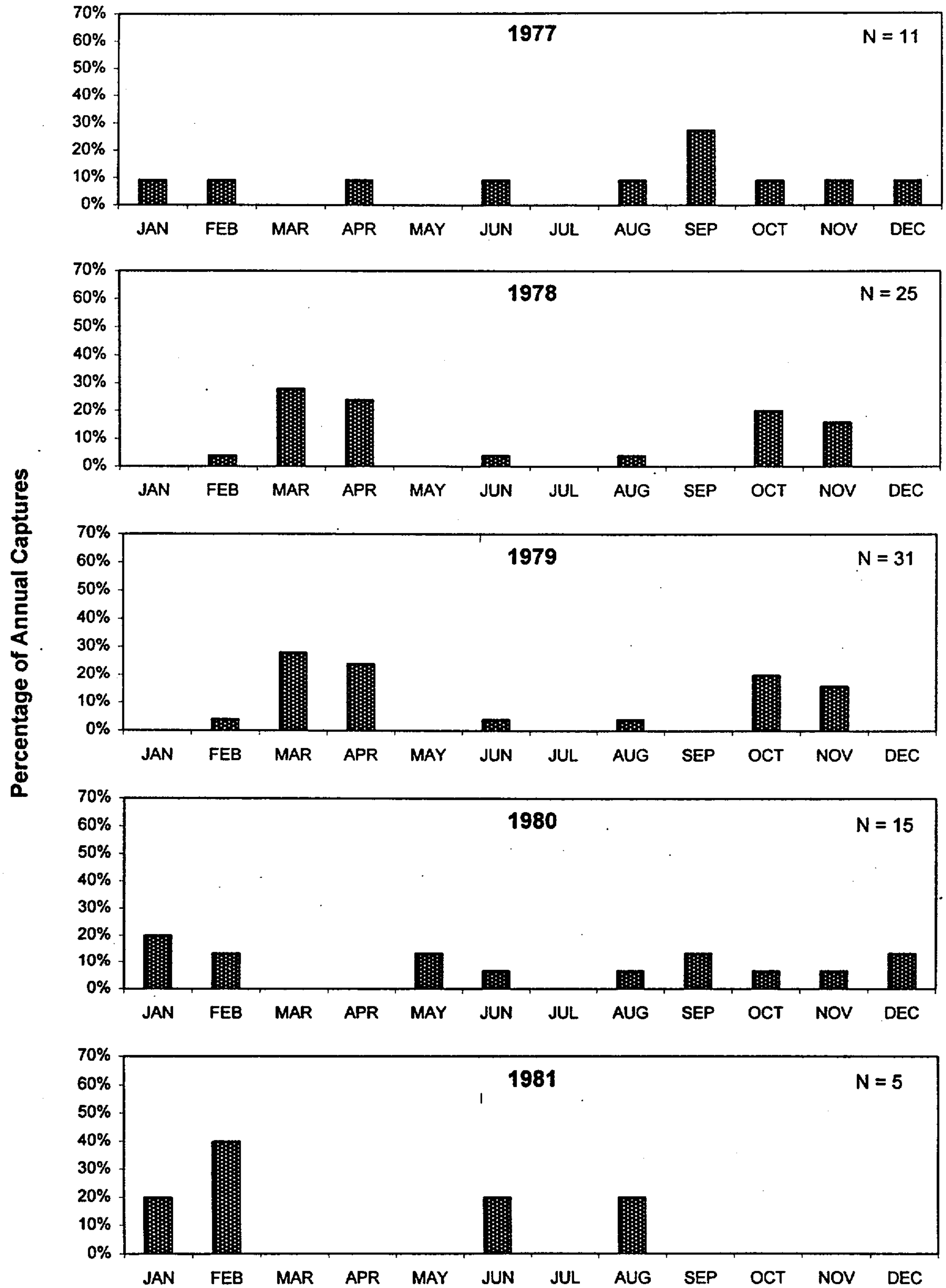


Figure 28. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

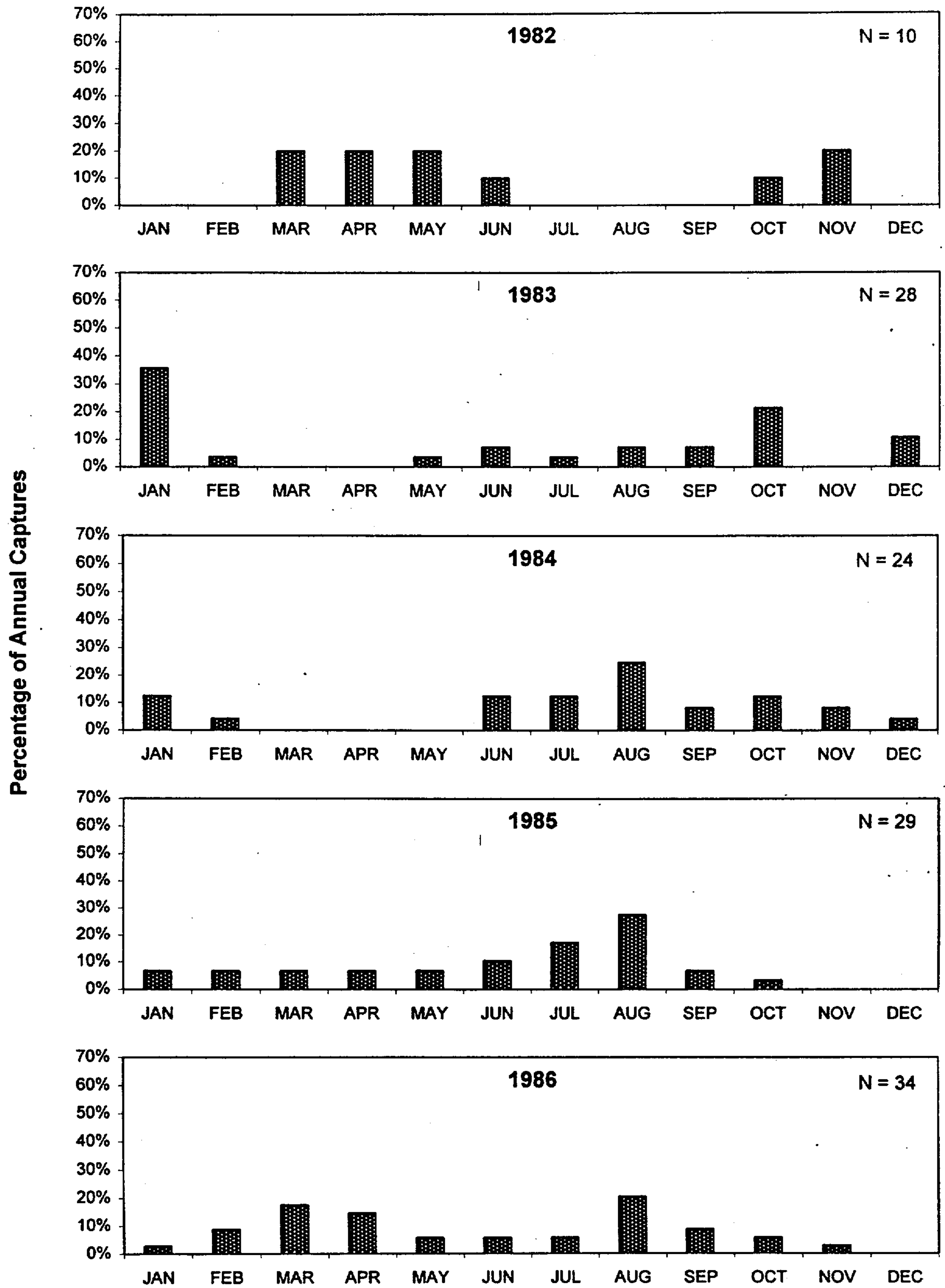


Figure 29. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

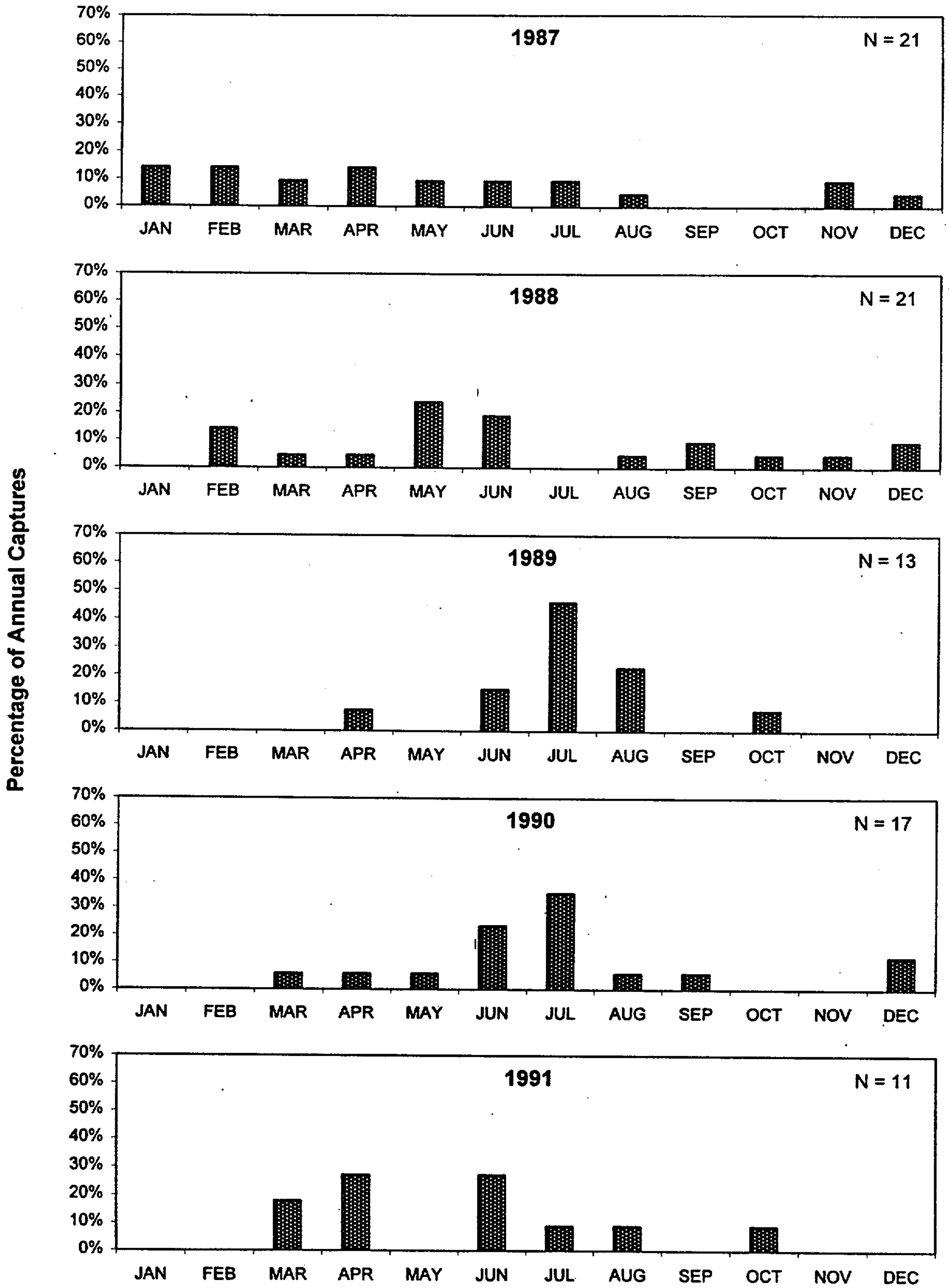


Figure 30. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

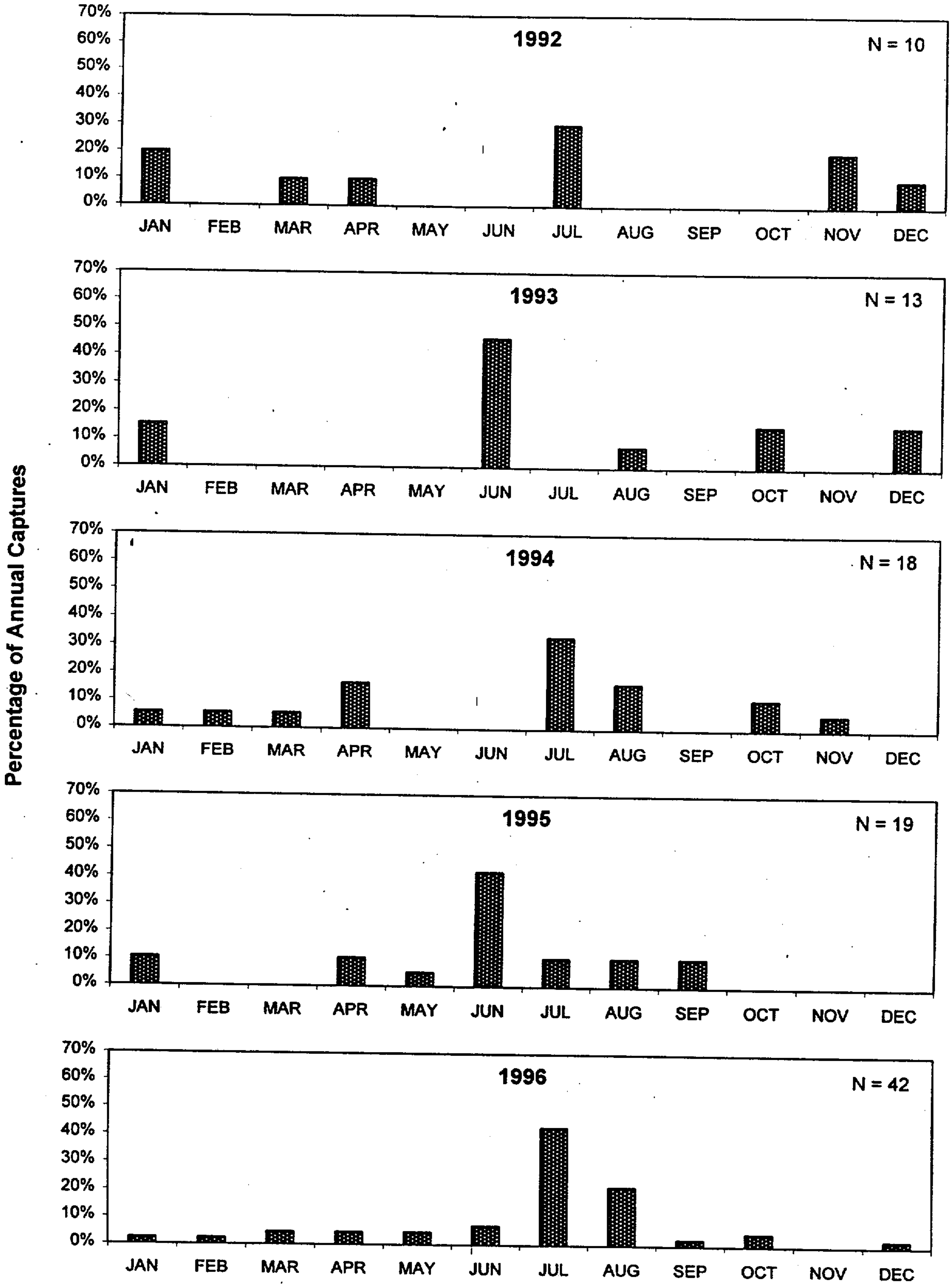


Figure 31. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

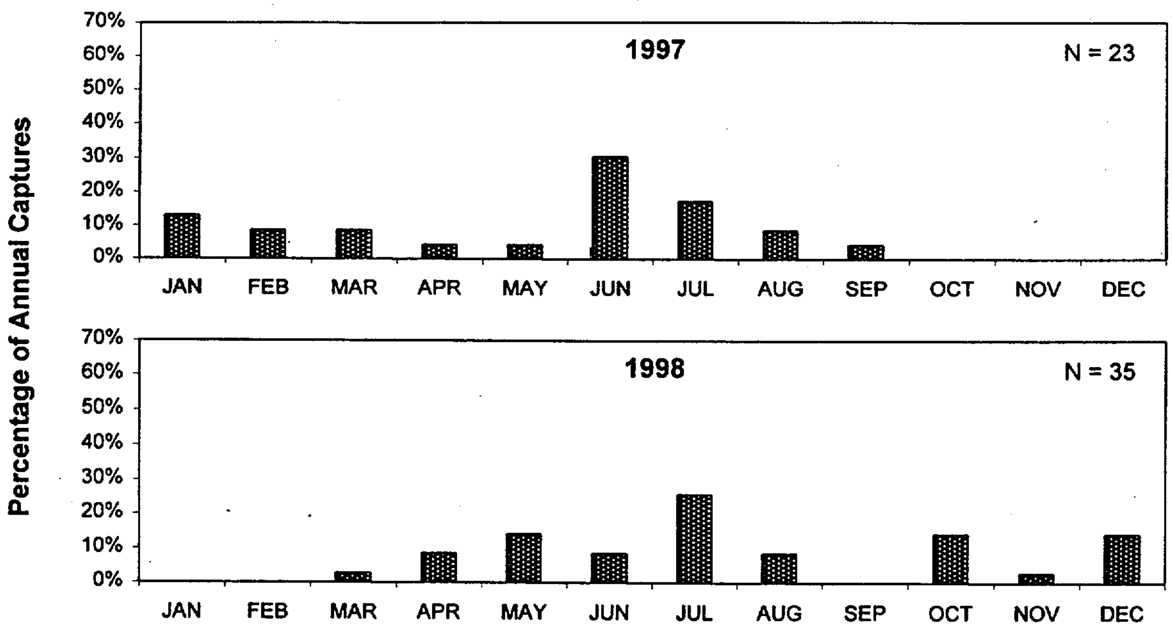


Figure 32. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

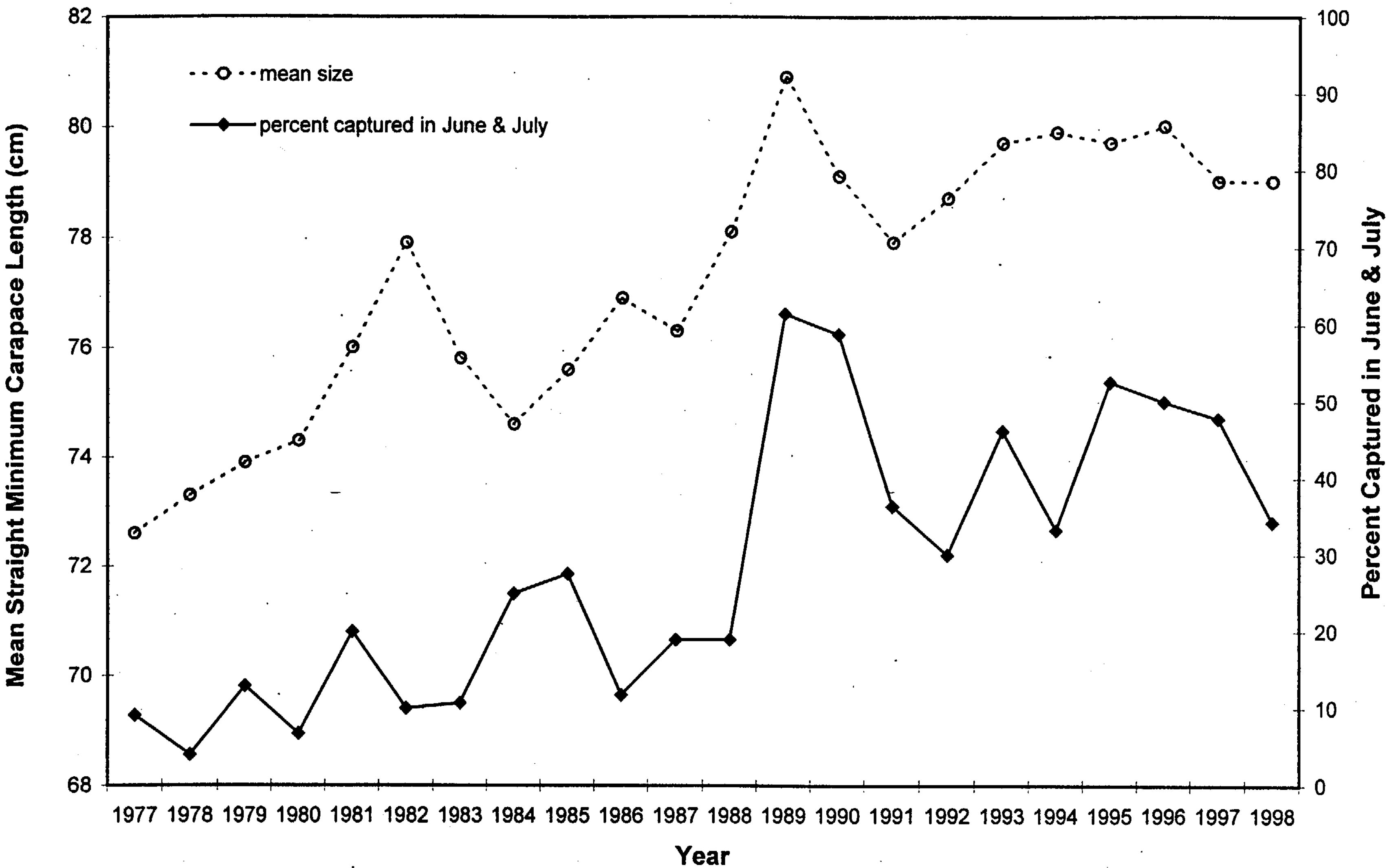


Figure 33. Mean size (straight minimum carapace length) of subadult loggerhead turtles compared to the percentage of annual subadult loggerhead captures that occurred during the months of June and July each year, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998.

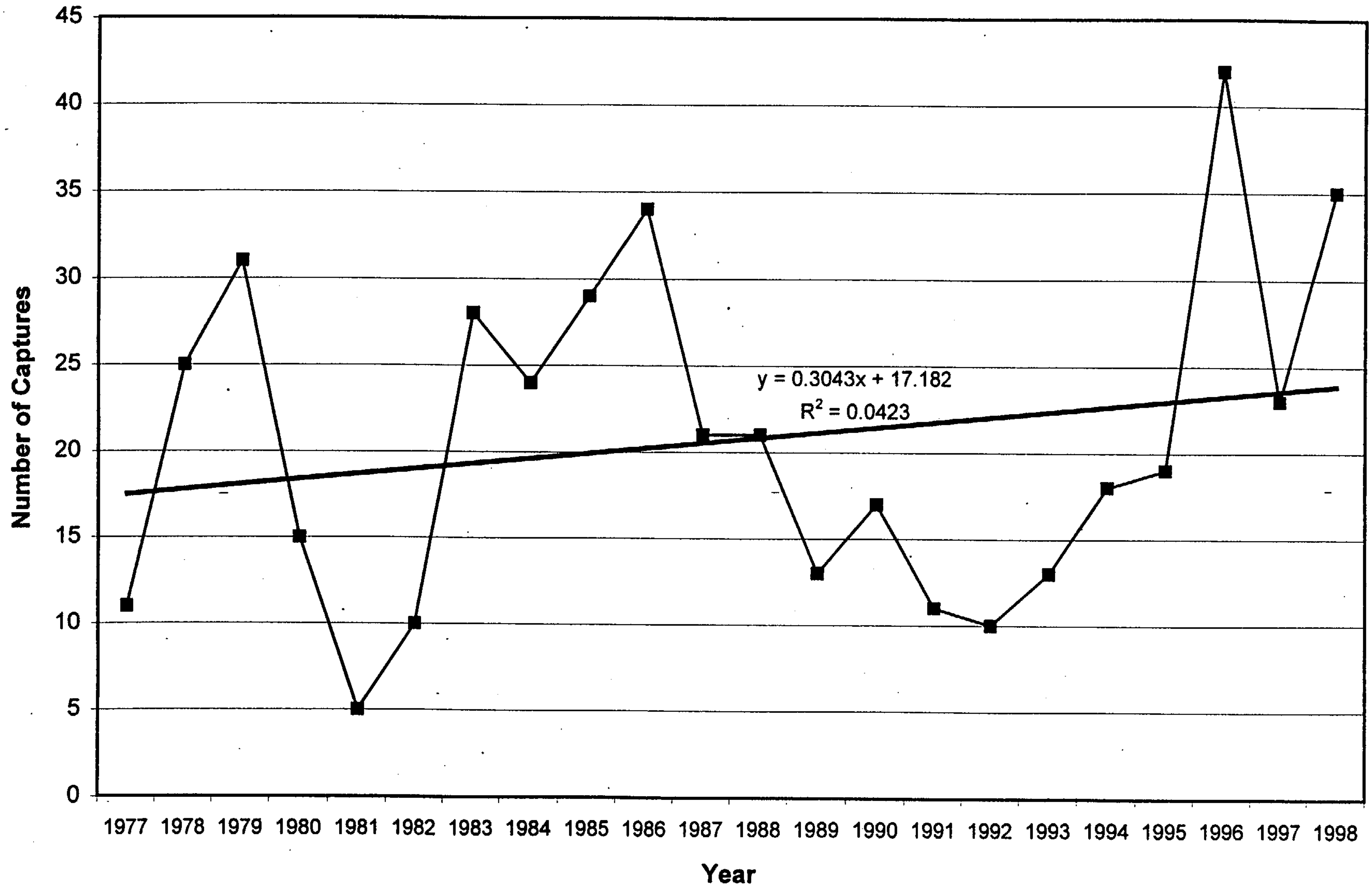


Figure 34. Annual number of subadult loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

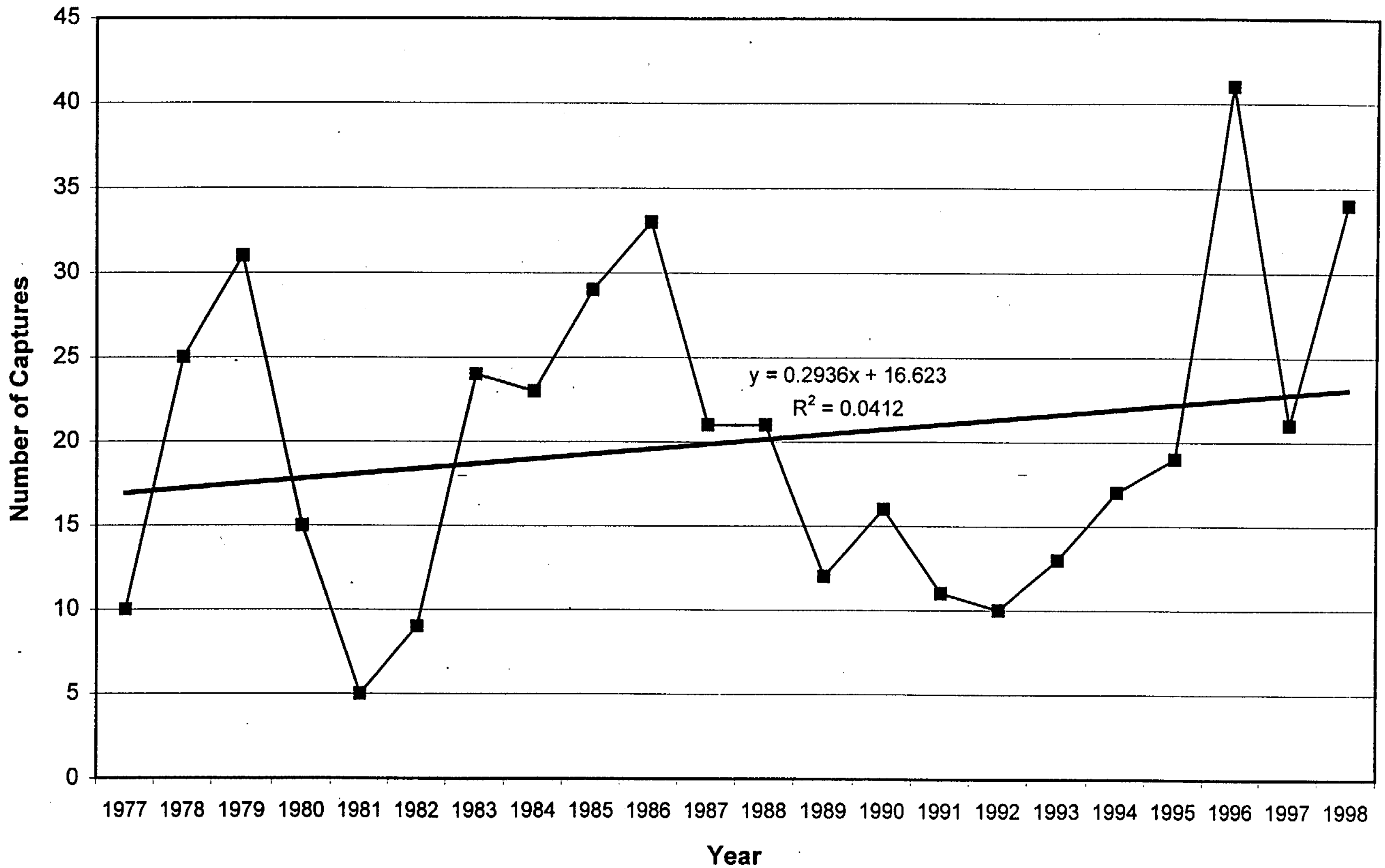


Figure 35. Annual number of subadult loggerhead captures (excluding recaptures), St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

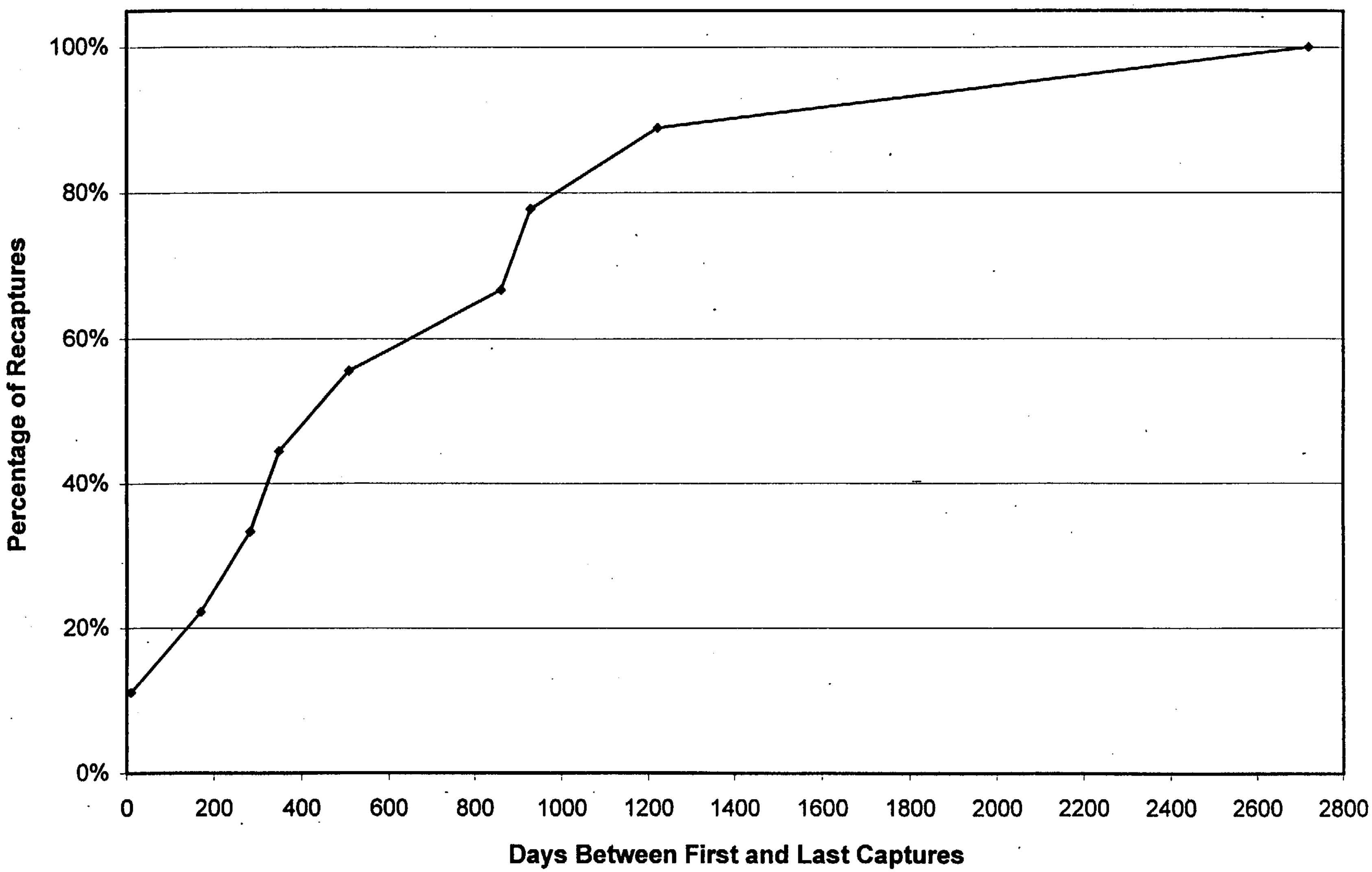


Figure 36. The percentage of subadult loggerhead recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

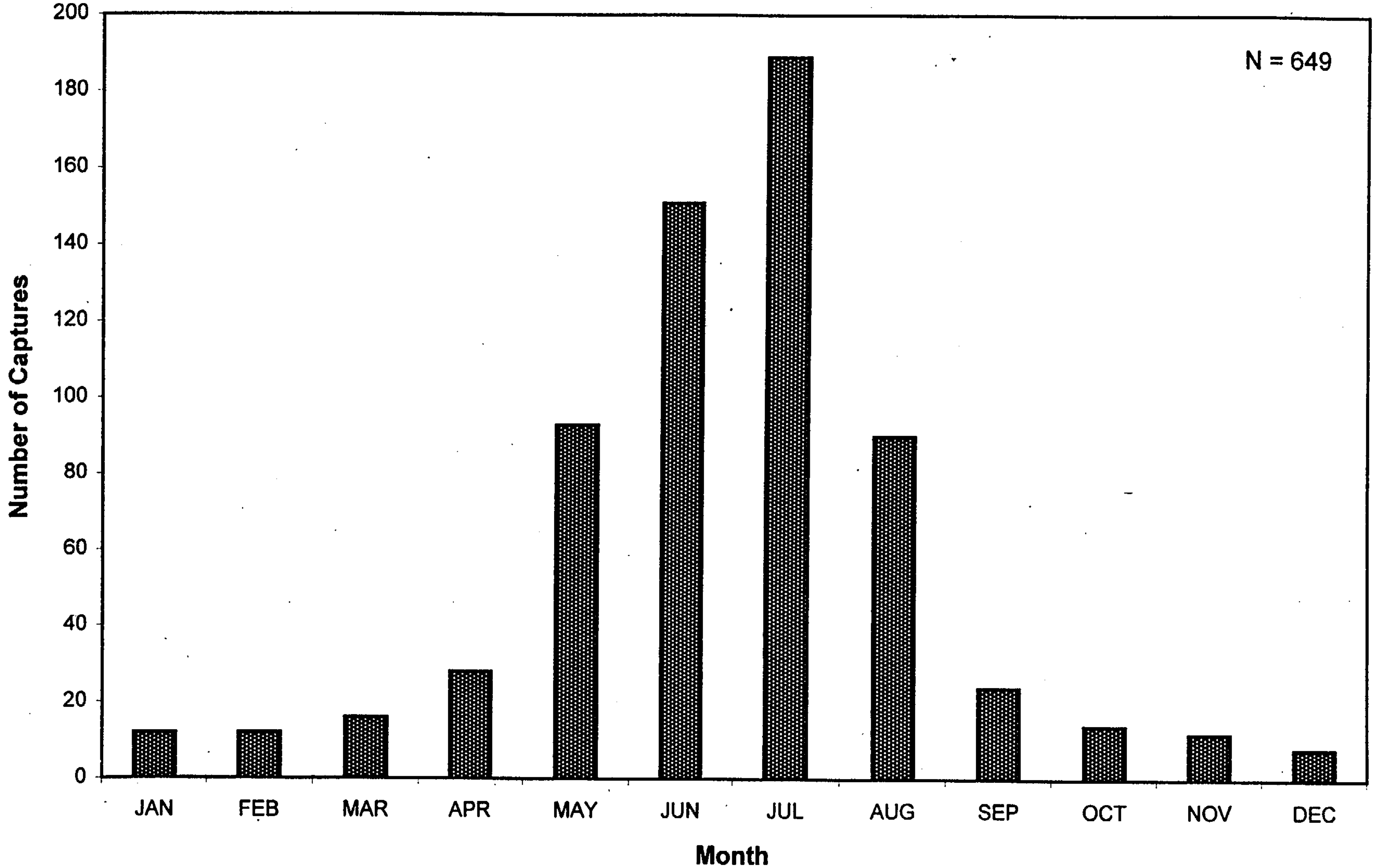


Figure 37. Number of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. The data set includes 562 females, 75 males and 12 adults for which sex was not recorded. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

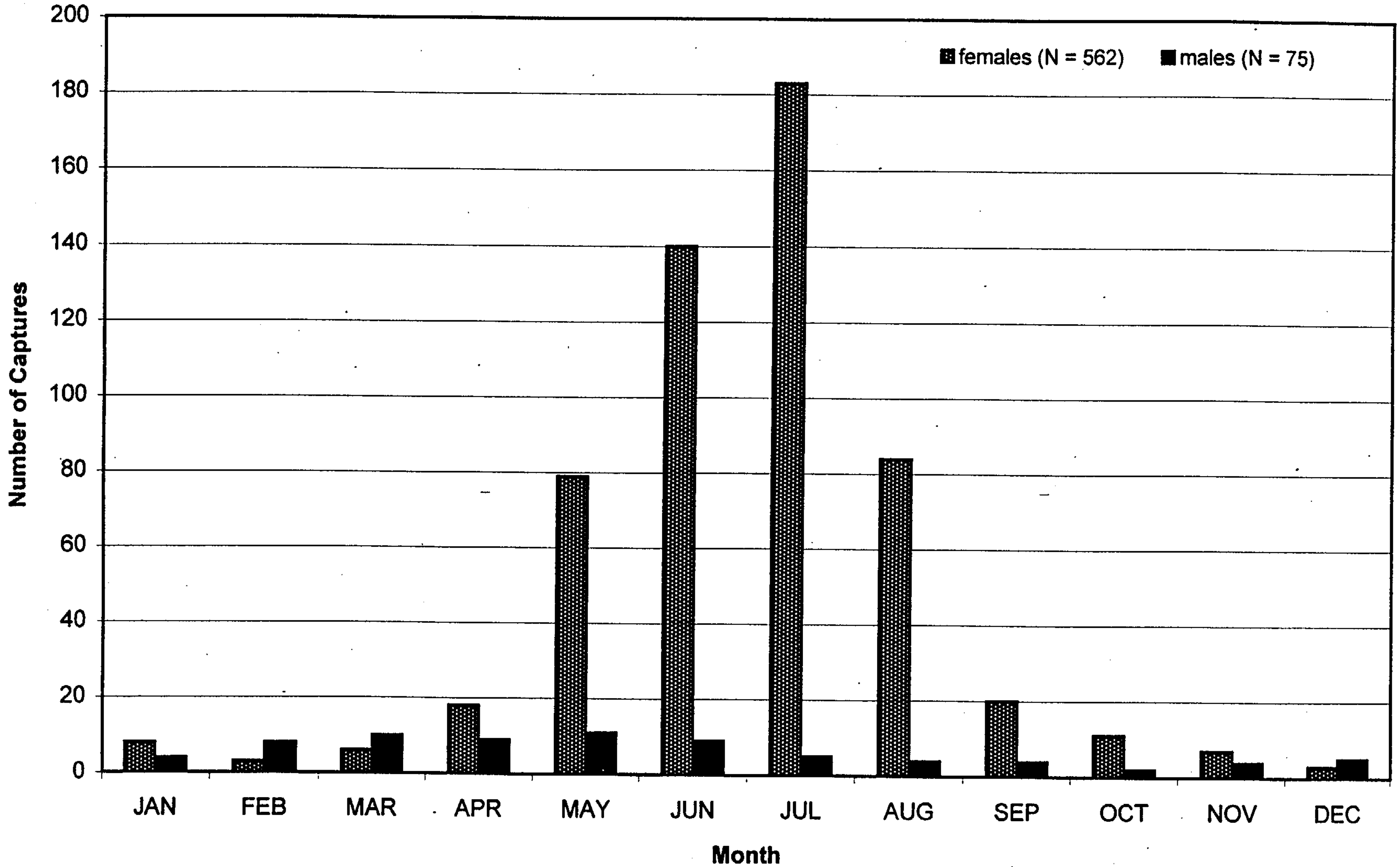


Figure 38. Number of adult male and female loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

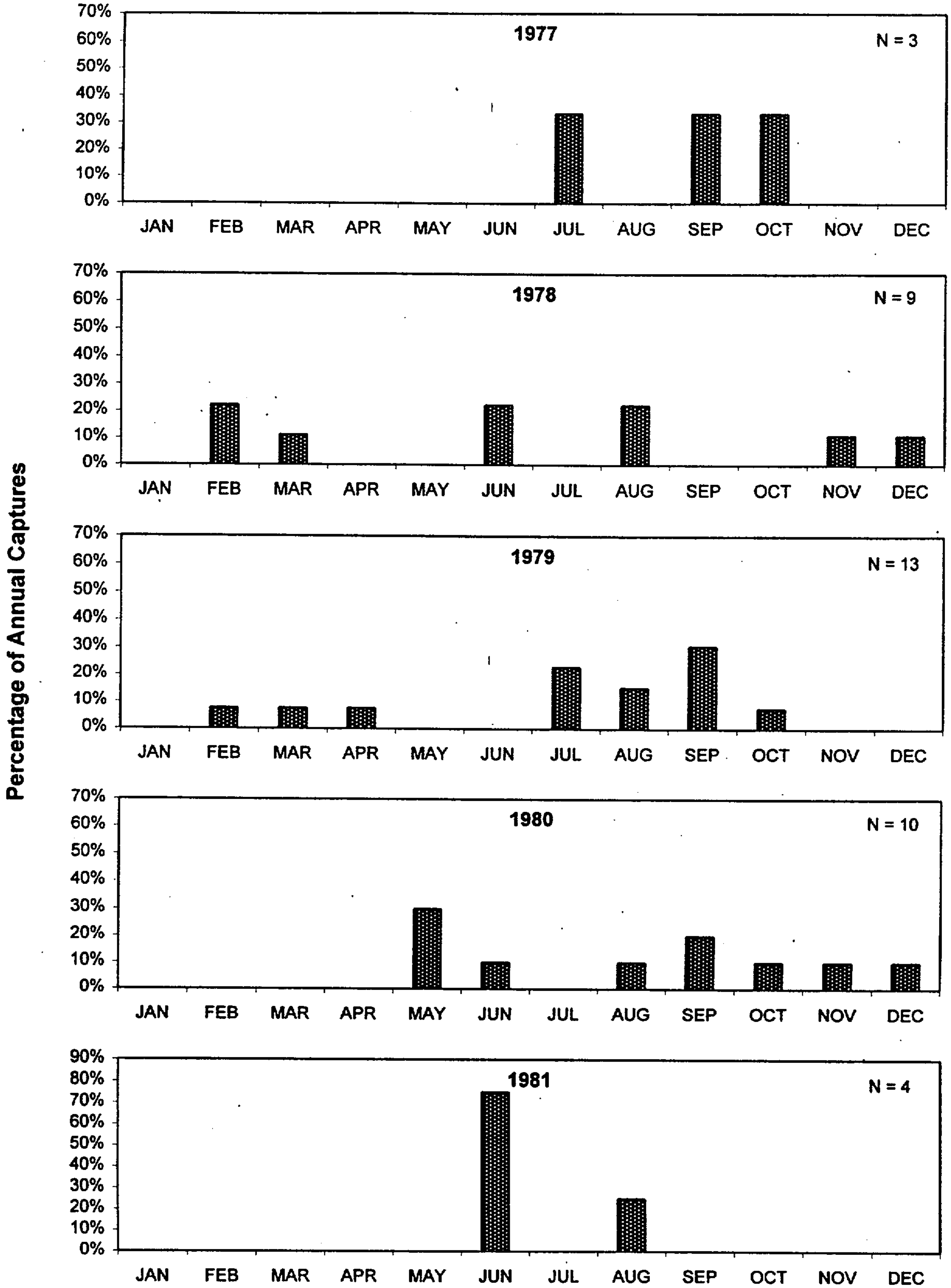


Figure 39. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

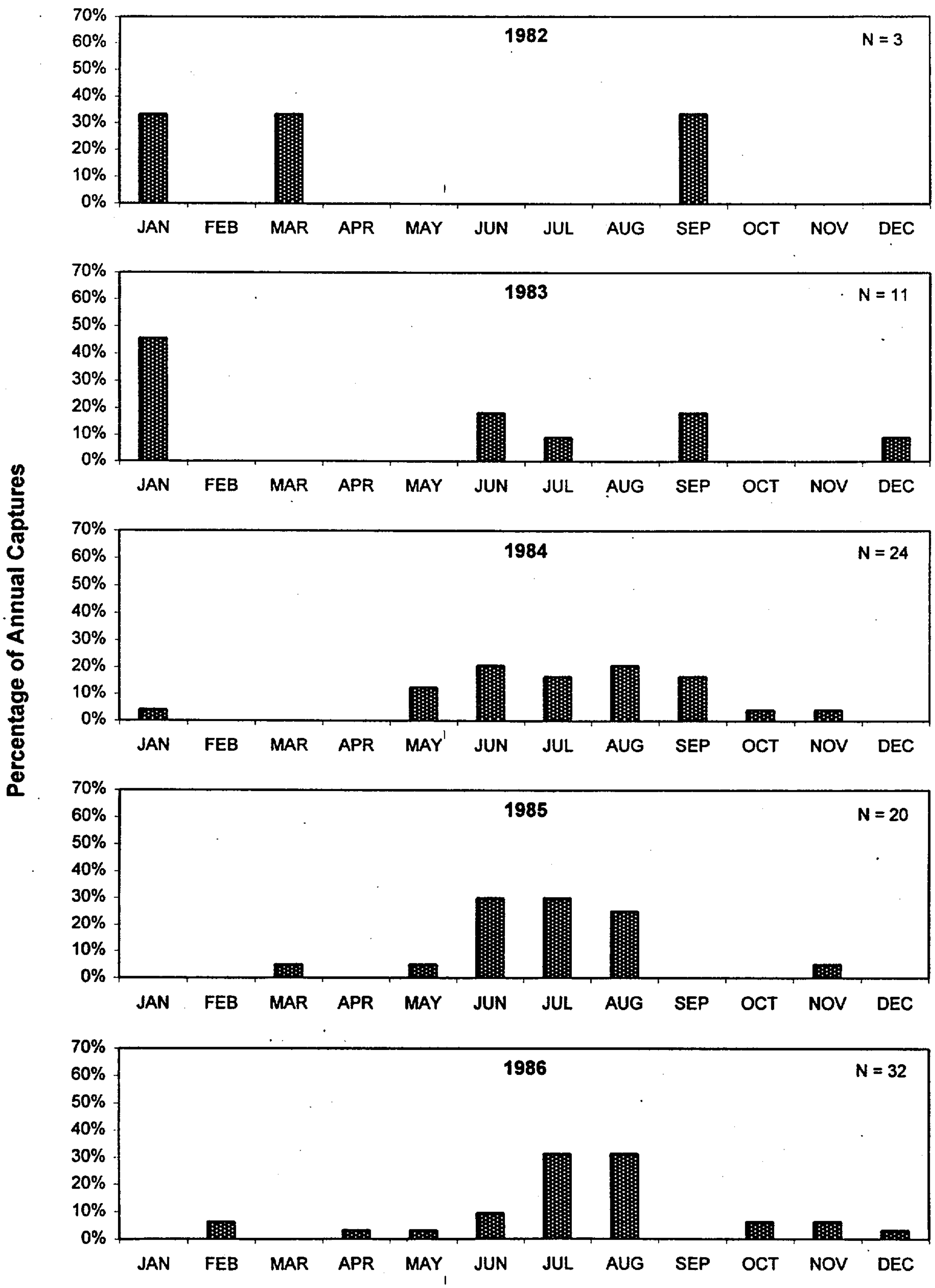


Figure 40. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

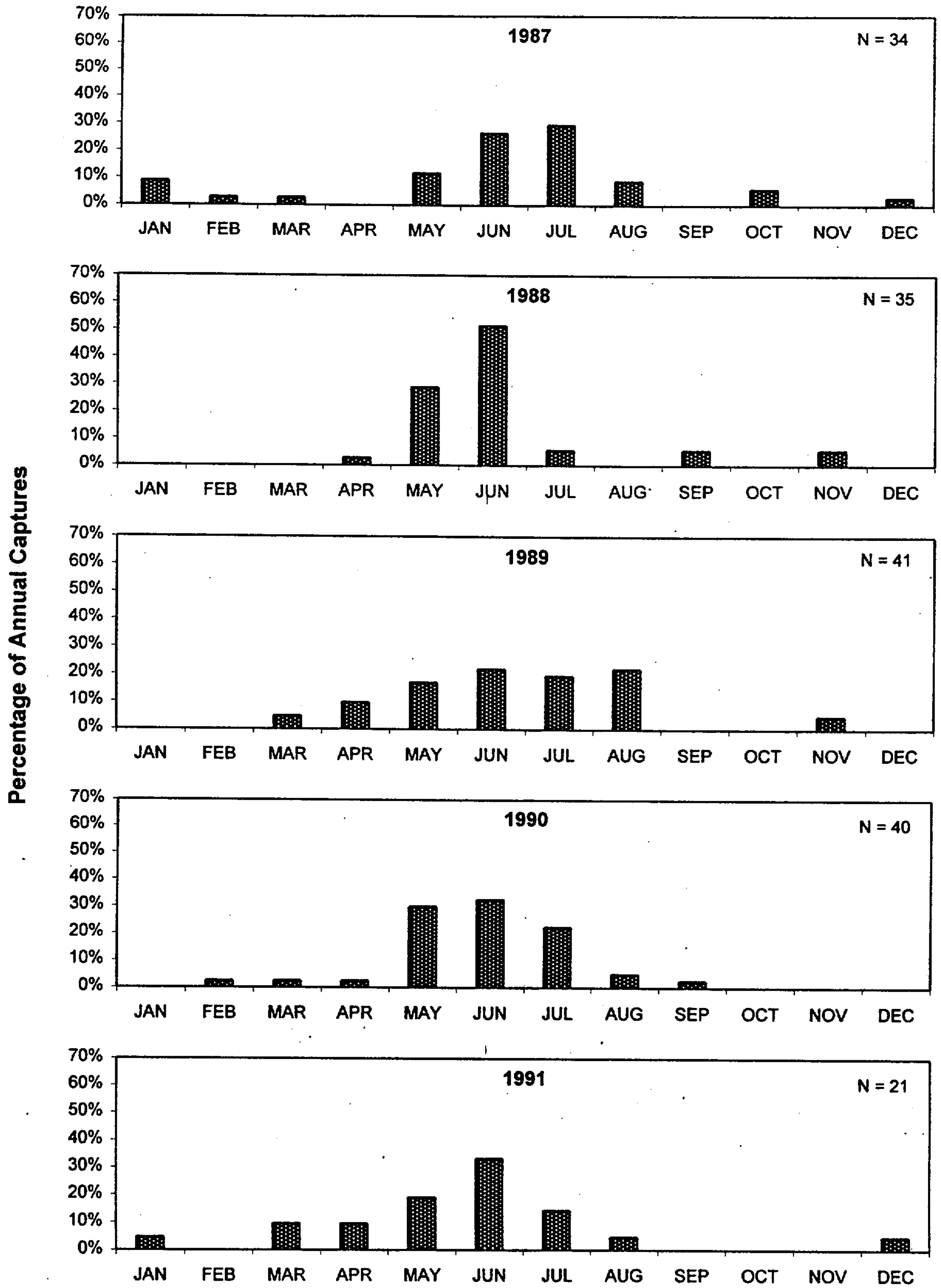


Figure 41. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

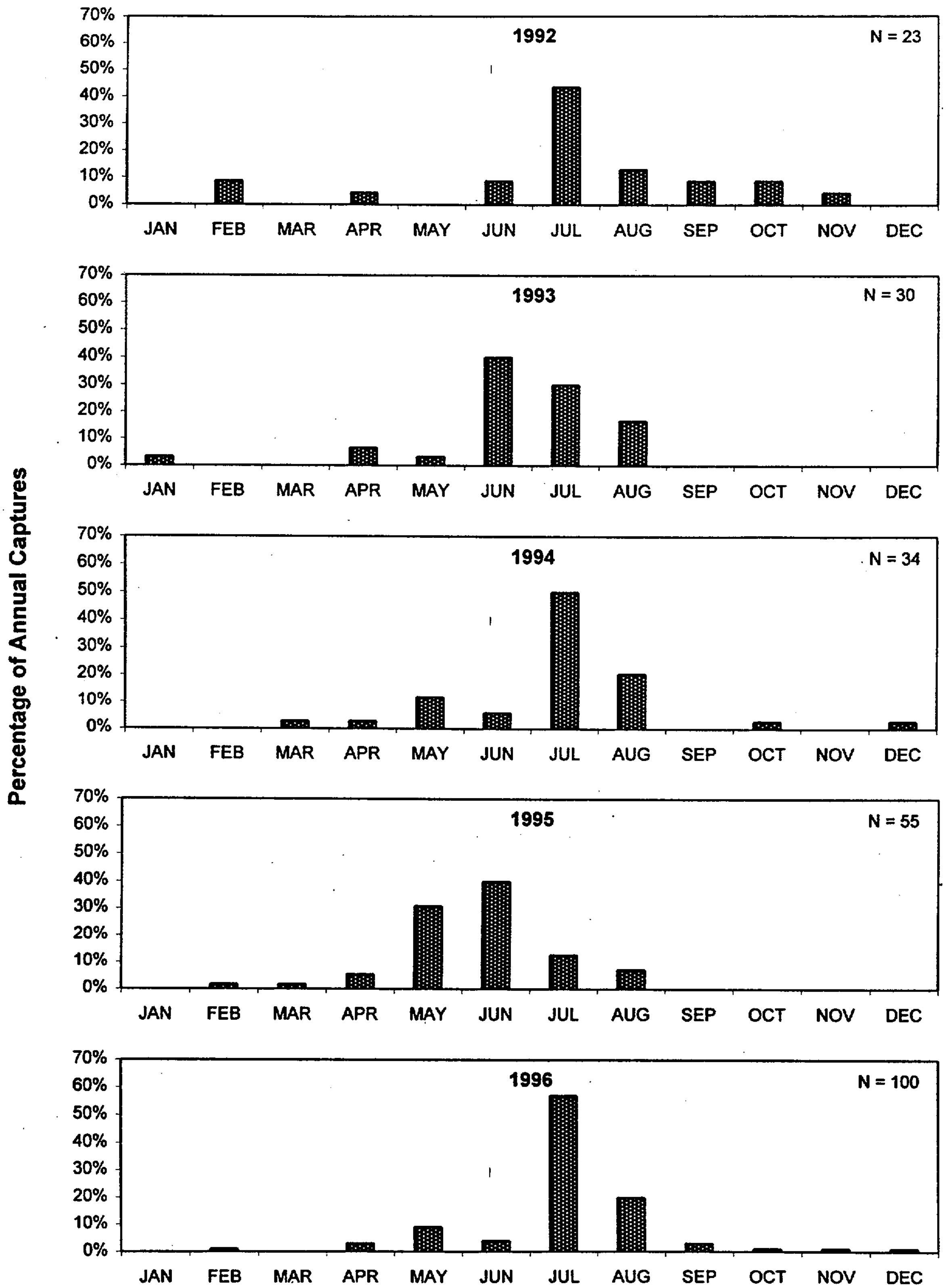


Figure 42. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

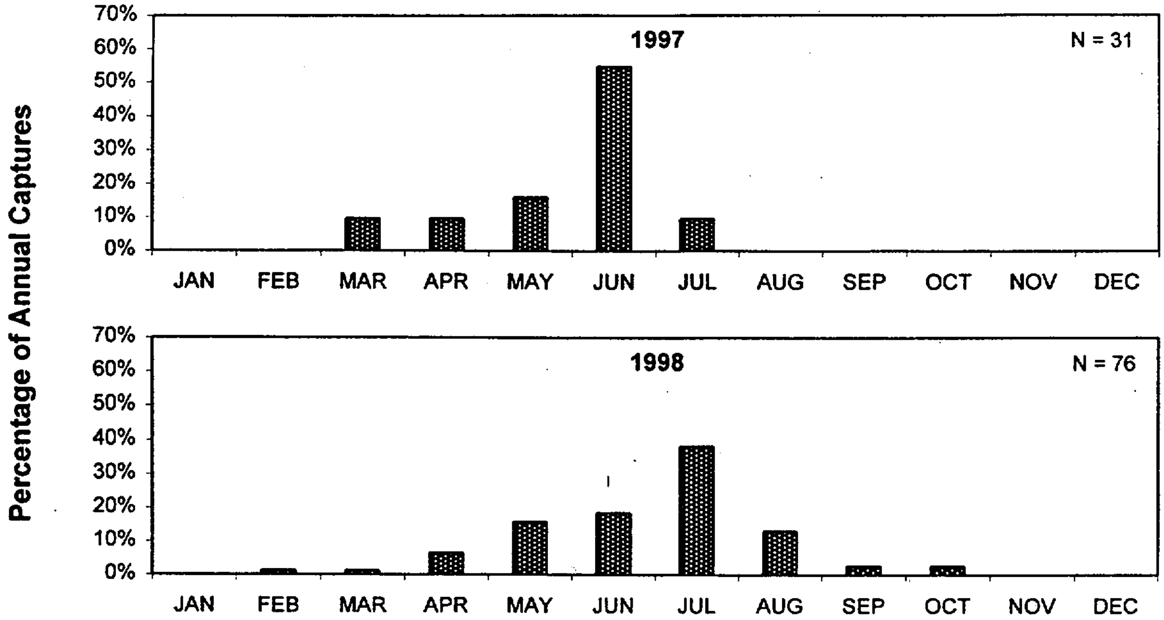


Figure 43. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

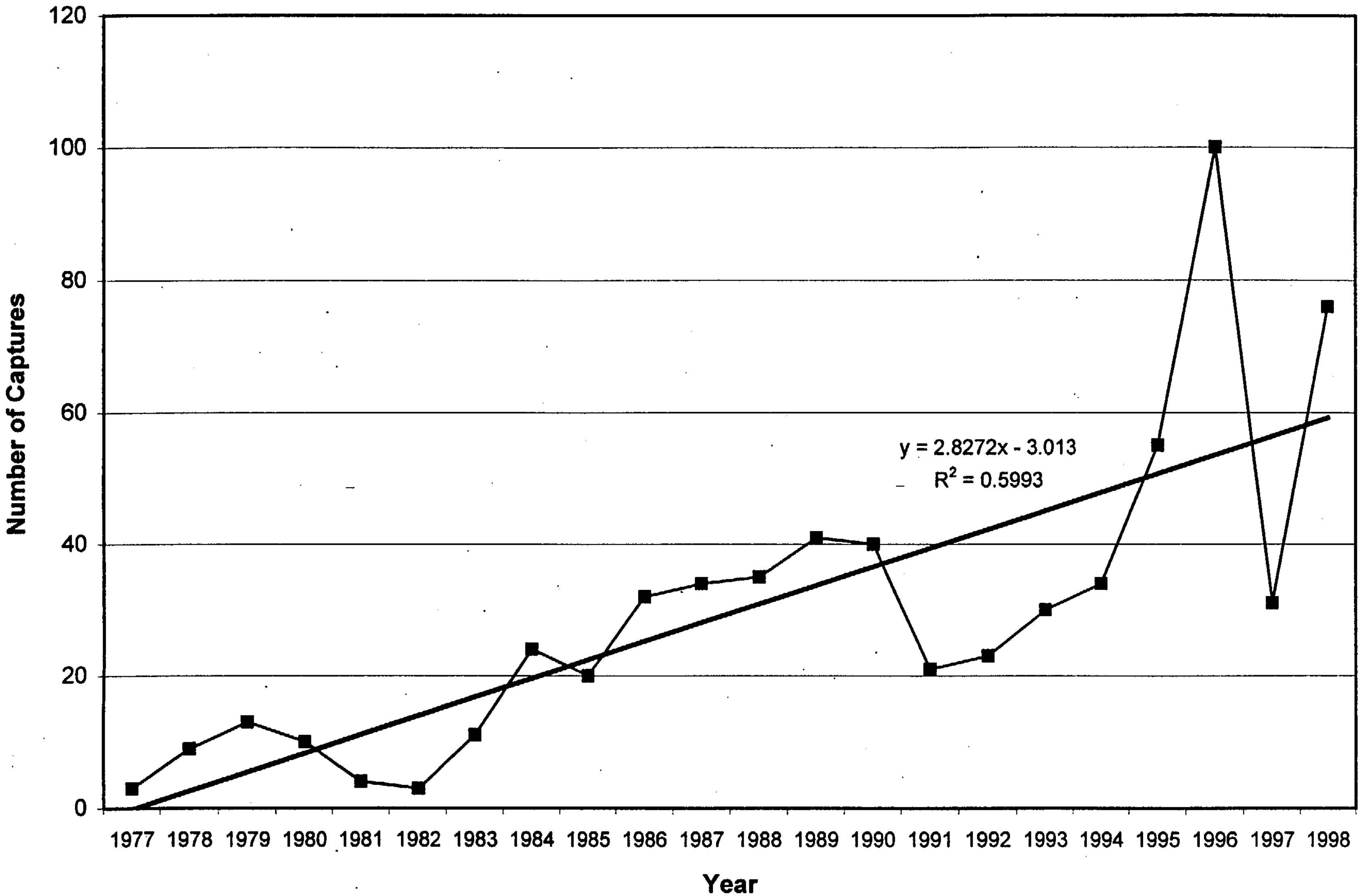


Figure 44. Annual number of adult loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

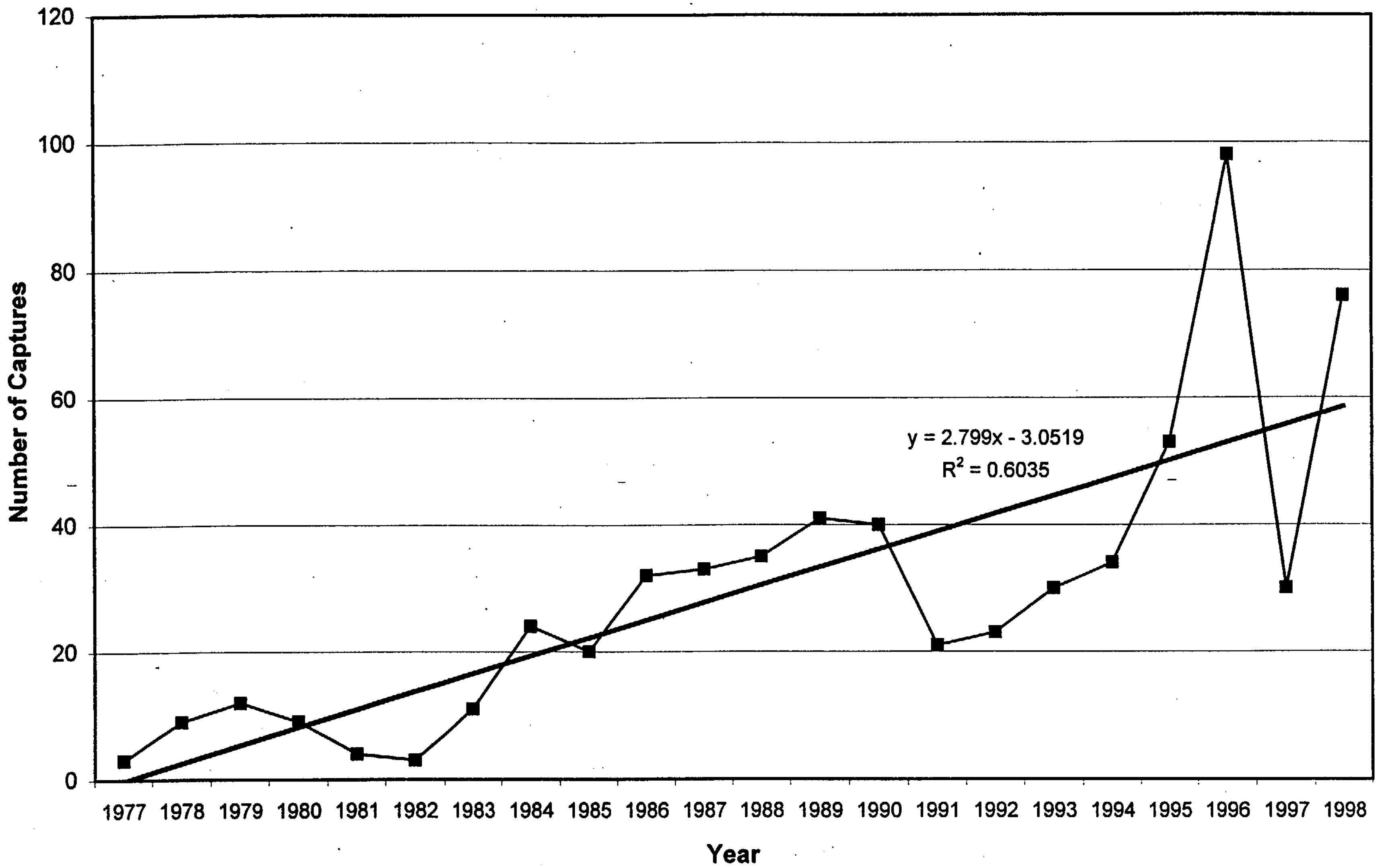


Figure 45. Annual number of adult loggerhead captures (excluding recaptures), St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

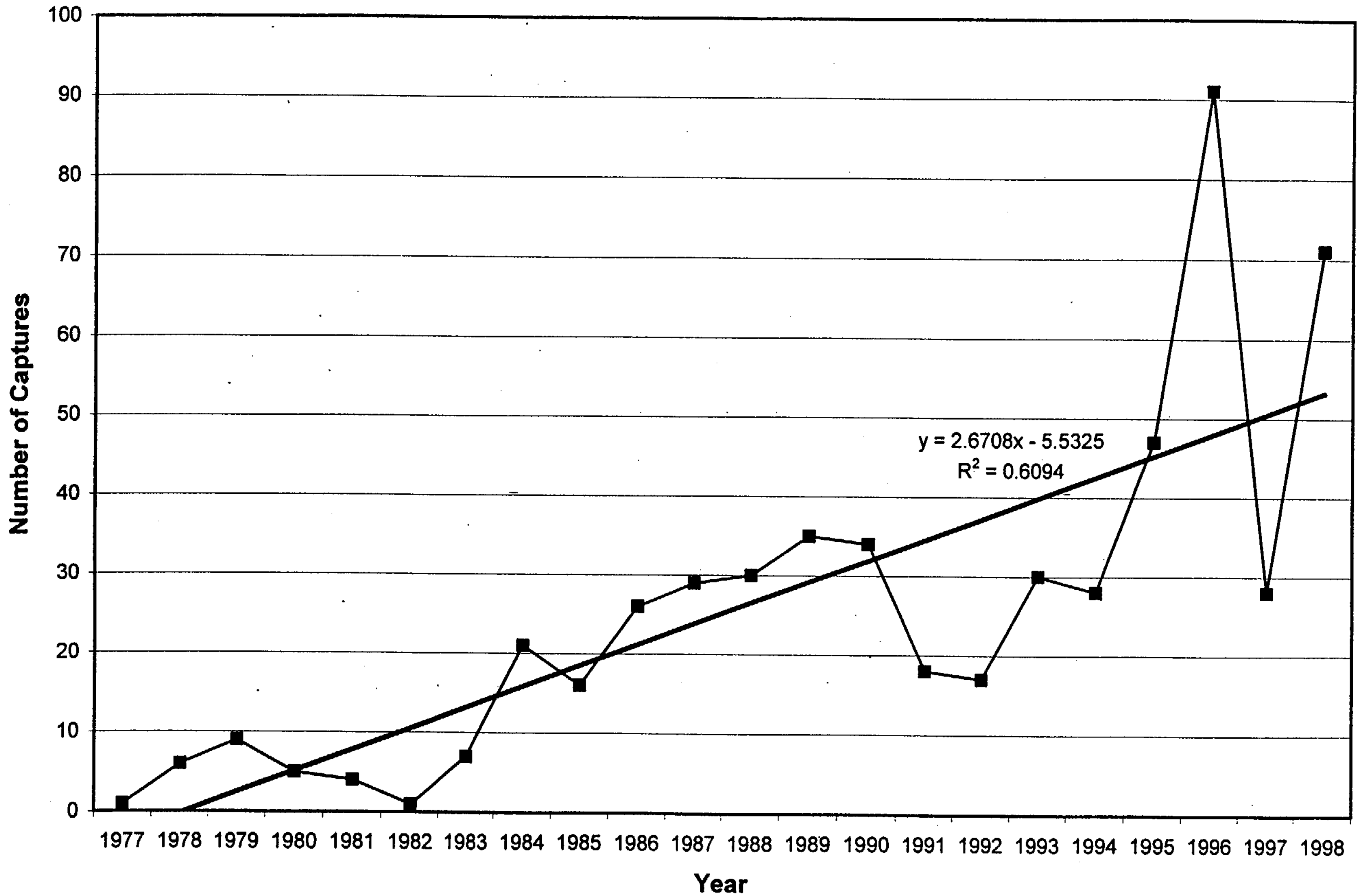


Figure 46. Annual number of adult female loggerhead captures excluding recaptures, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

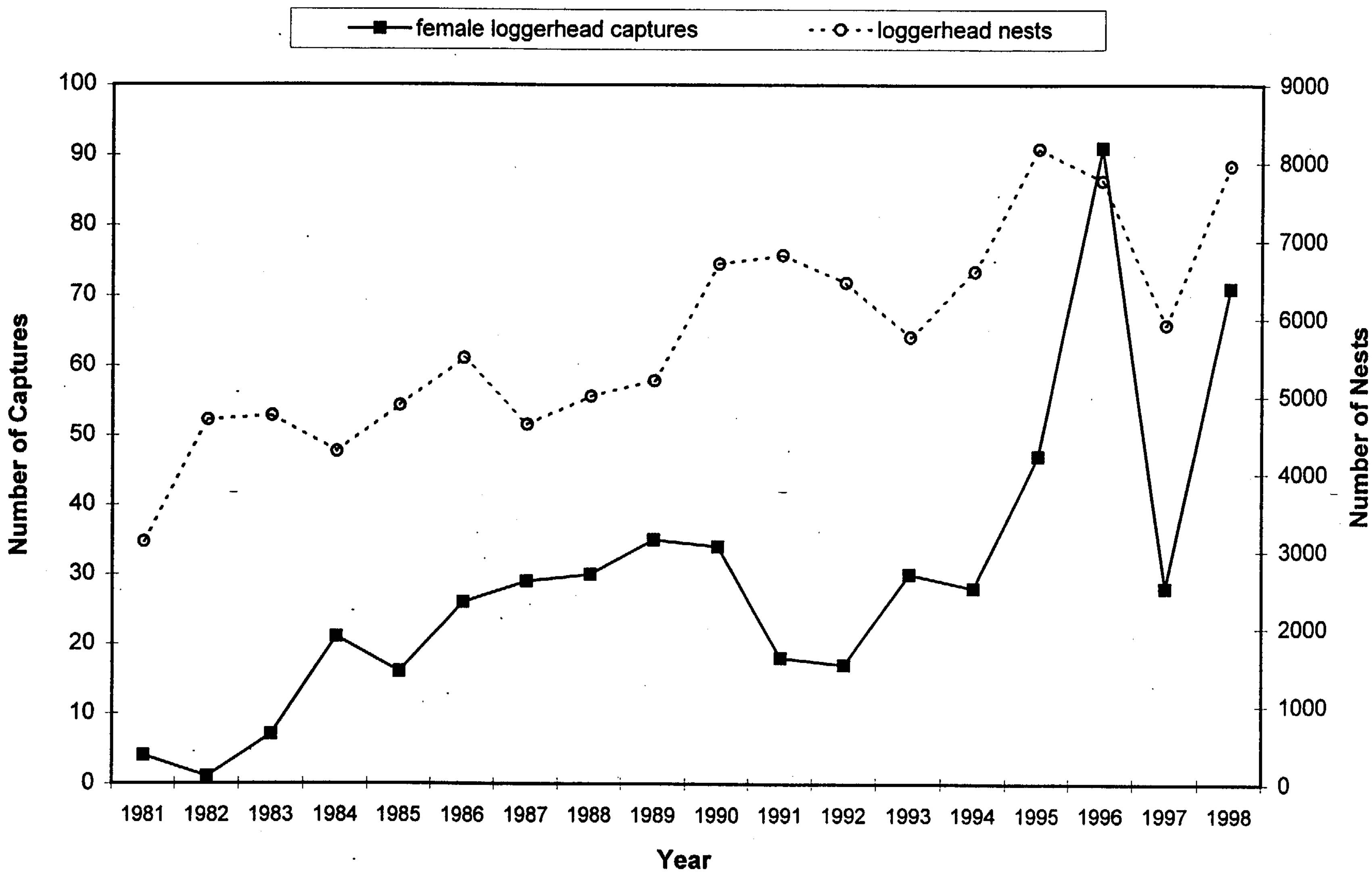


Figure 47. Annual numbers of adult female loggerhead captures at the St. Lucie Plant compared to the annual number of loggerhead nests on Hutchinson Island, Florida, 1981-1998. Annual nesting data are not available prior to 1981.

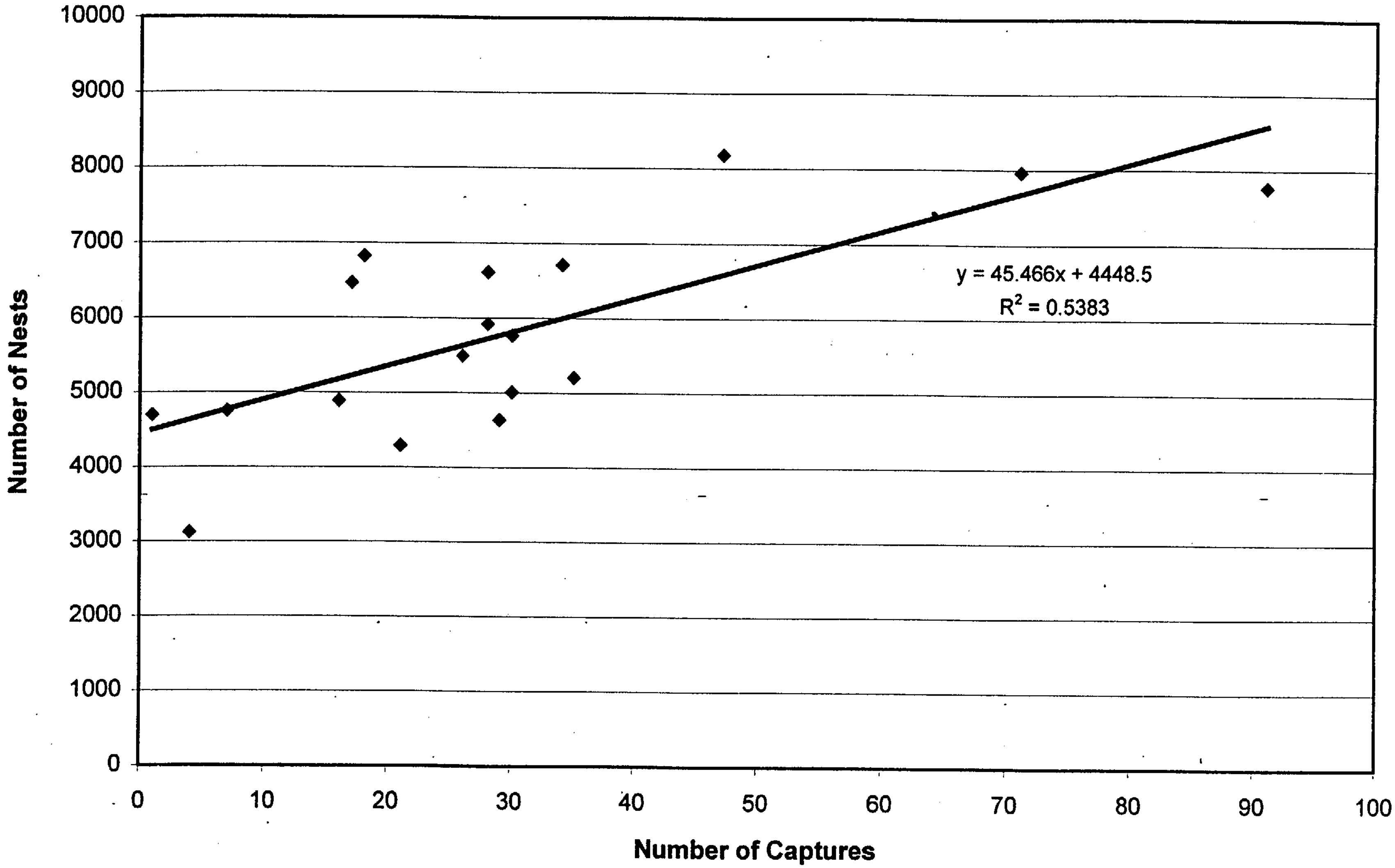


Figure 48. Relationship of annual numbers of adult female loggerhead captures at the St. Lucie Plant to the annual numbers of loggerhead nests on Hutchinson Island, Florida, 1981-1998. Annual nesting data are not available prior to 1981.

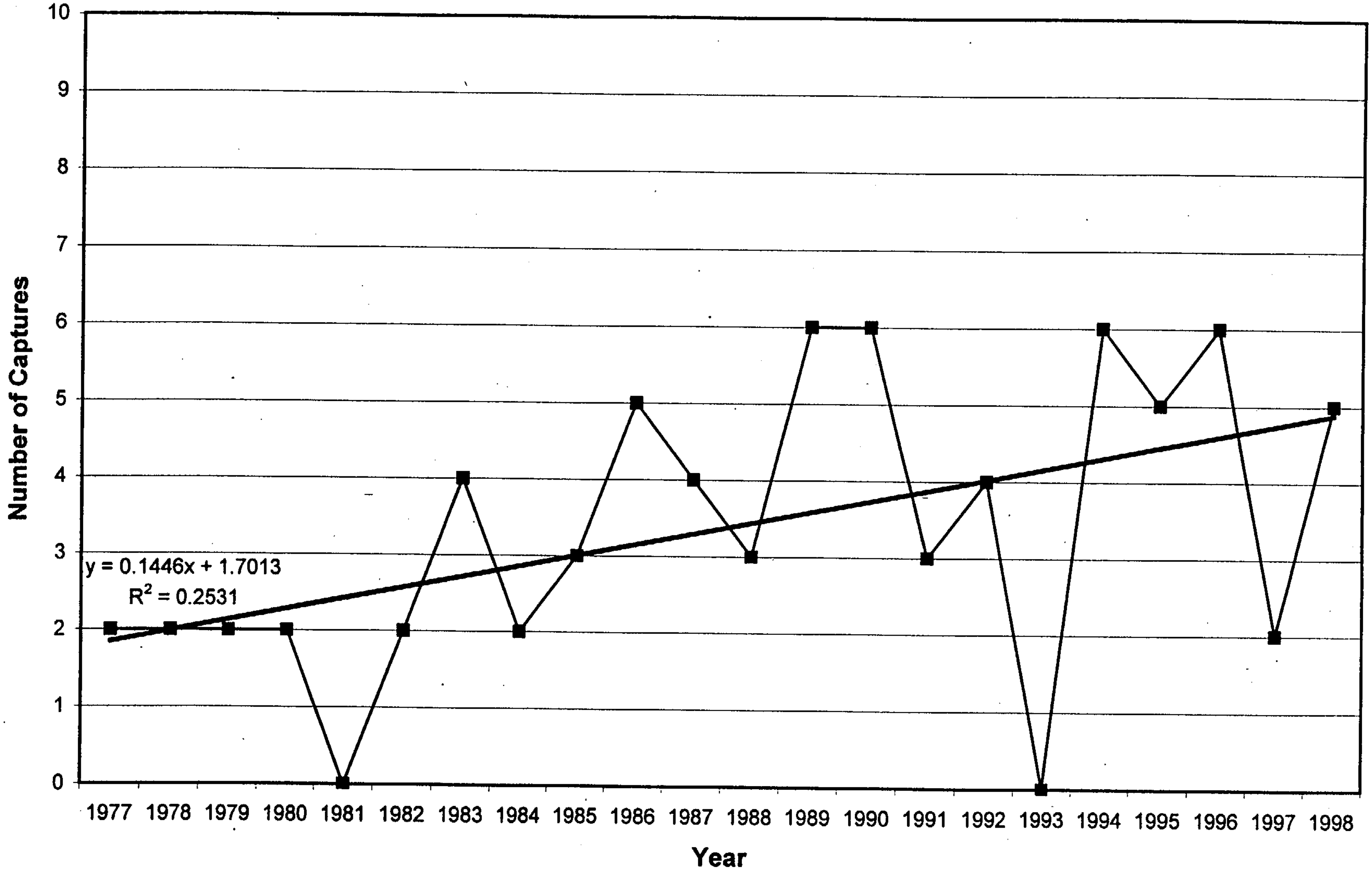


Figure 49. Annual number of adult male loggerhead captures excluding recaptures, St. Lucie Plant, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

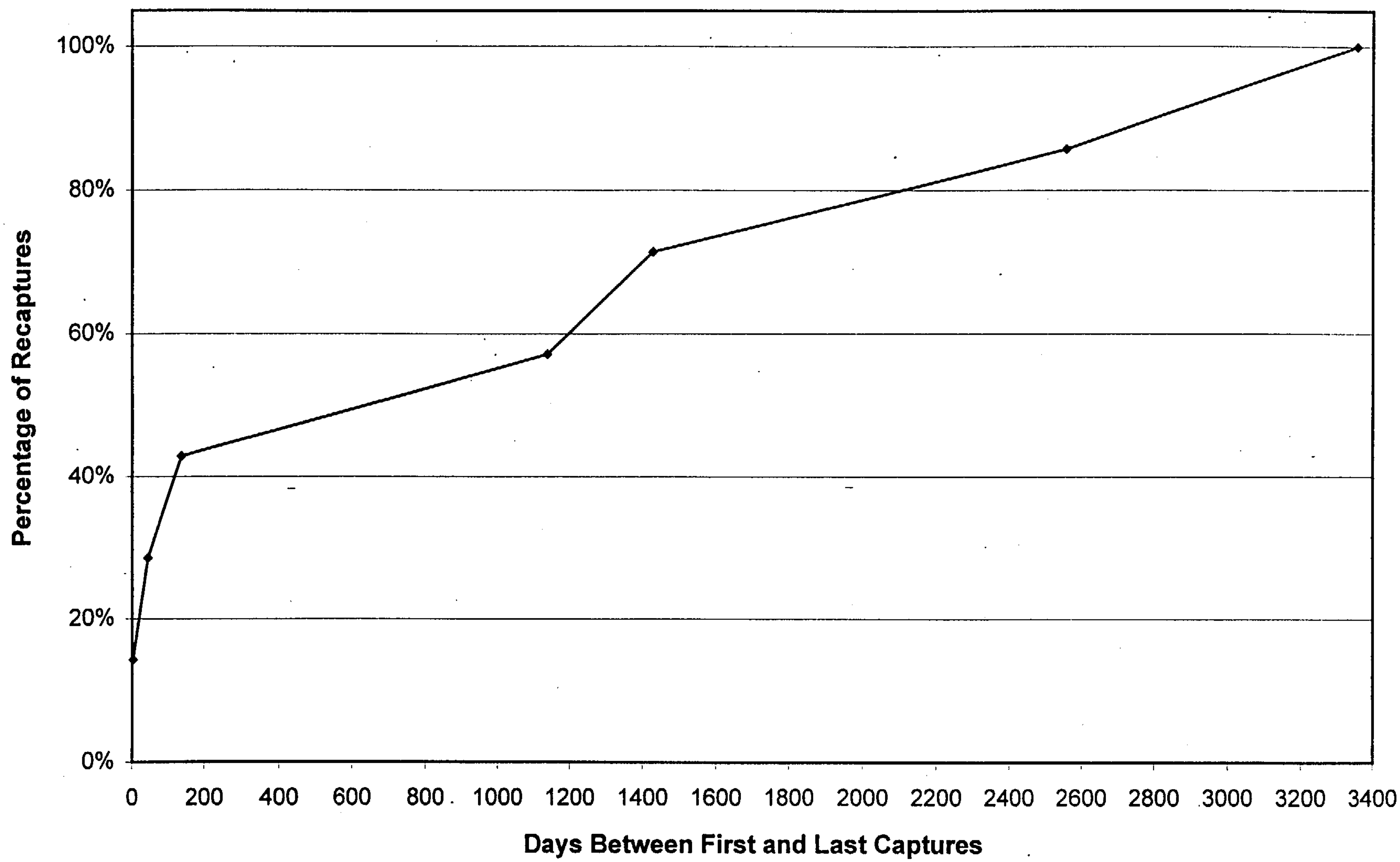


Figure 50. The percentage of adult loggerhead captures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

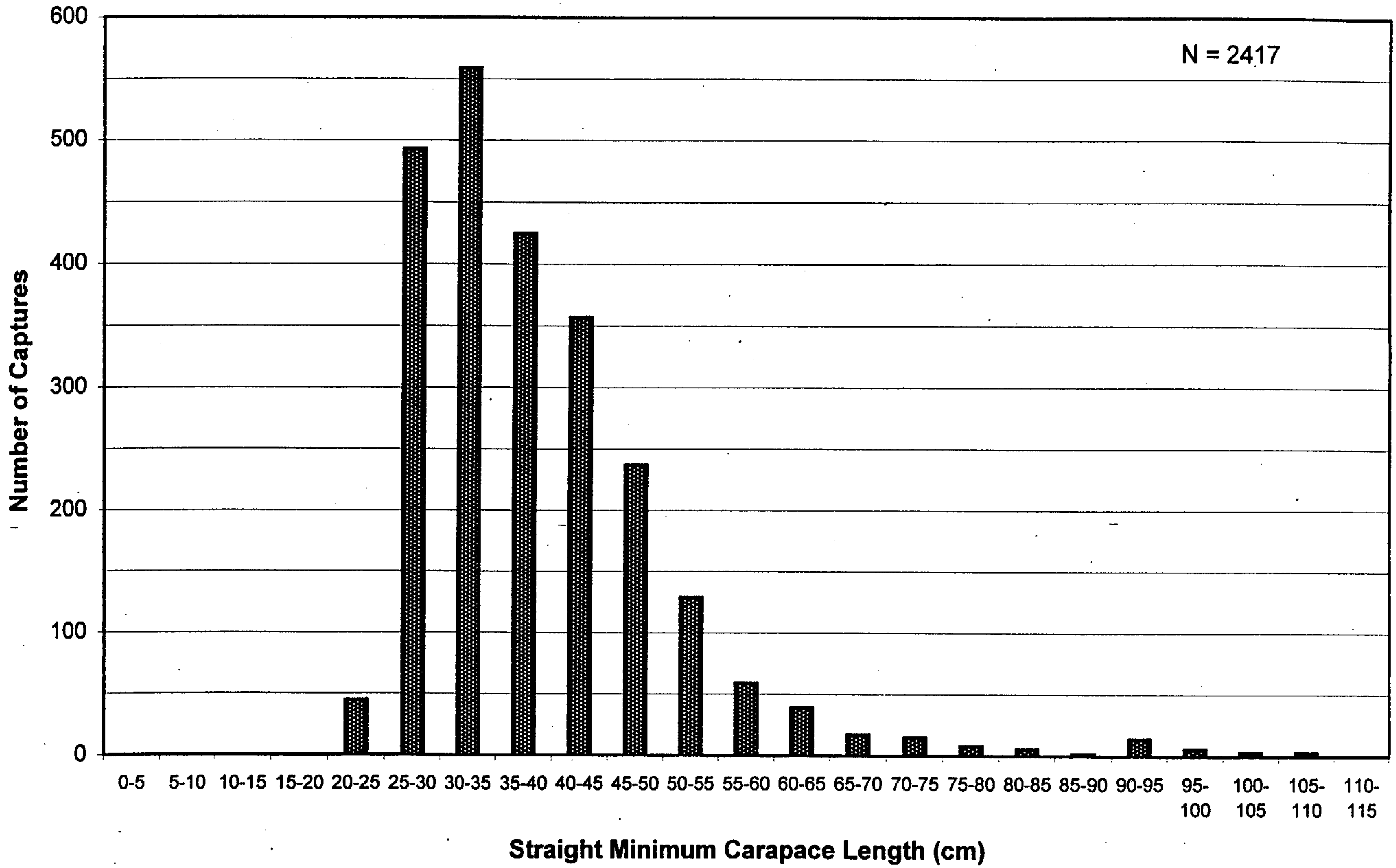


Figure 51. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

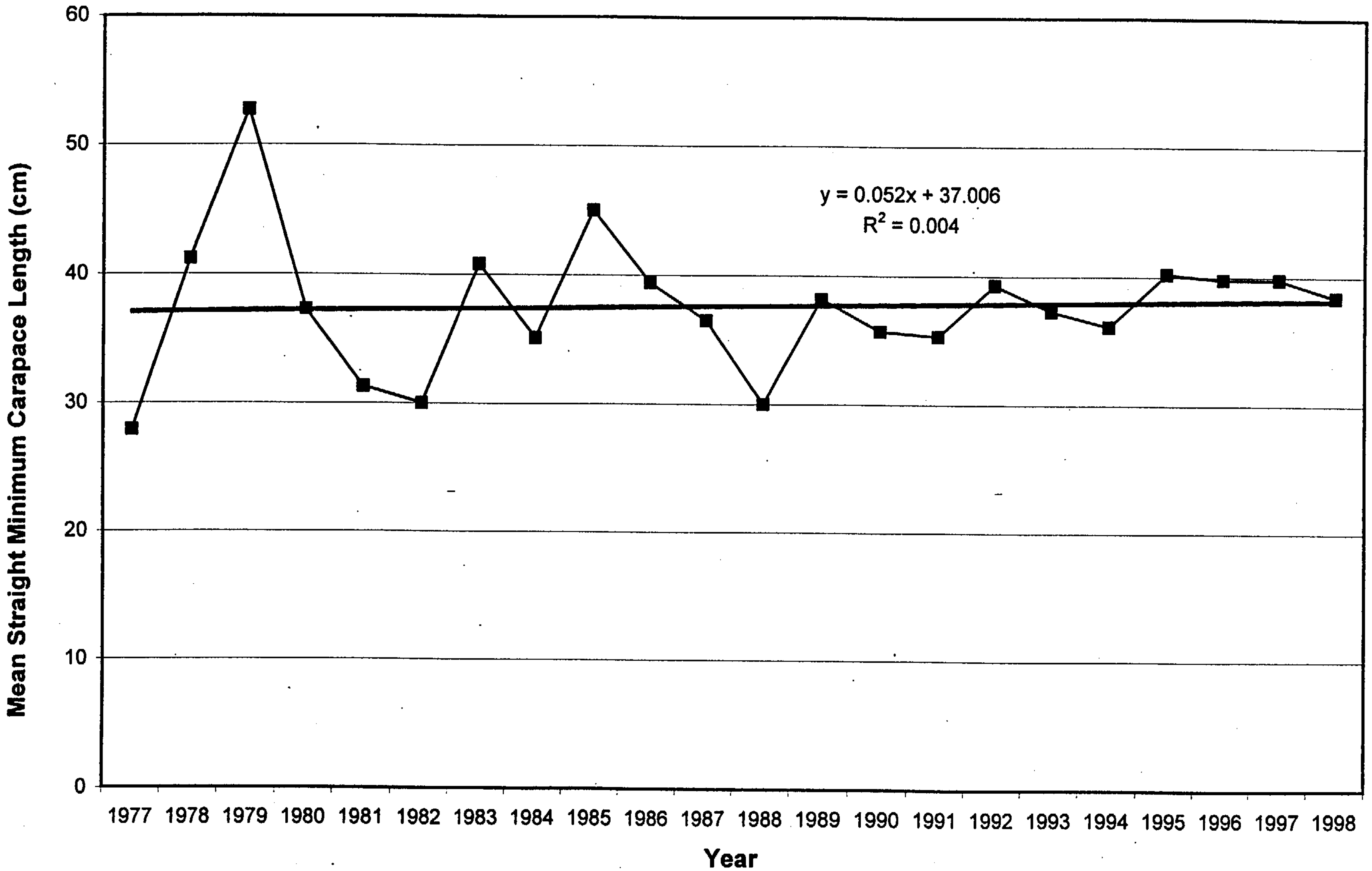


Figure 52. Mean size (straight minimum carapace length) of all green turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Note: no green turtles were captured during 1996.

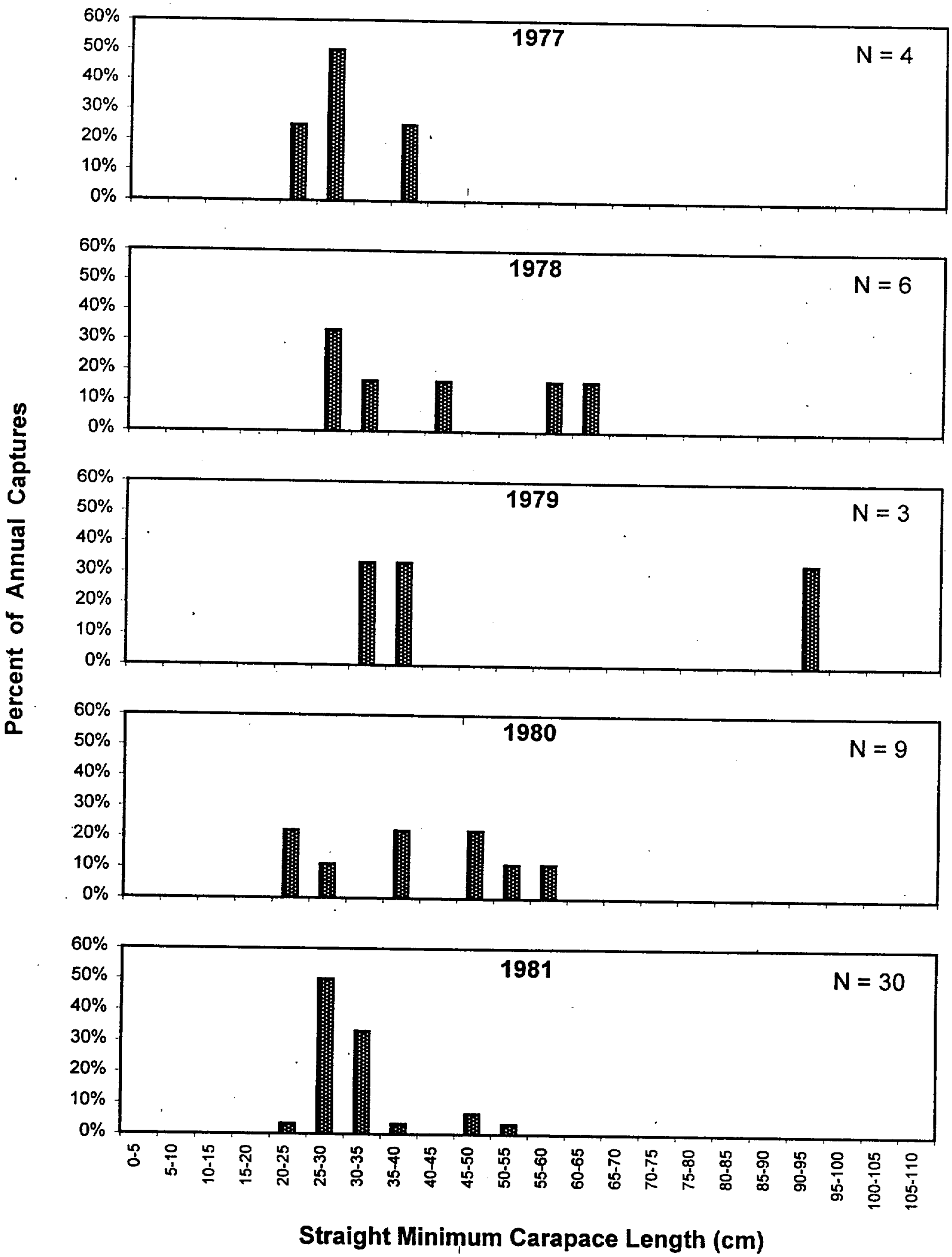


Figure 53. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Note: no green turtles were captured during 1976.

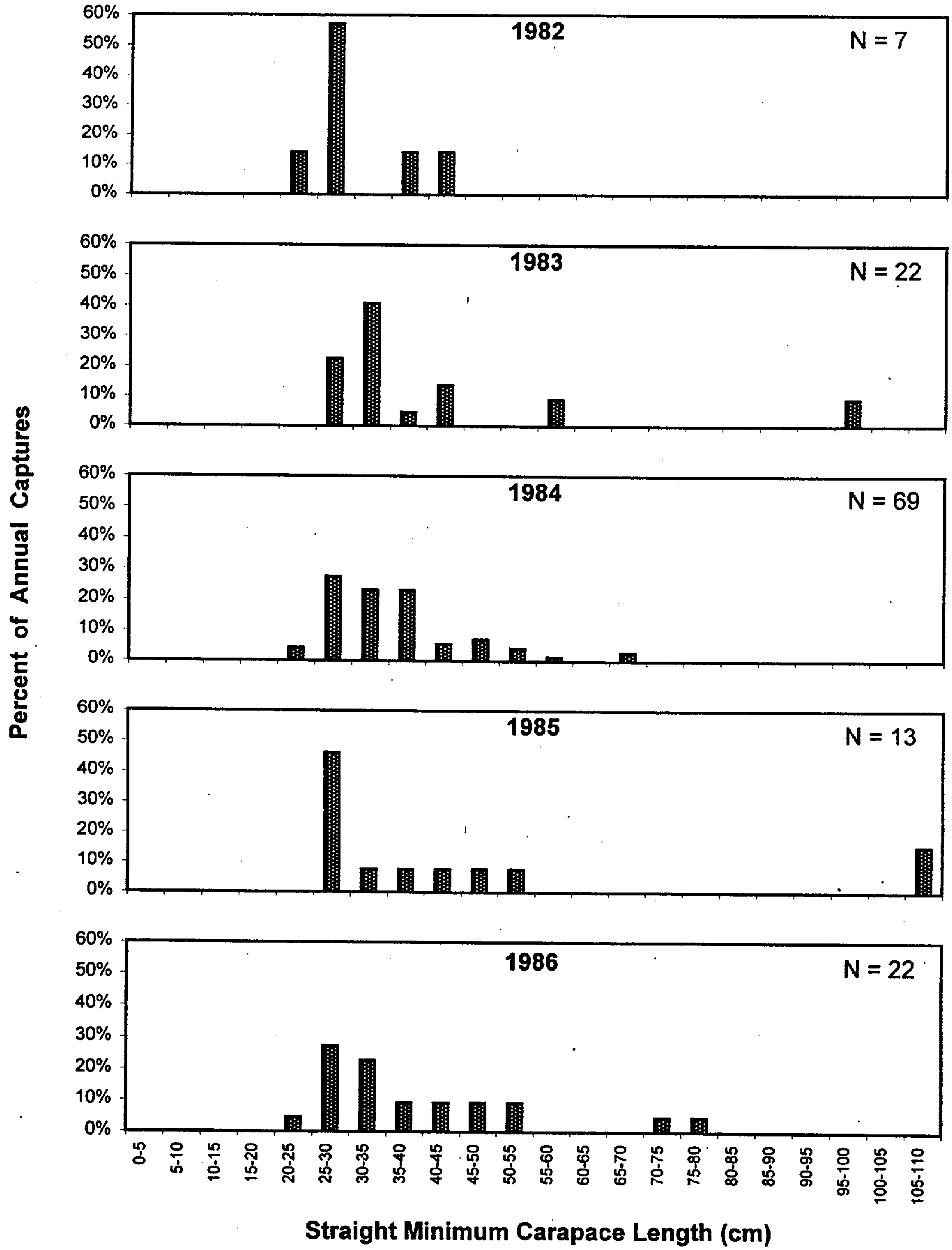


Figure 54. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

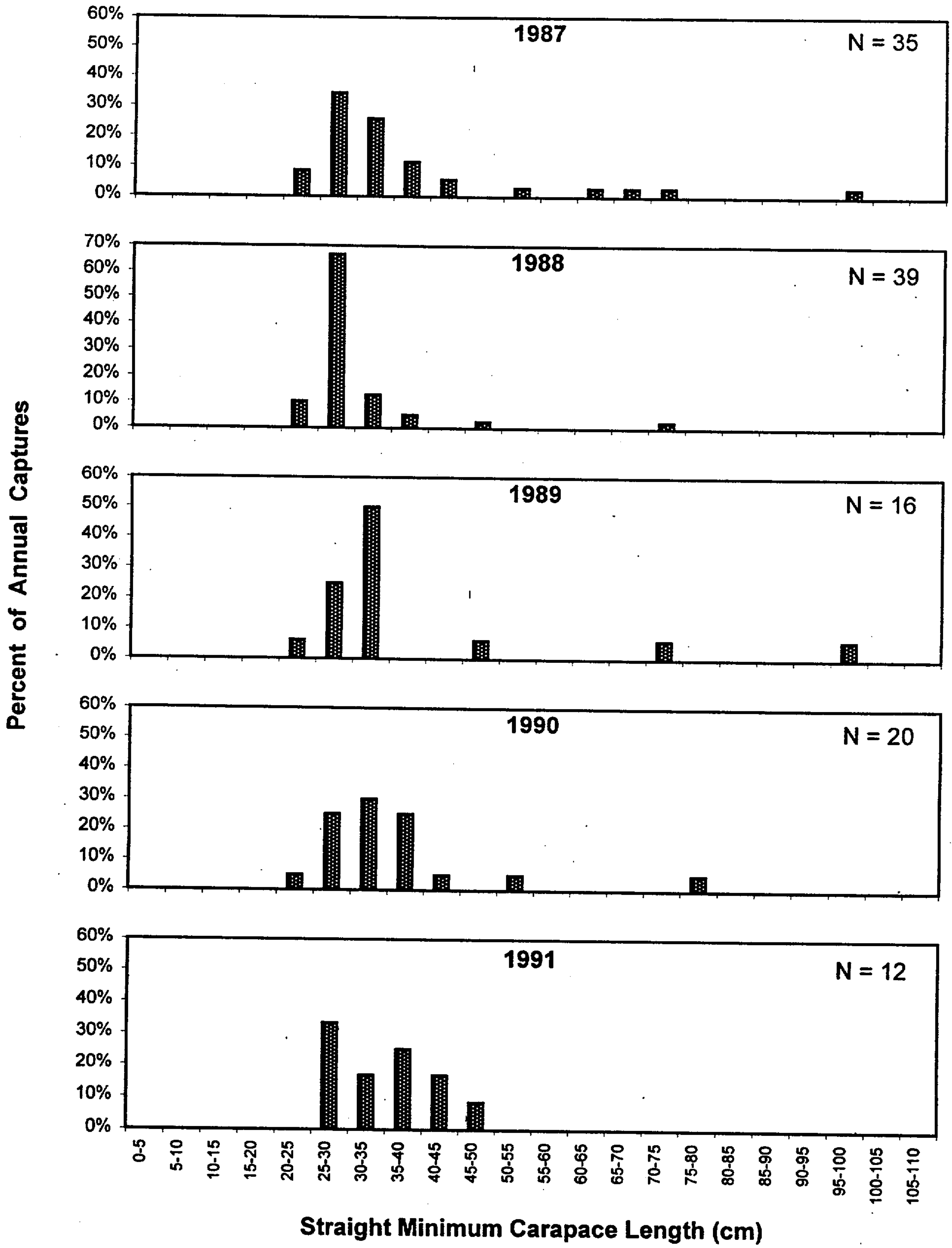


Figure 55. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

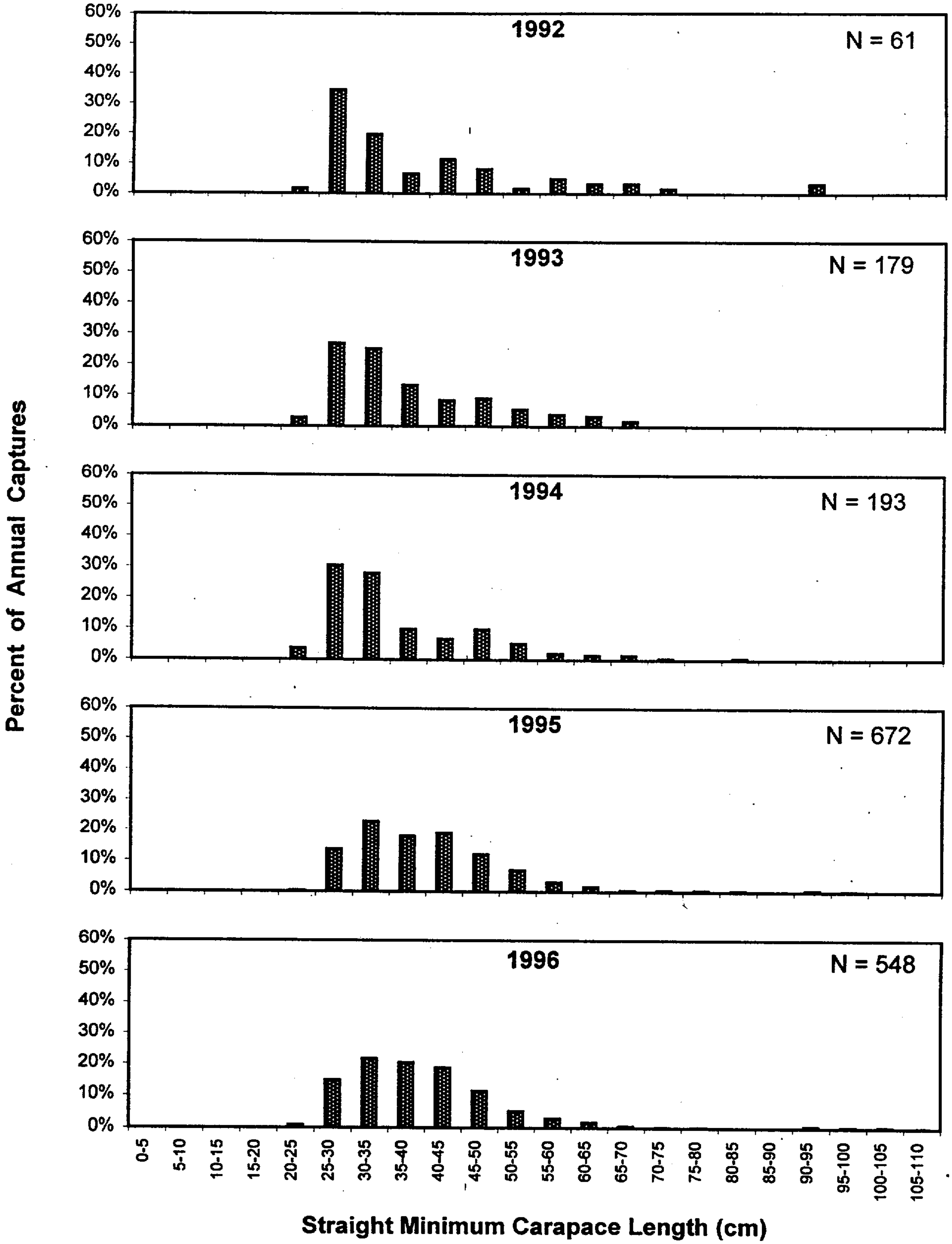


Figure 56. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

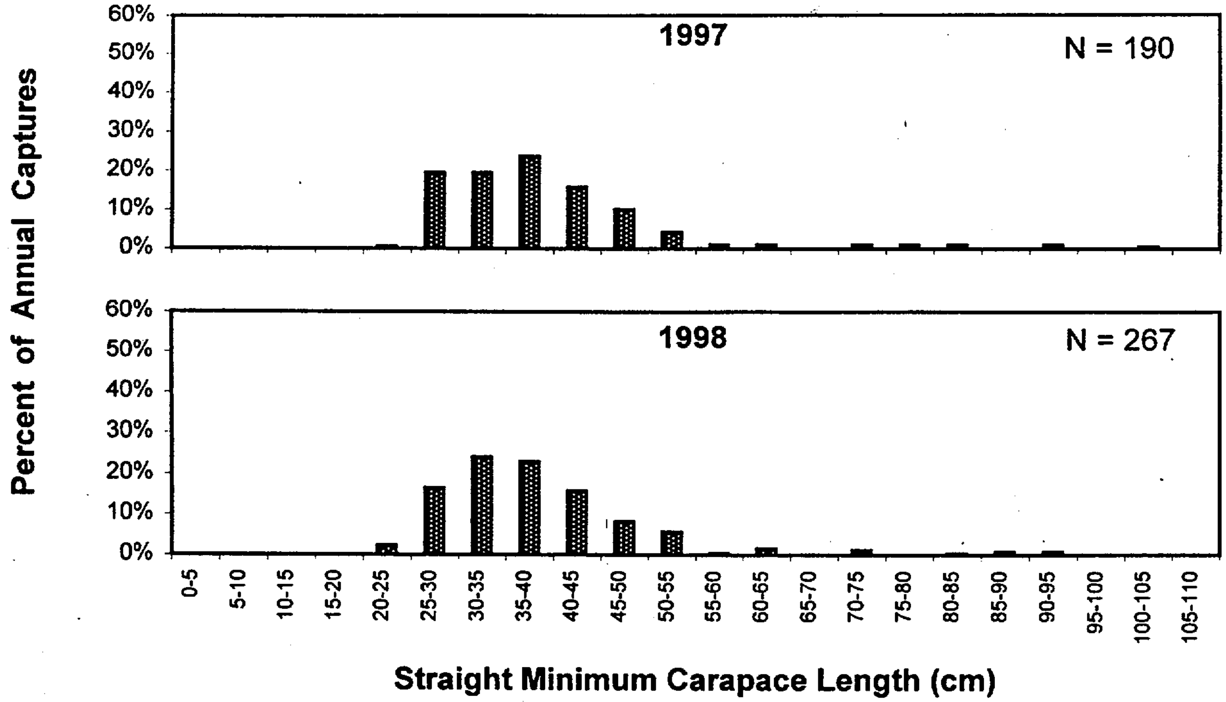


Figure 57. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

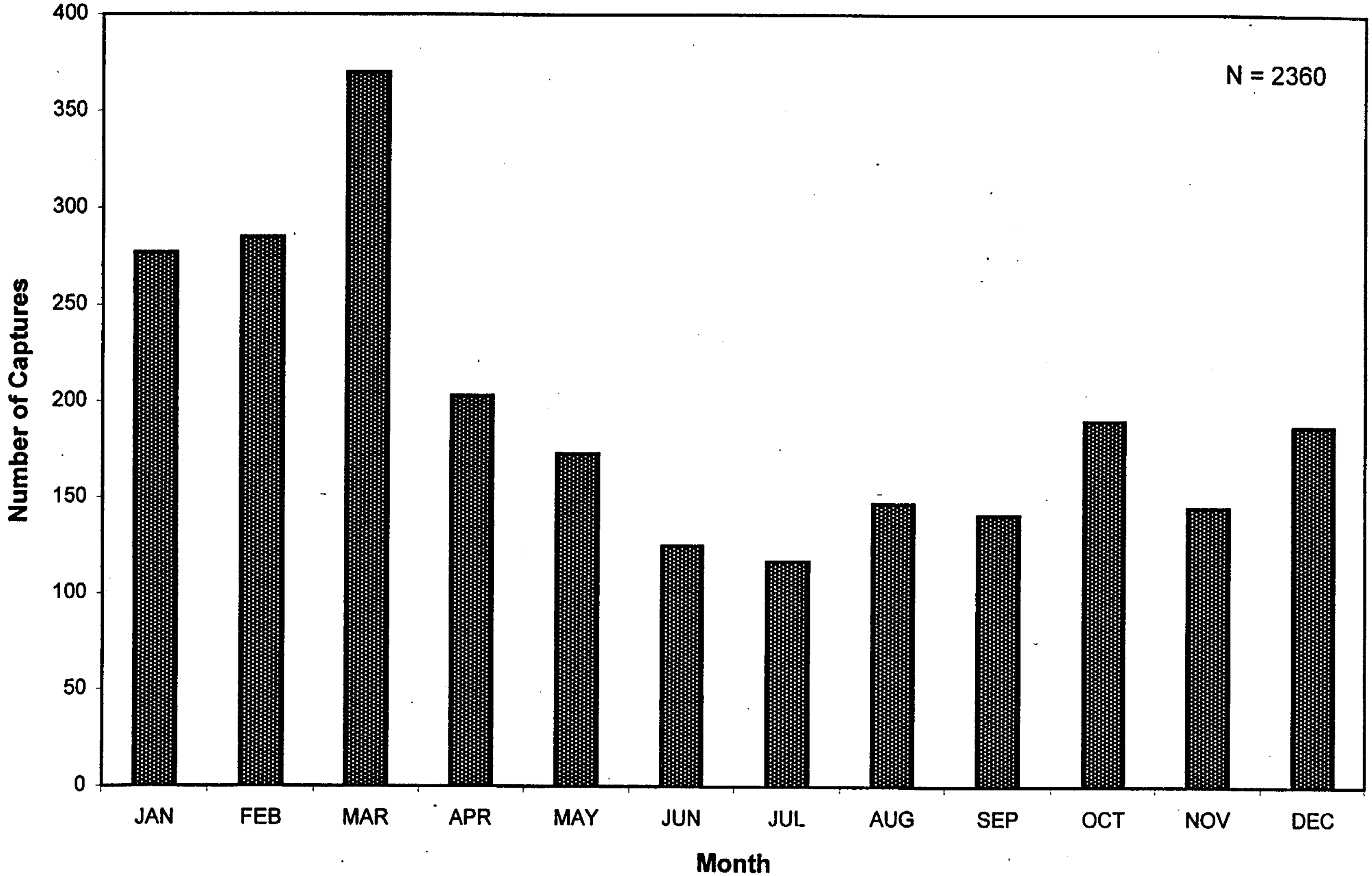


Figure 58. Number of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Note: no green turtles were captured during 1976.

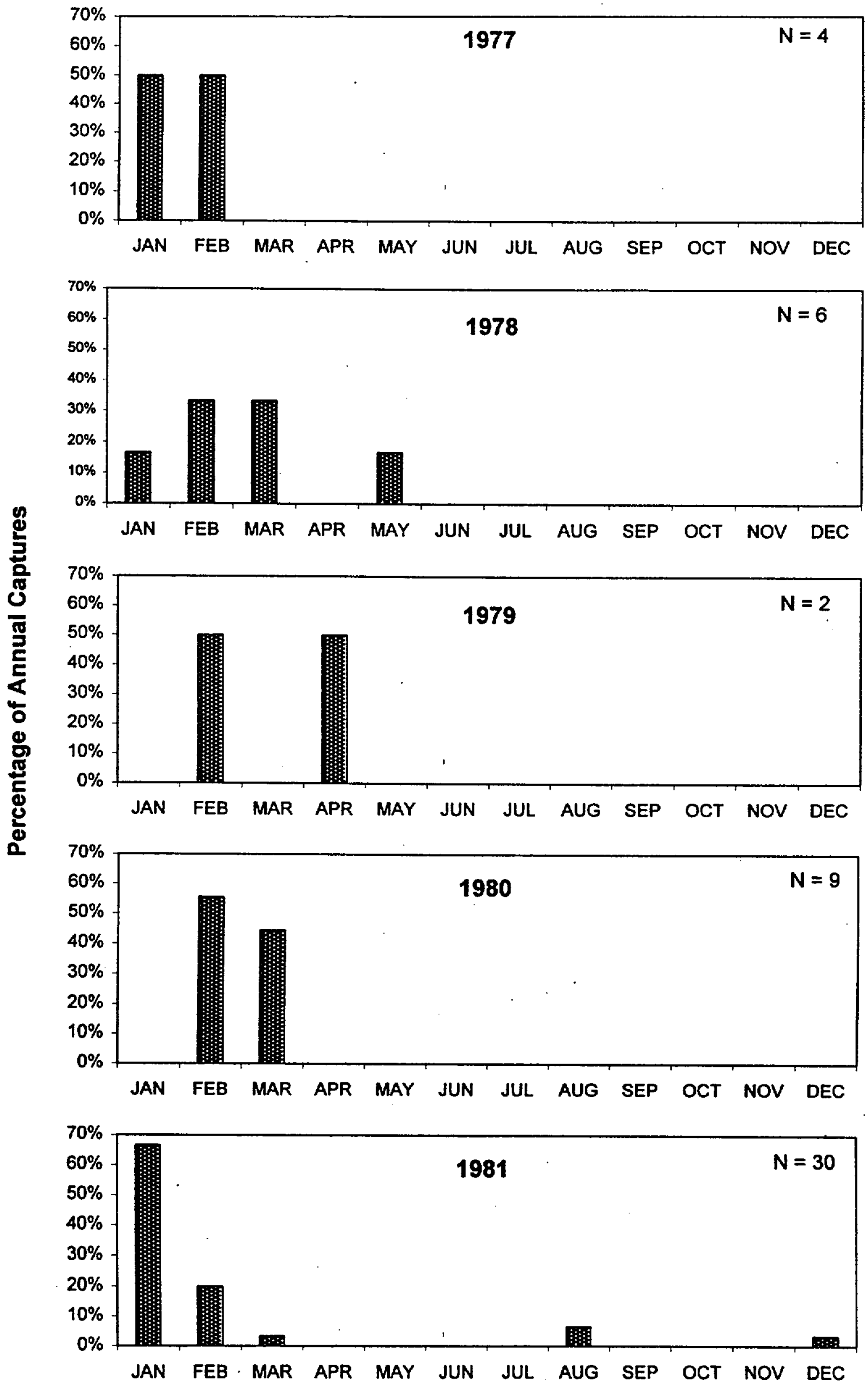


Figure 59. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Note: no green turtles were captured during 1976.

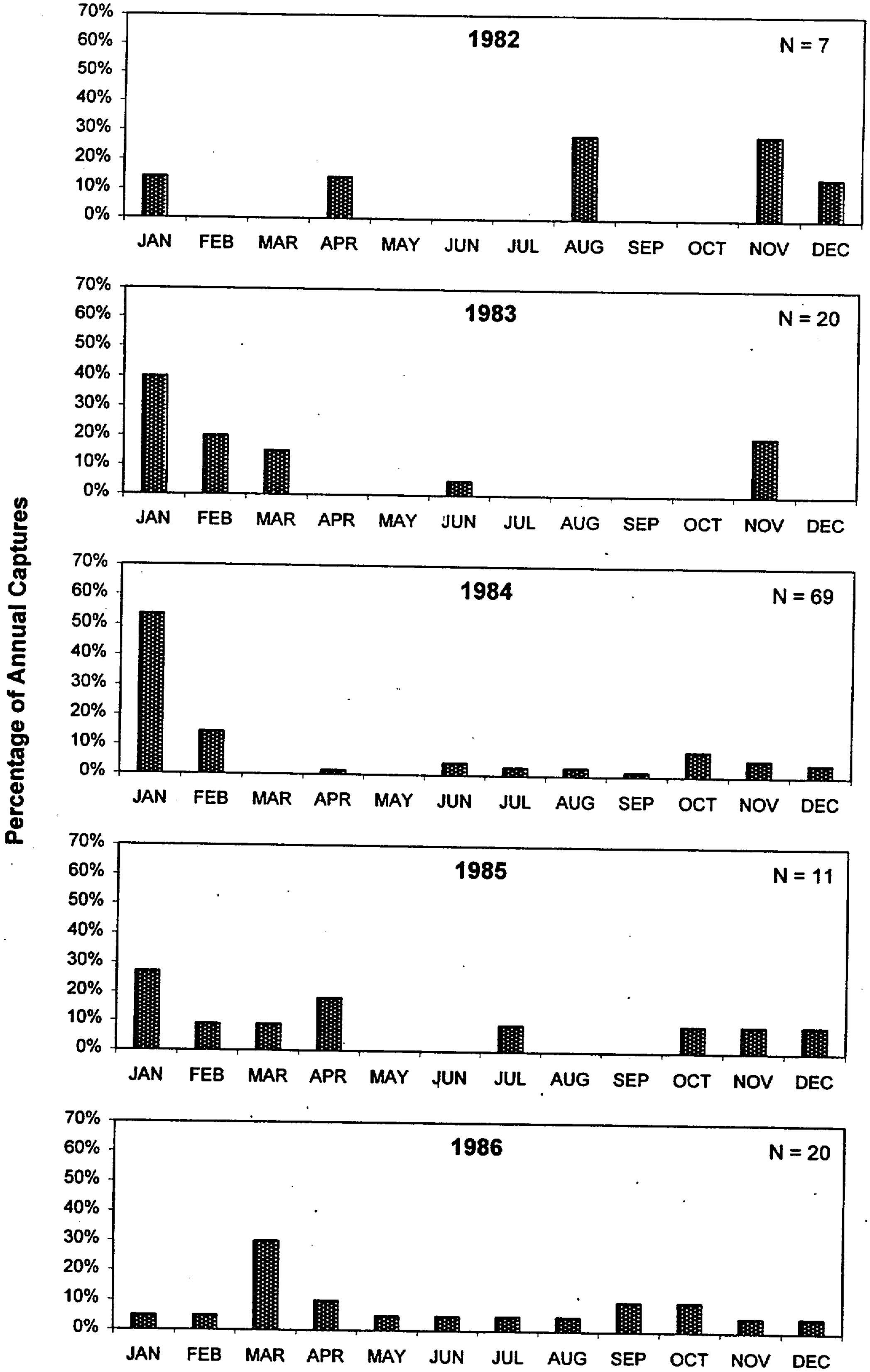


Figure 60. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

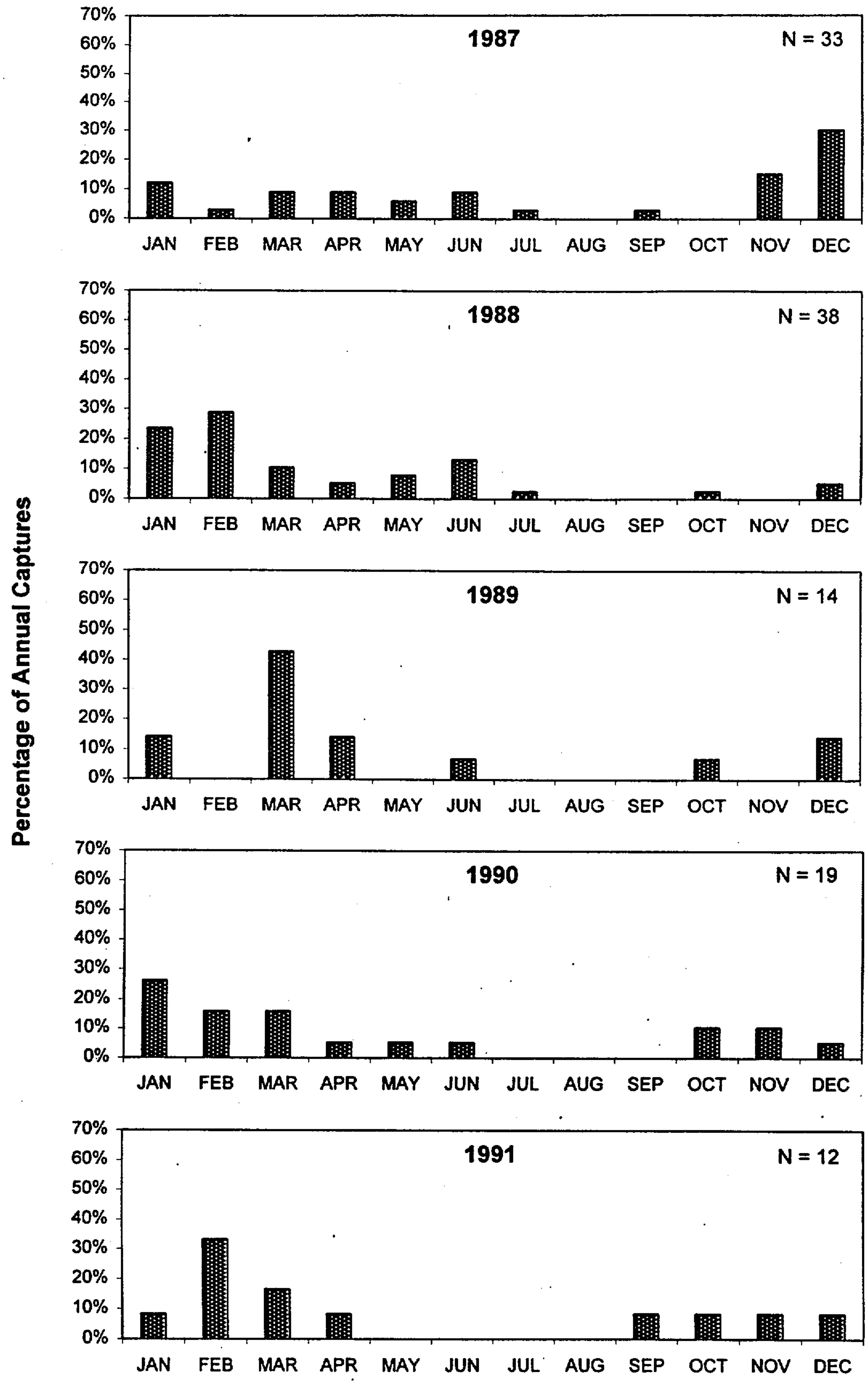


Figure 61. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

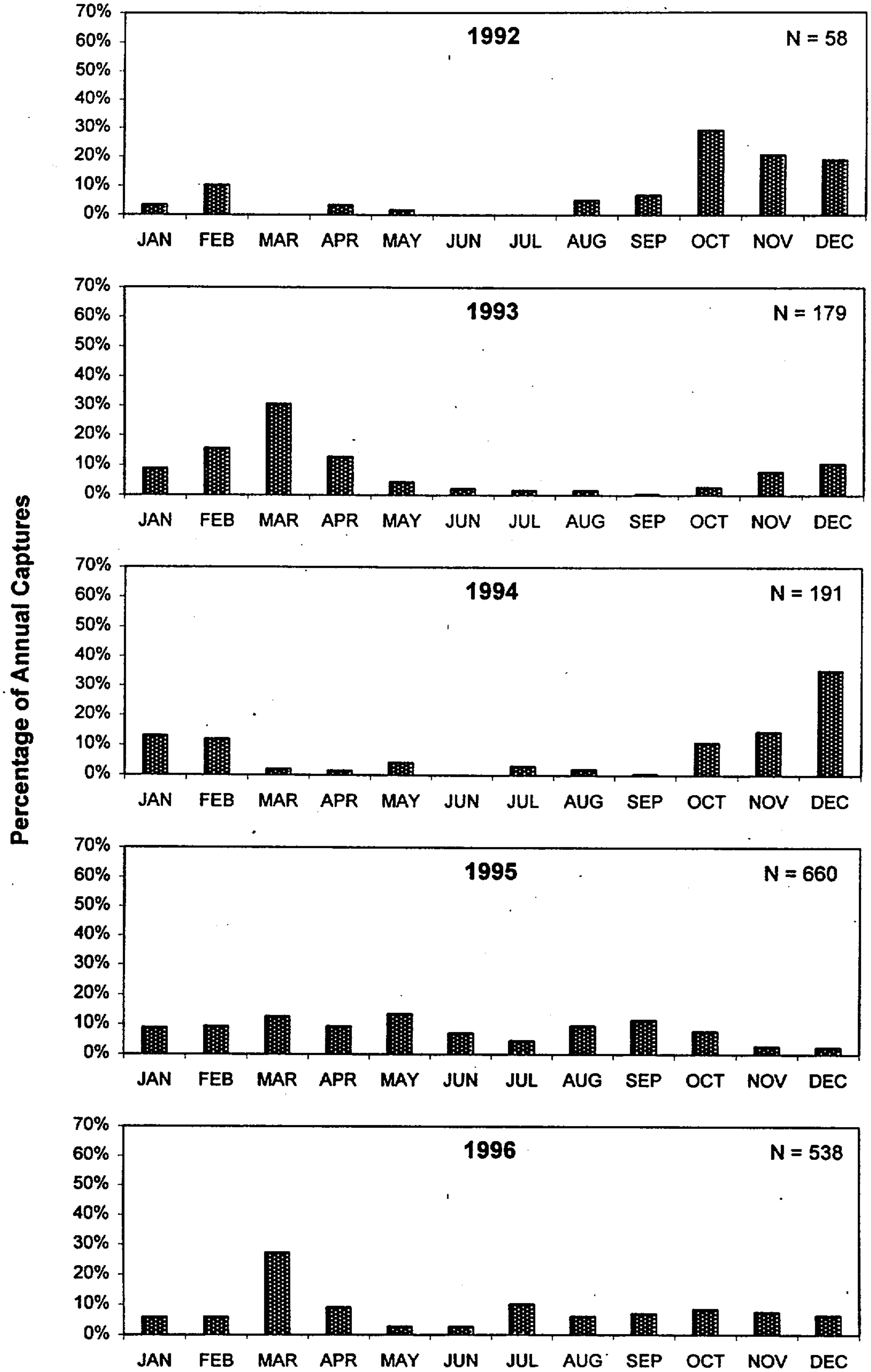


Figure 62. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

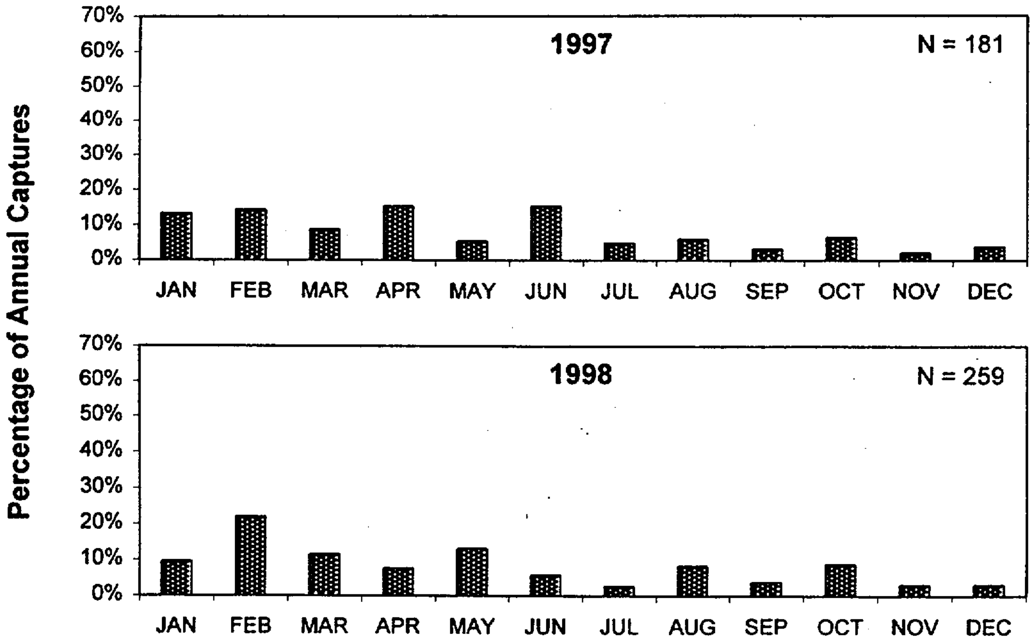


Figure 63. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

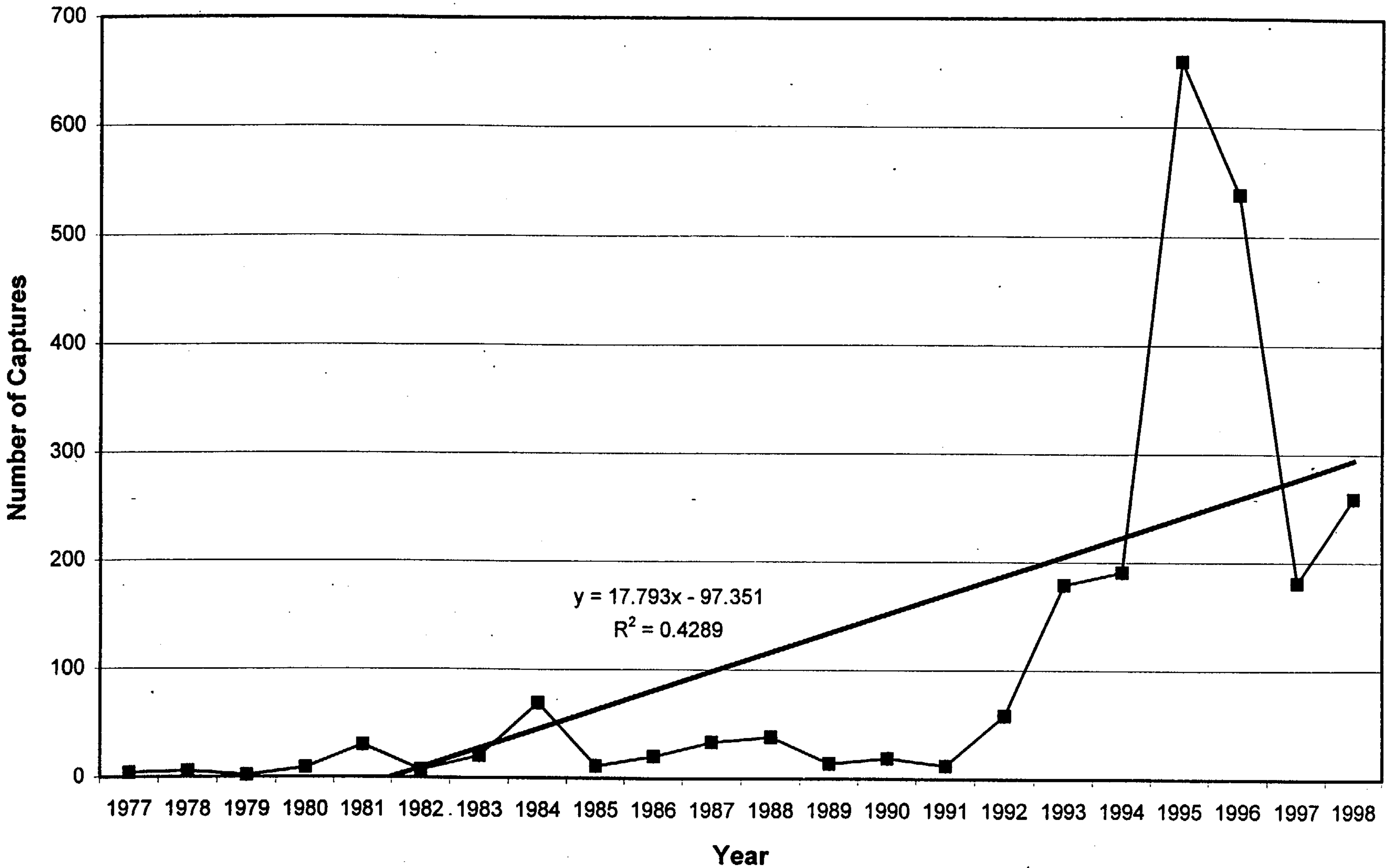


Figure 64. Annual number of juvenile green turtle captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1996 were excluded since the power plant did not begin operation until May of that year.

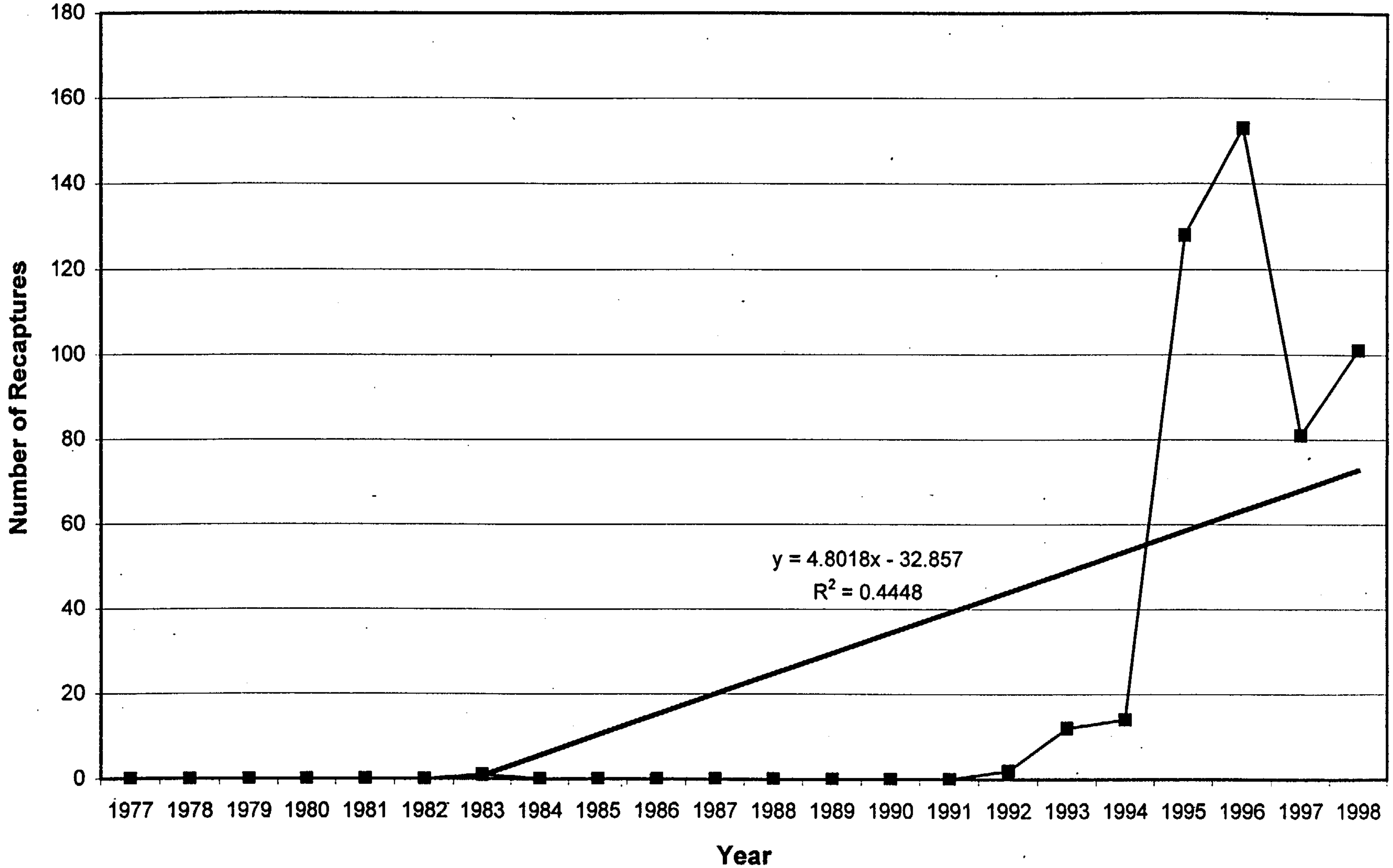


Figure 65. Annual number of juvenile green turtle recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977 1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

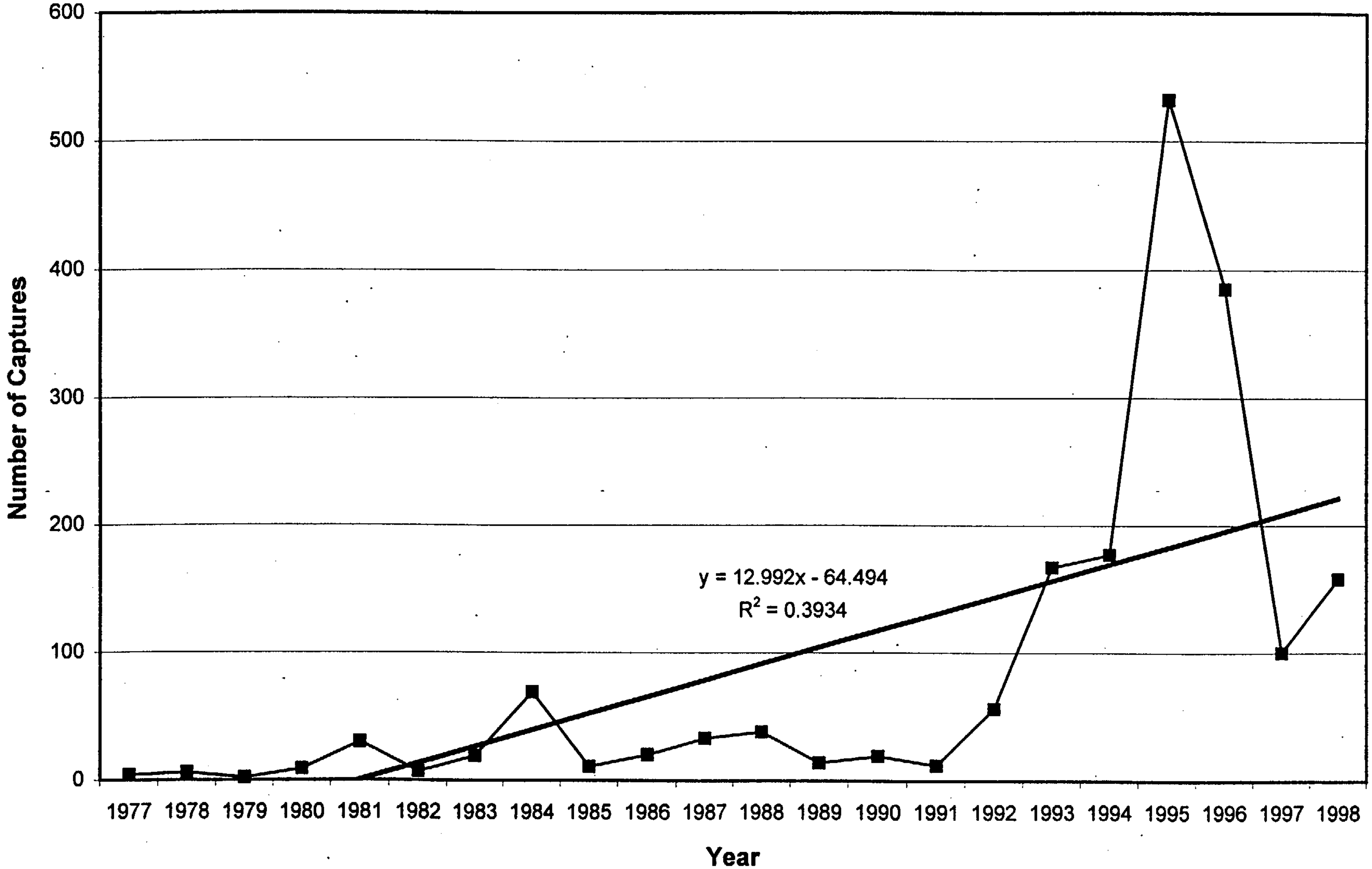


Figure 66. Annual number of juvenile green turtle captures excluding recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

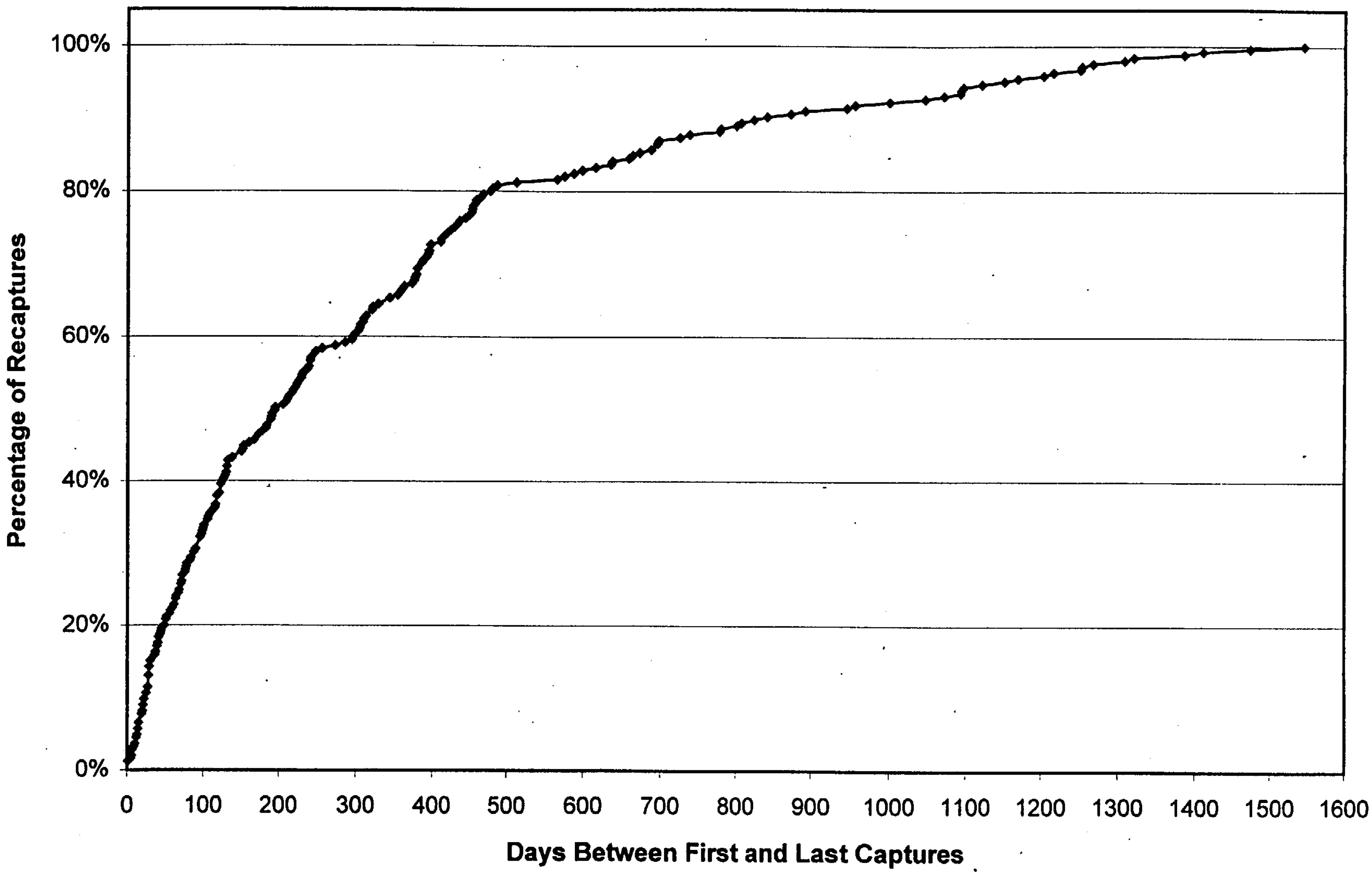


Figure 67. The percentage of juvenile green turtle recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

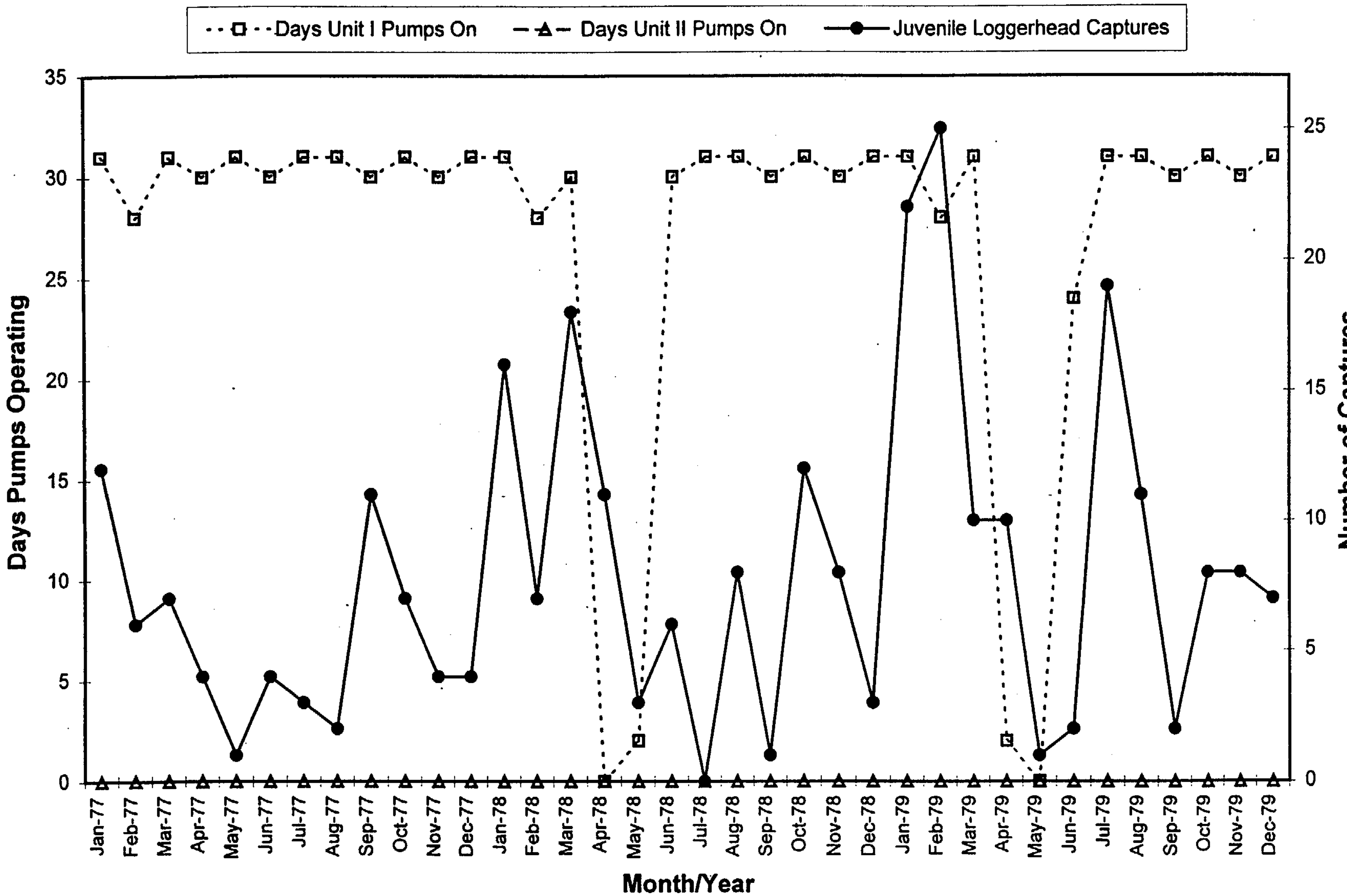


Figure 68. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1977 - December 1979.

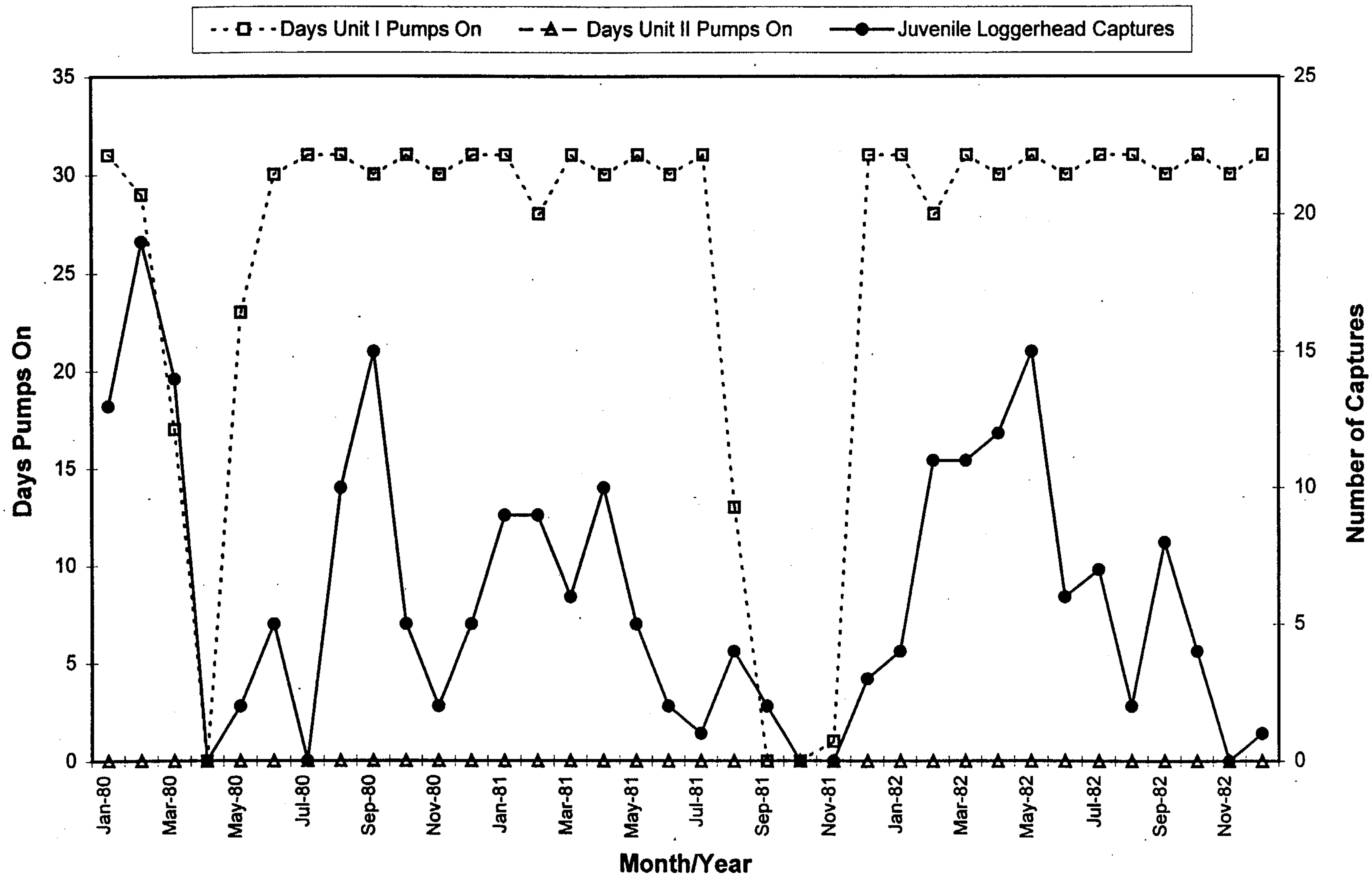


Figure 69. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1980 - December 1982.

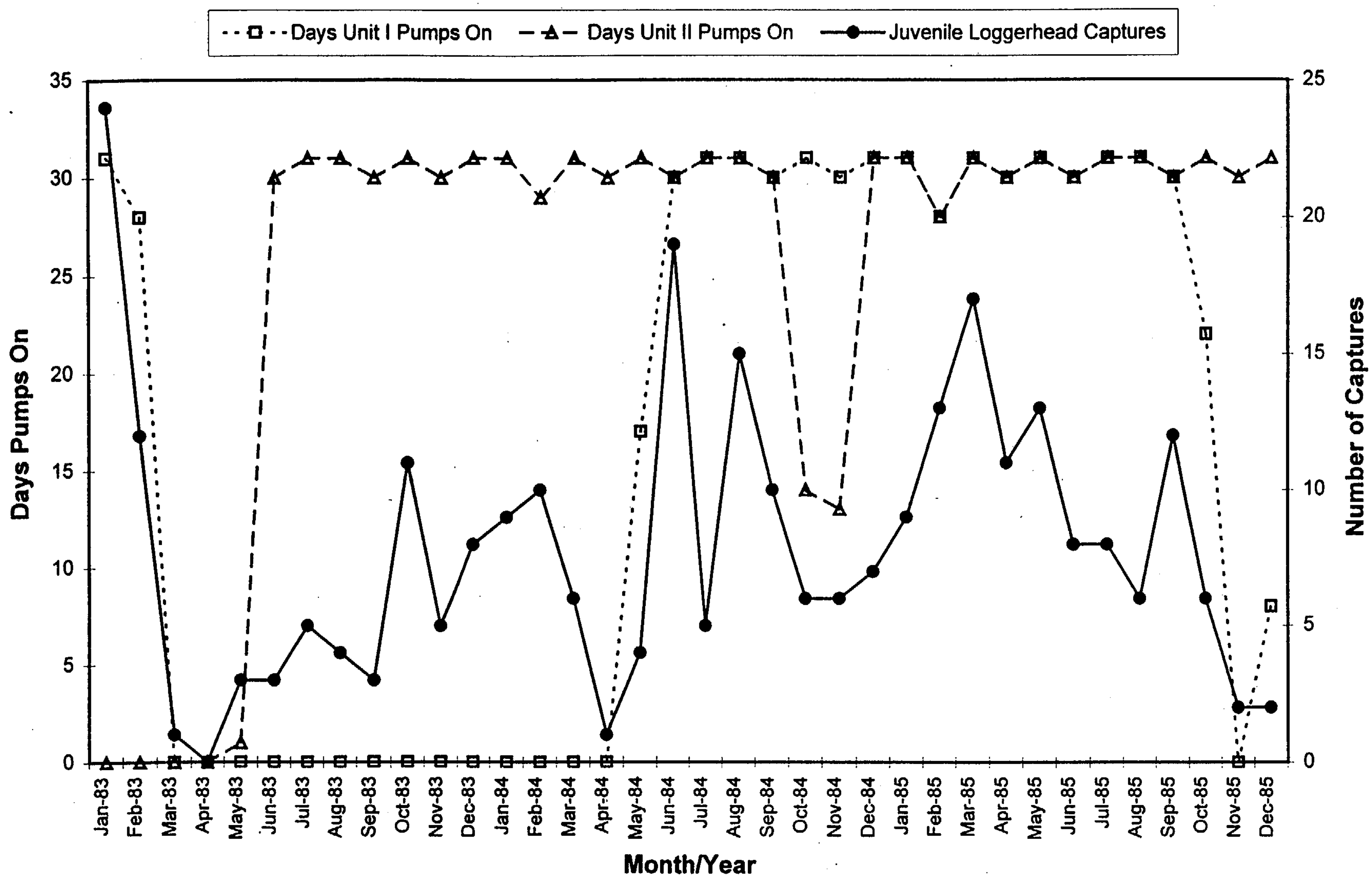


Figure 70. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1983 - December 1985.

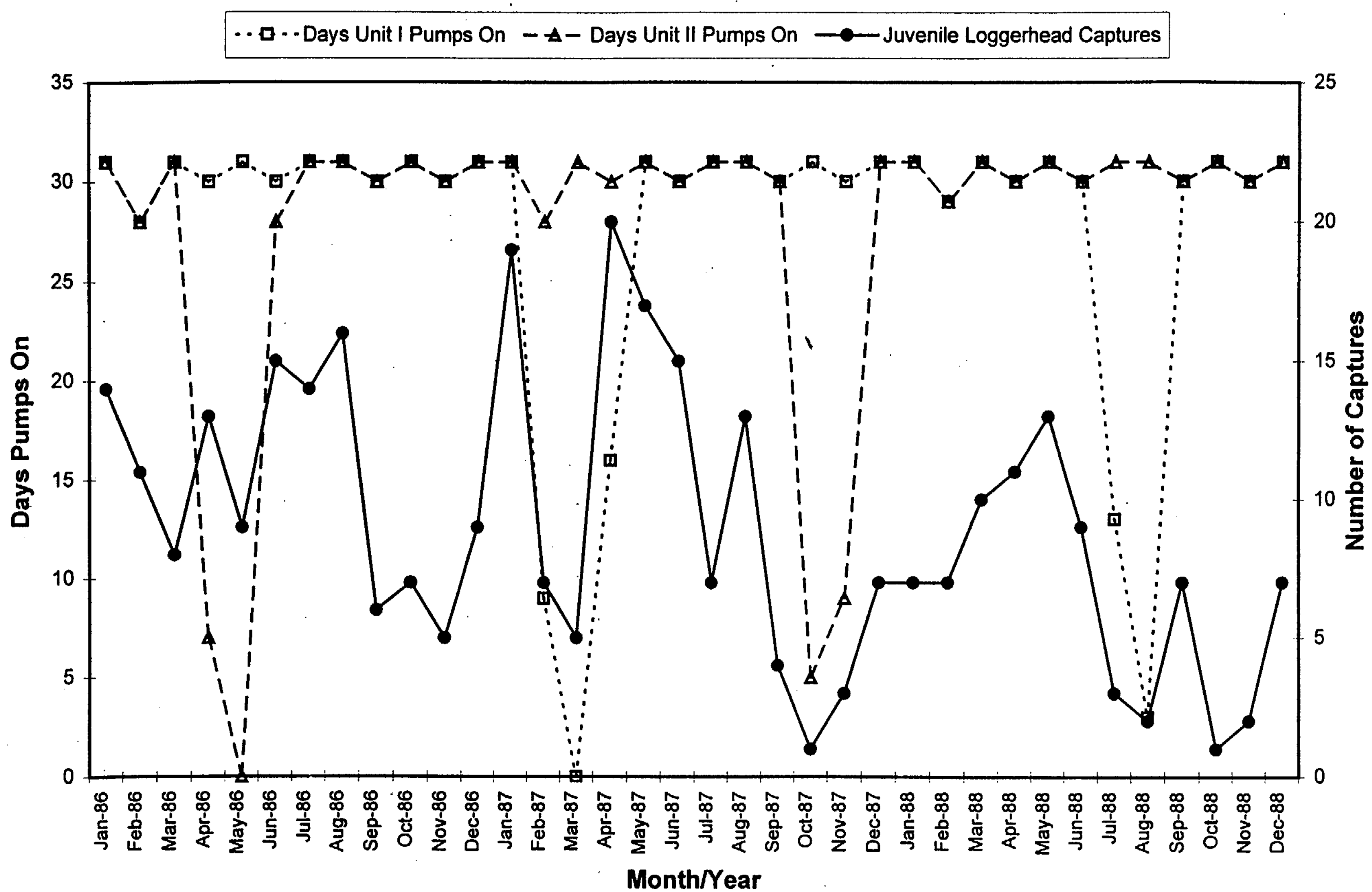


Figure 71. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1986 - December 1988.

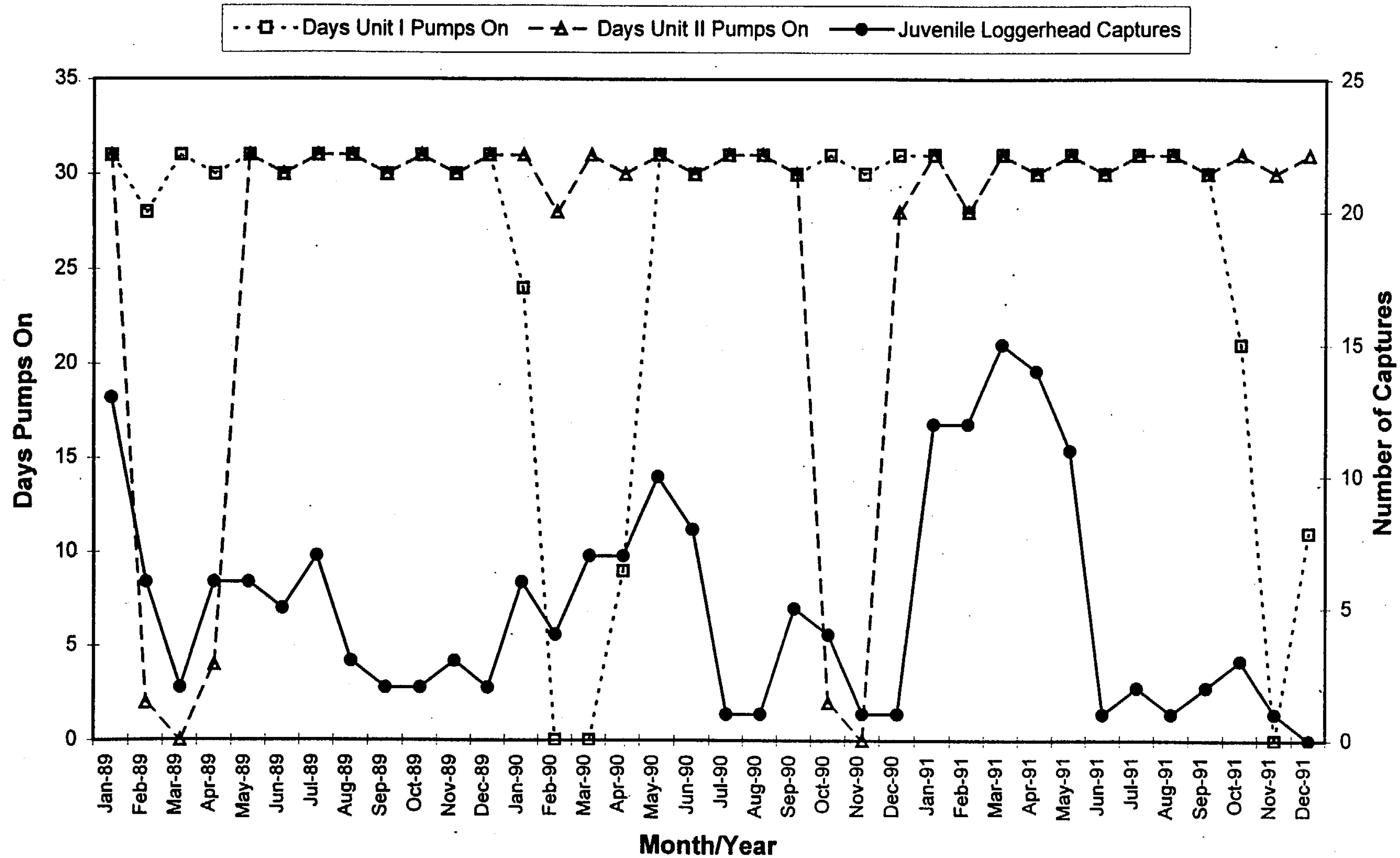


Figure 72. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1989 - December 1991.

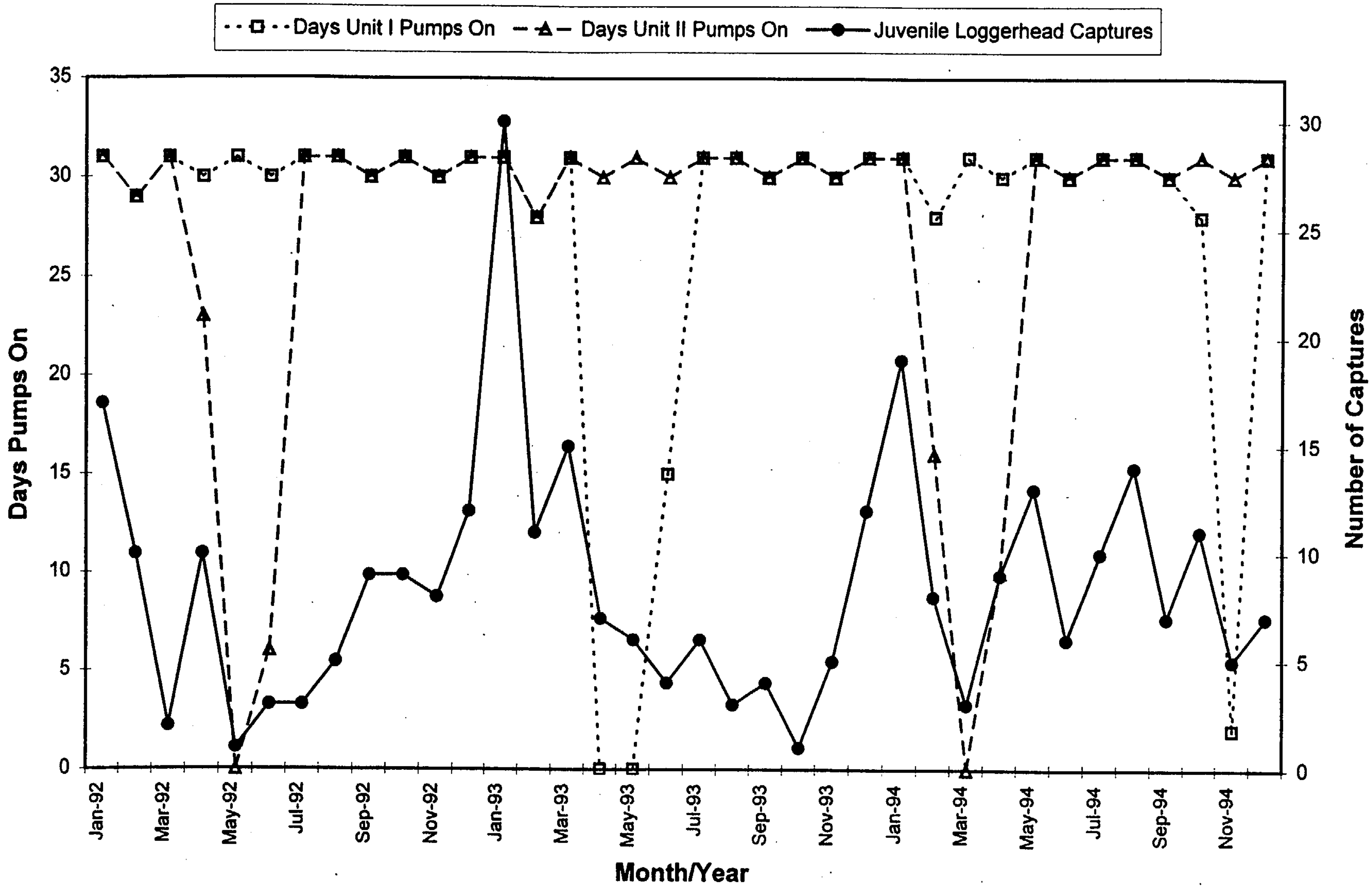


Figure 73. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1992 - December 1994.

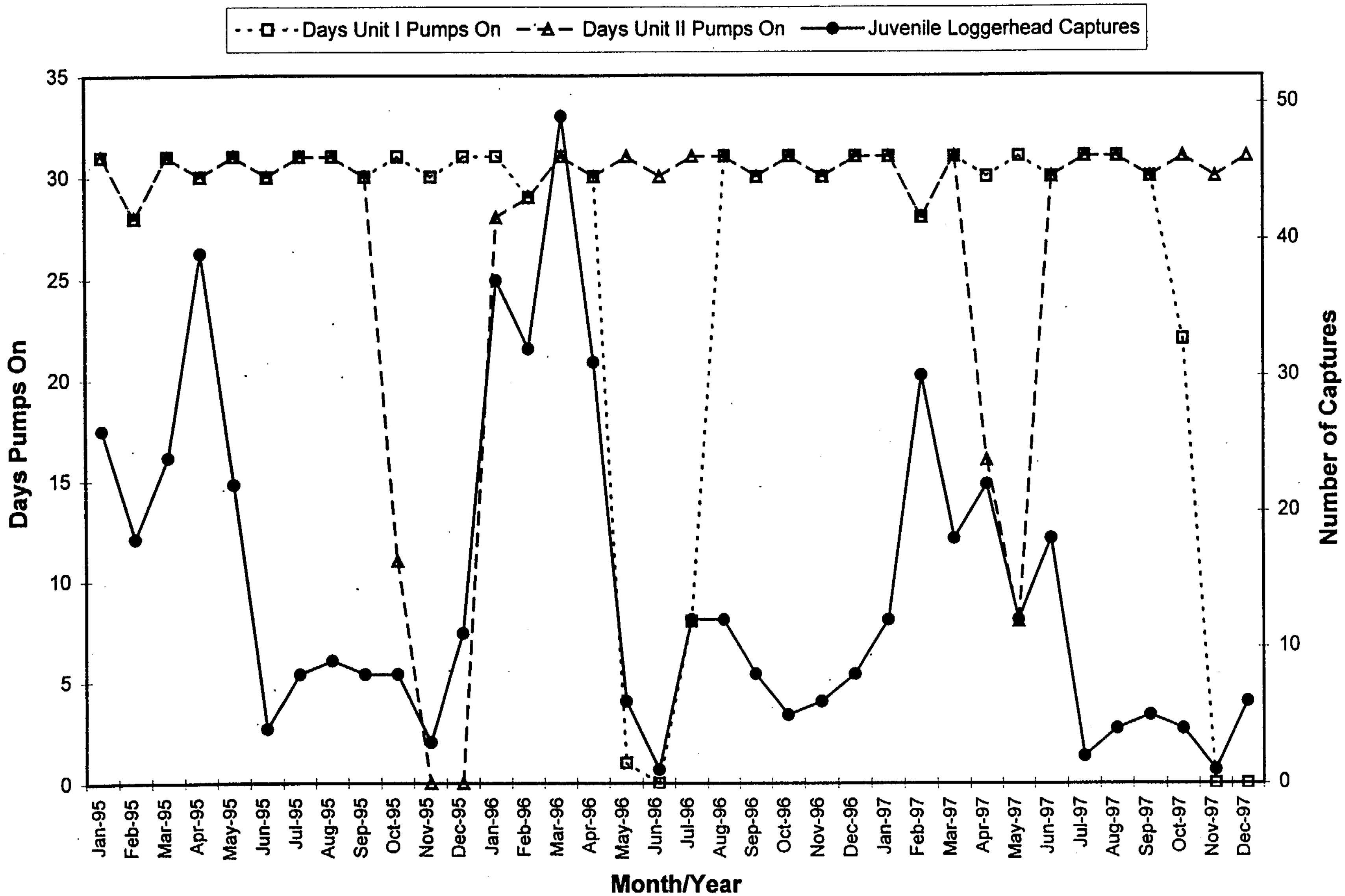


Figure 74. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1995 - December 1997.

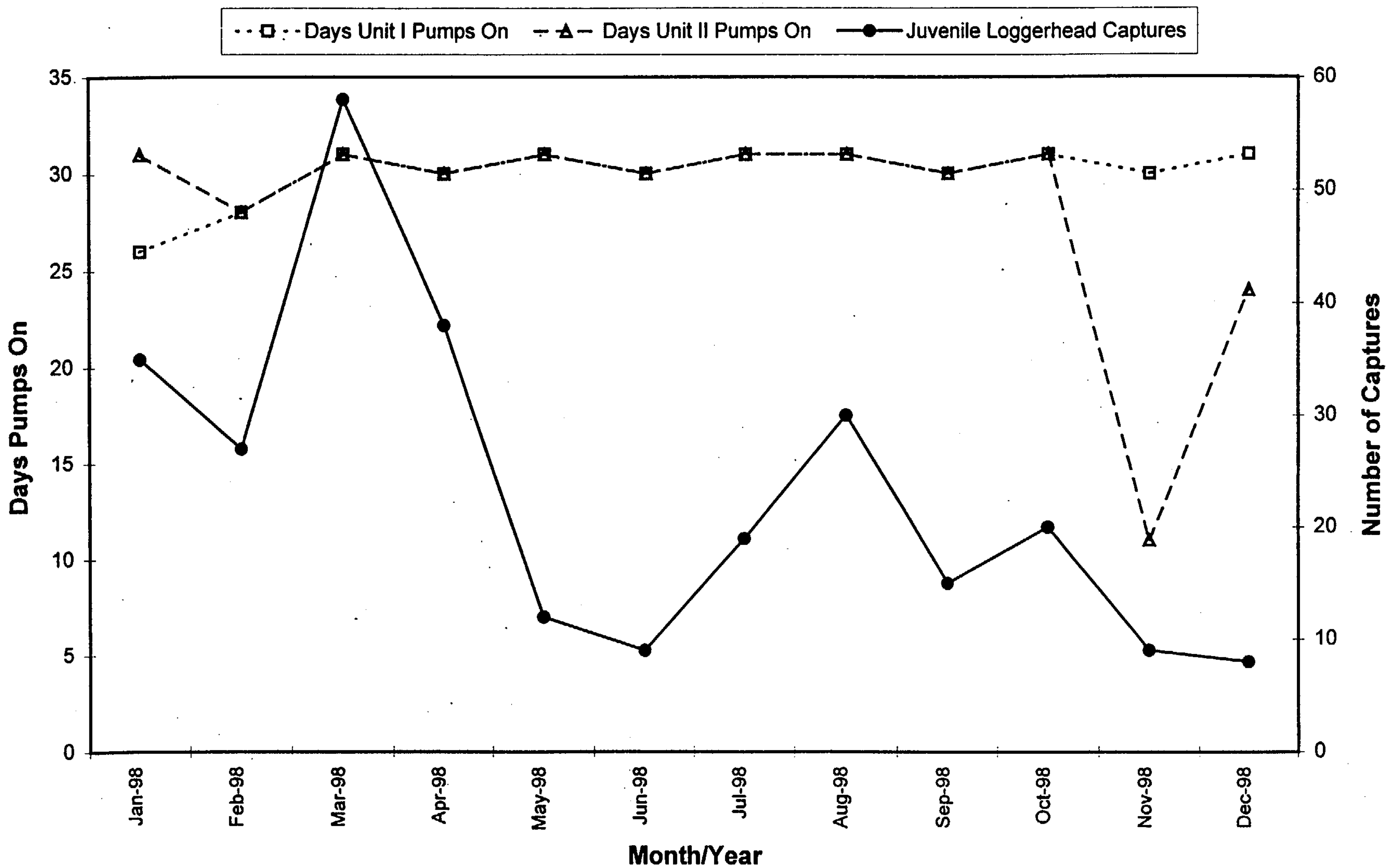


Figure 75. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1998 - December 1998.

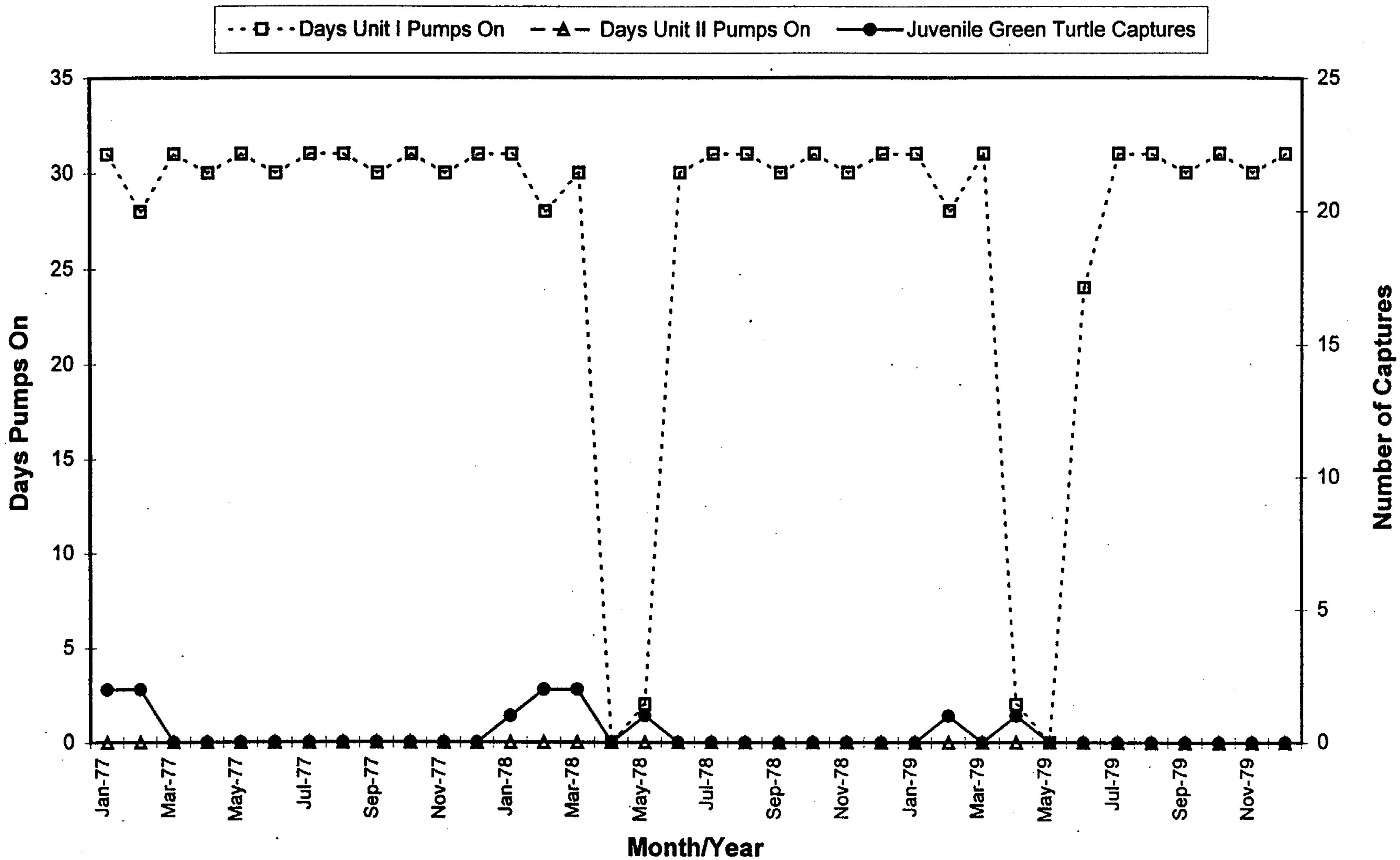


Figure 76. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1977 - December 1979.

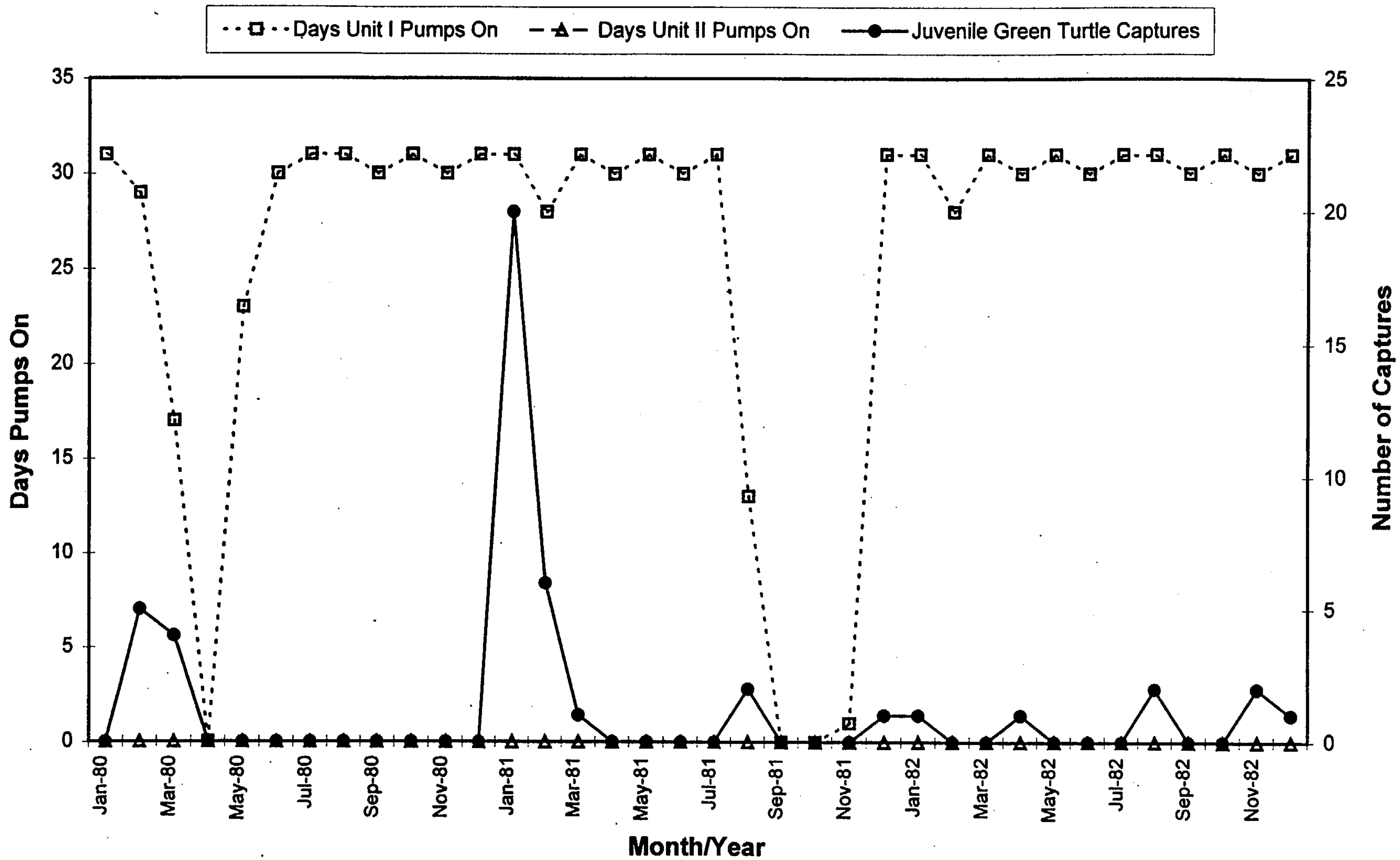


Figure 77. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1980 - December 1982.

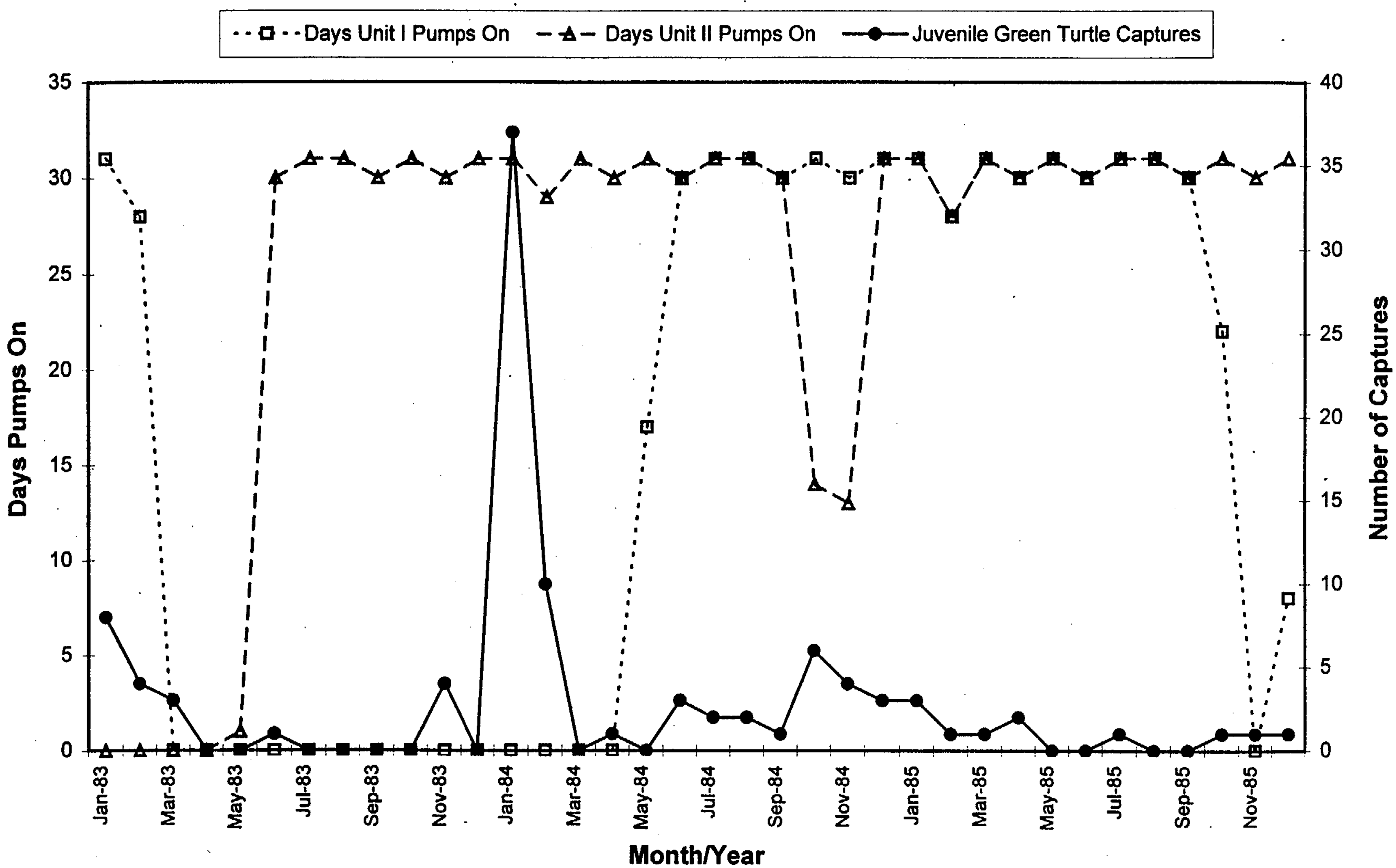


Figure 78. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1983 - December 1985.

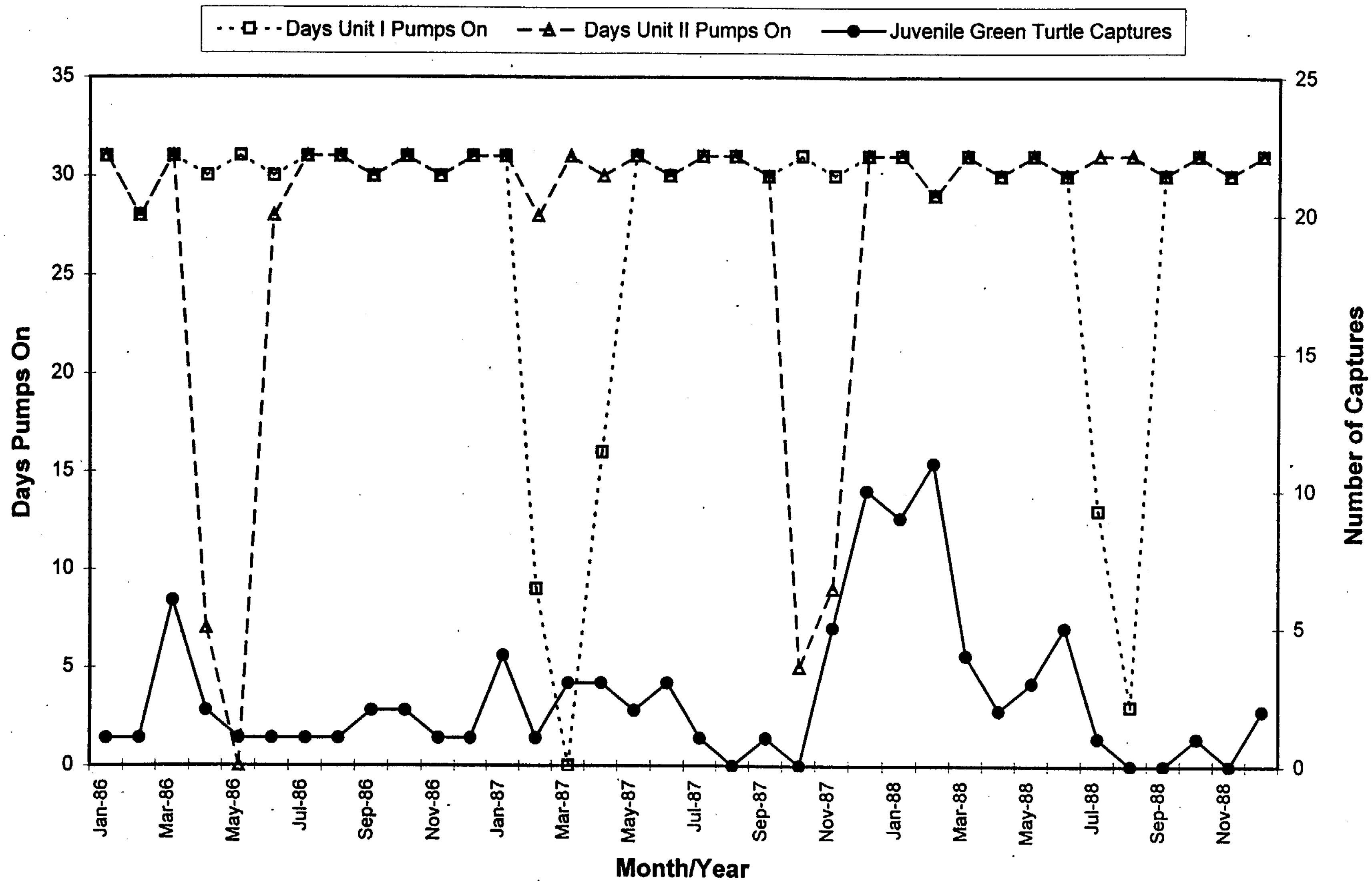


Figure 79. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1986 - December 1988.

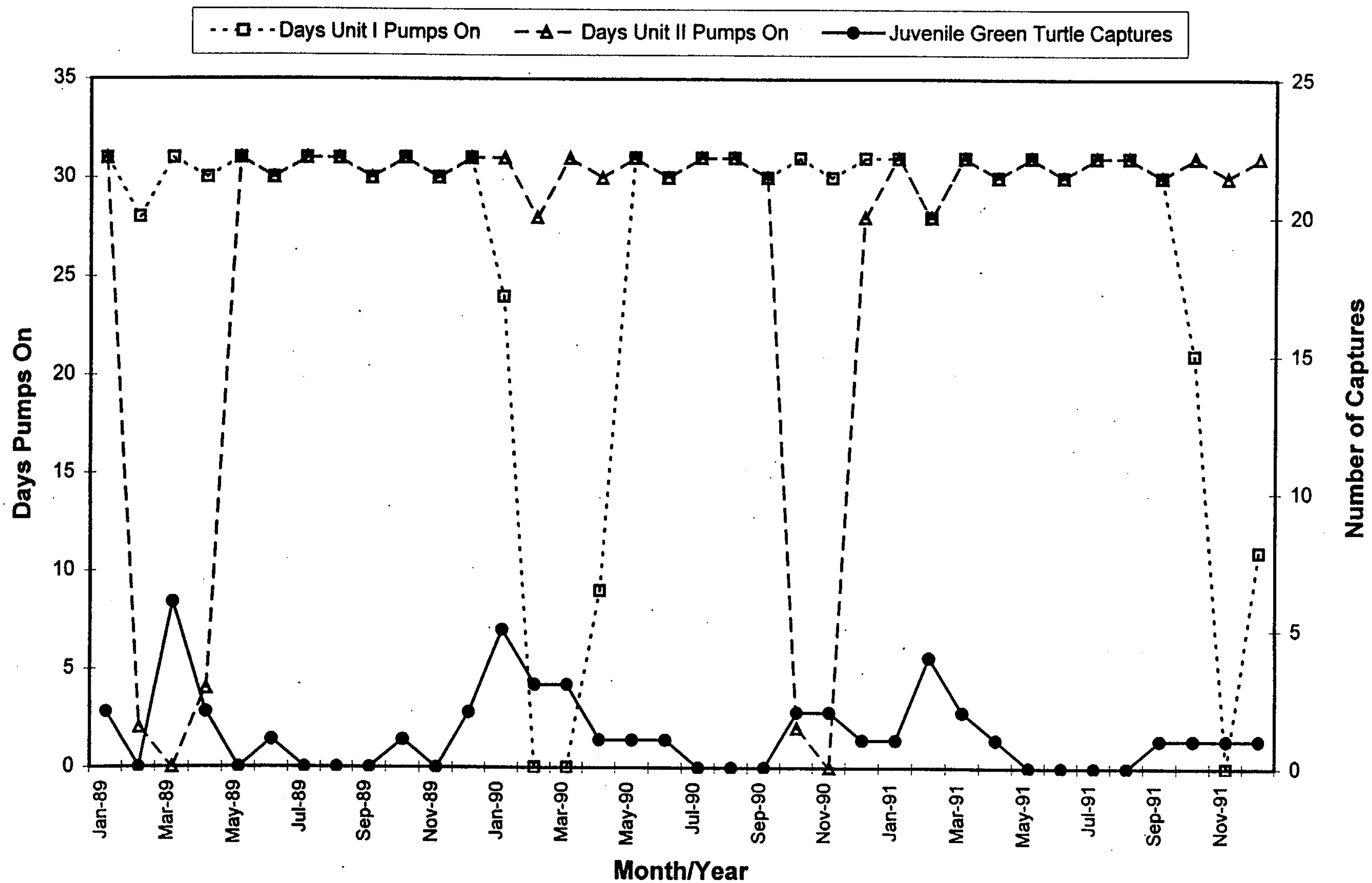


Figure 80. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1989 - December 1991.

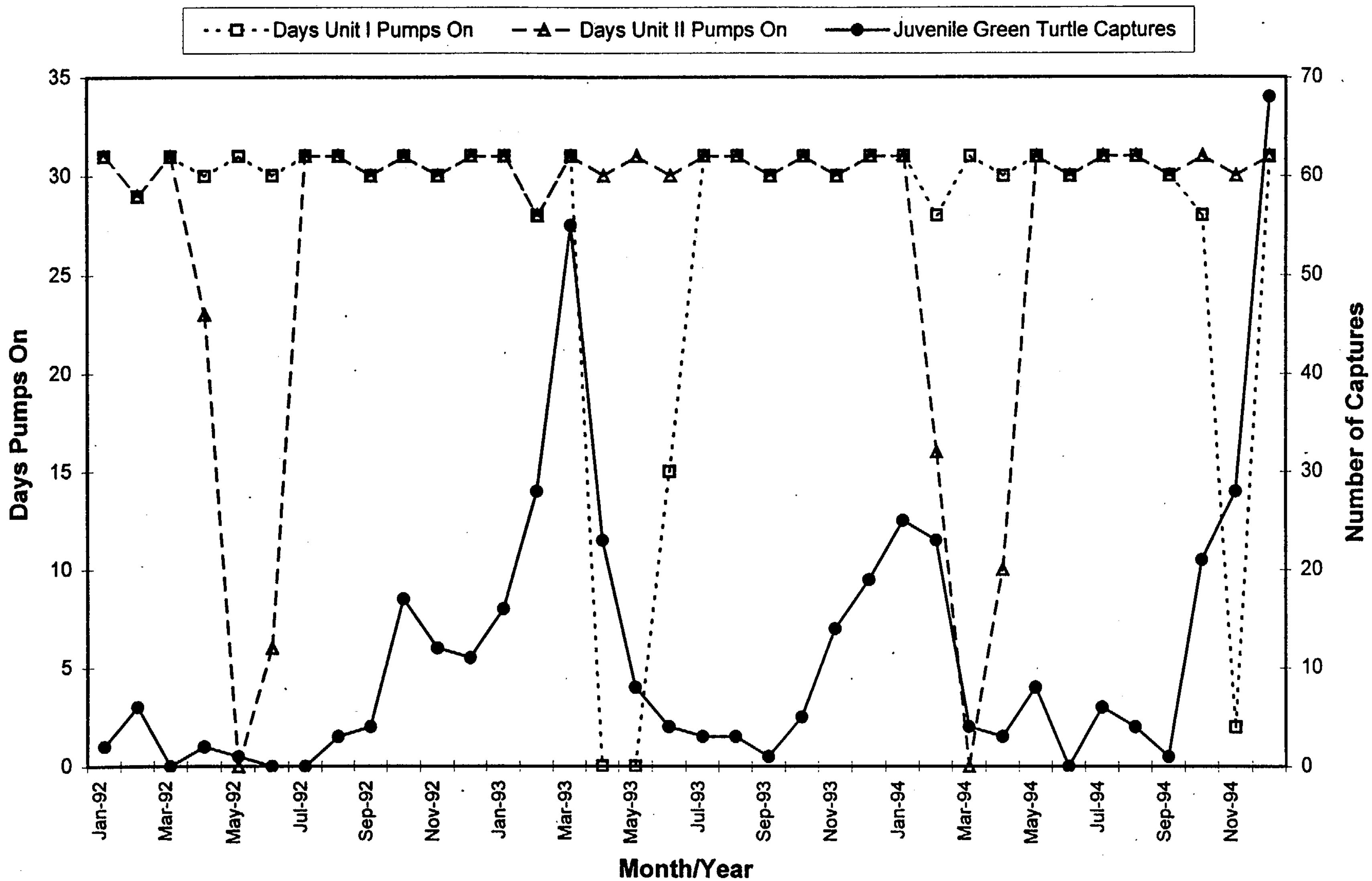


Figure 81. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1992 - December 1994.

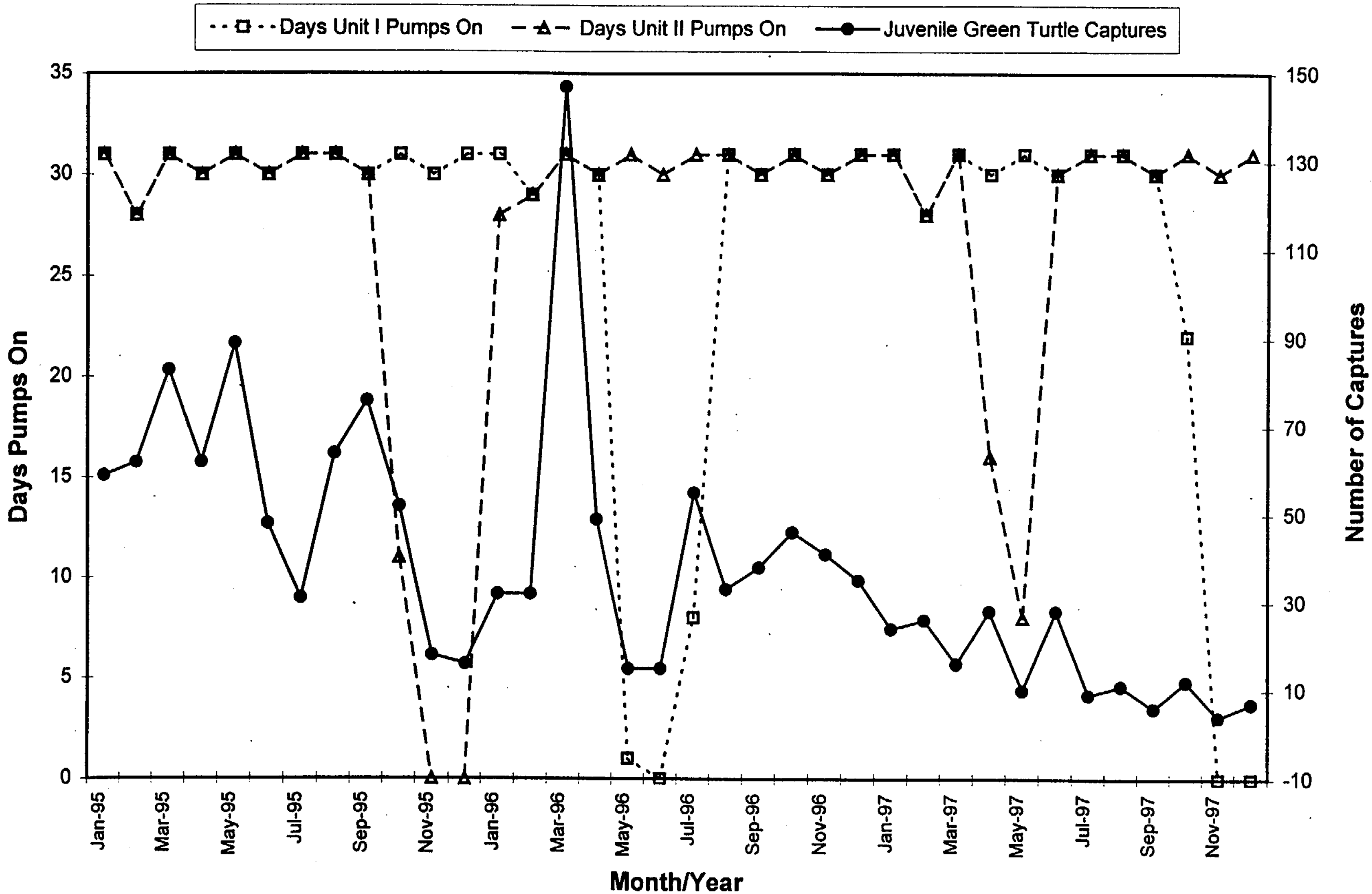


Figure 82. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1995 - December 1997.

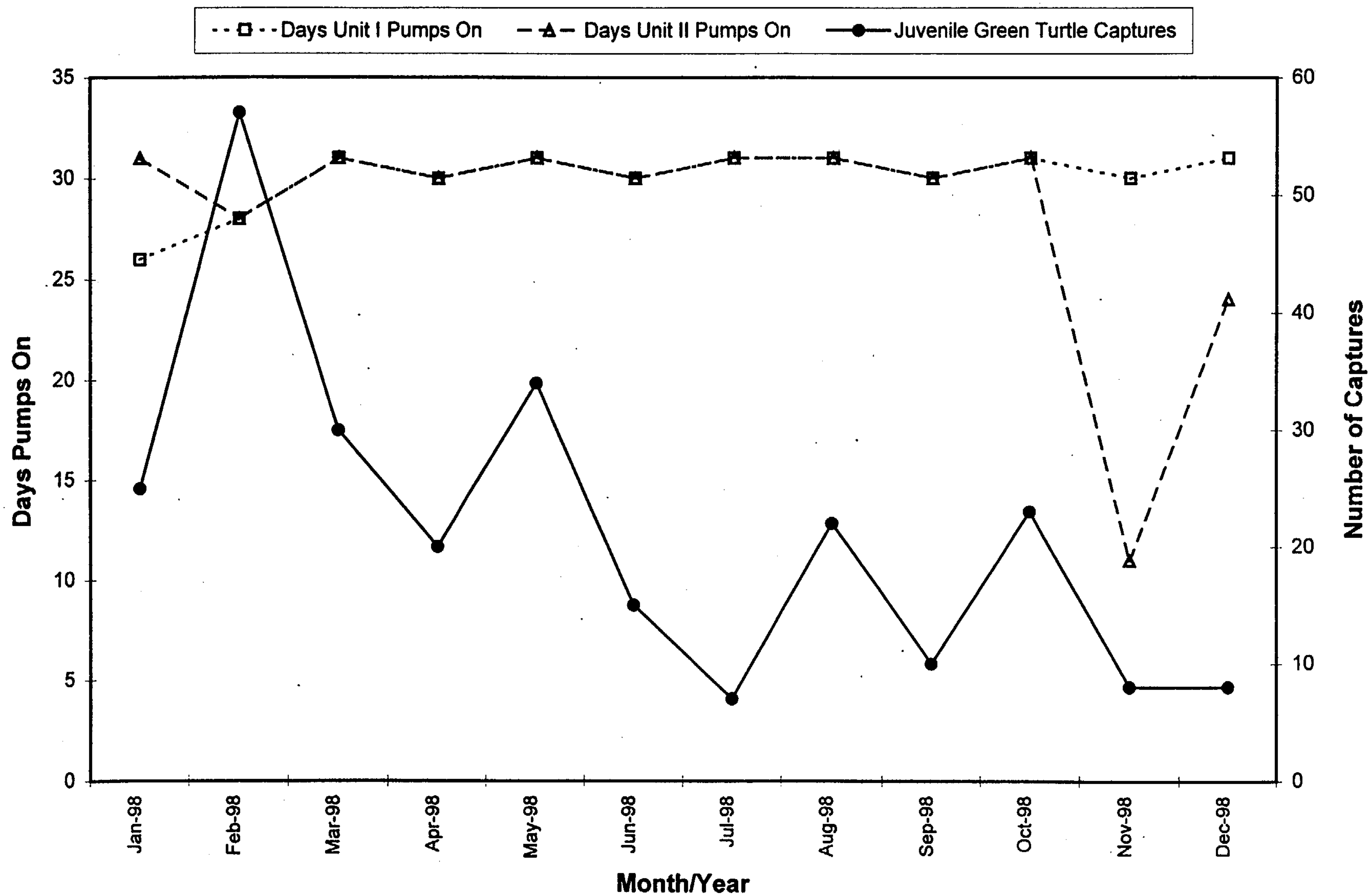


Figure 83. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1998 - December 1998.

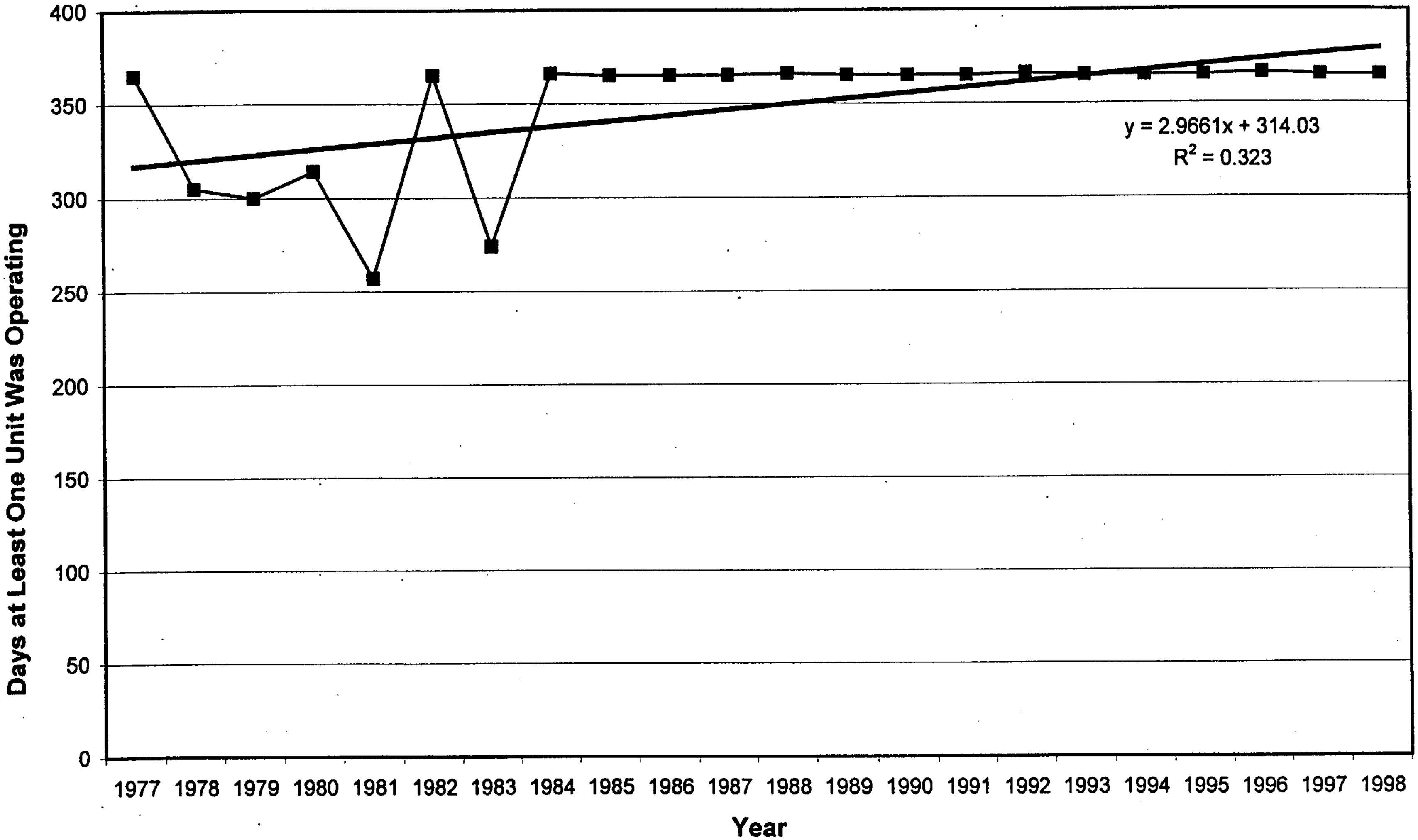


Figure 84. St. Lucie Plant operating status (the approximate number of days per year that at least one unit's circulating water pumps were operating), 1977-1998.

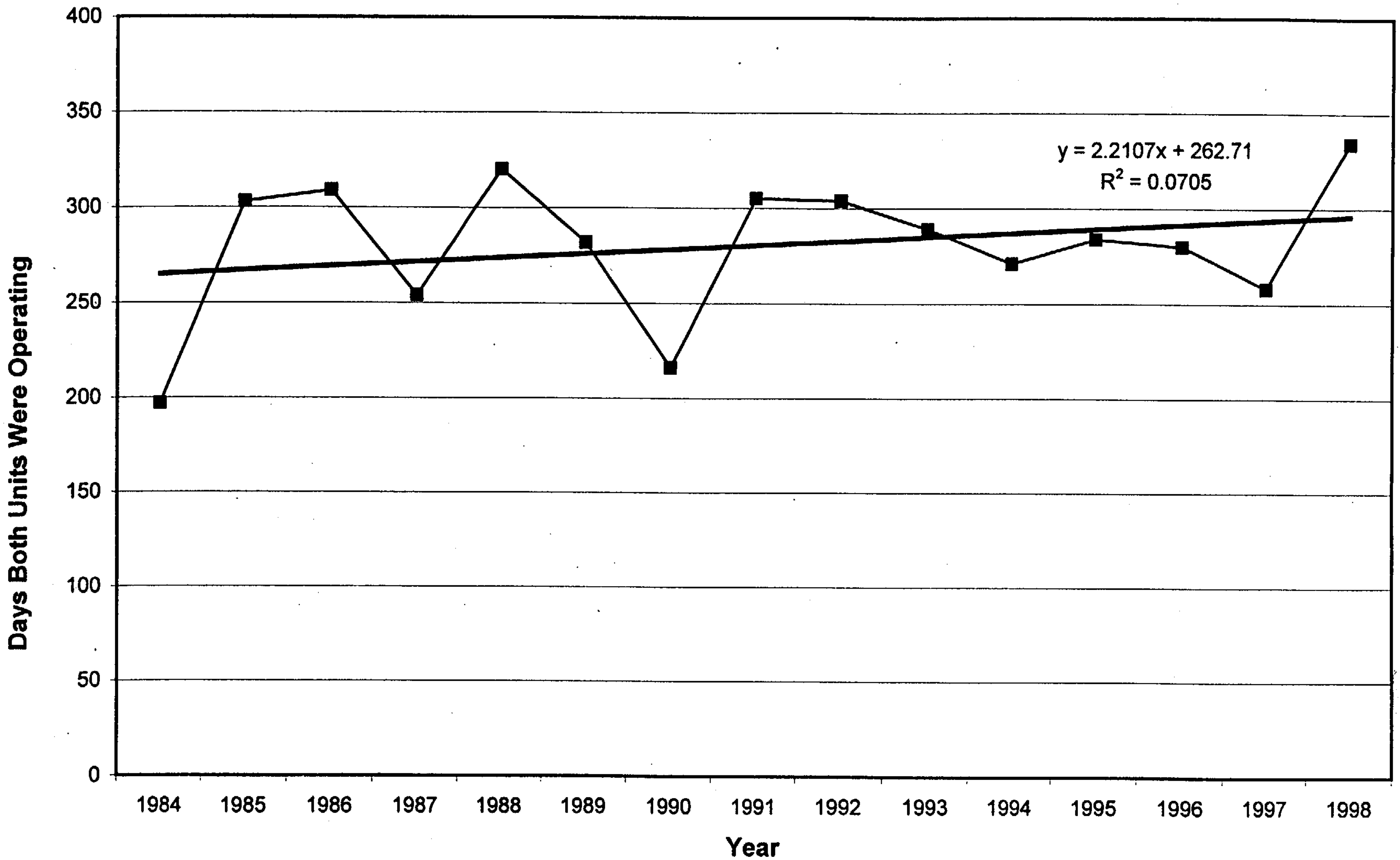


Figure 85. St. Lucie Plant operating status (the approximate number of days per year that circulating water pumps at both units were operating), 1984-1998.

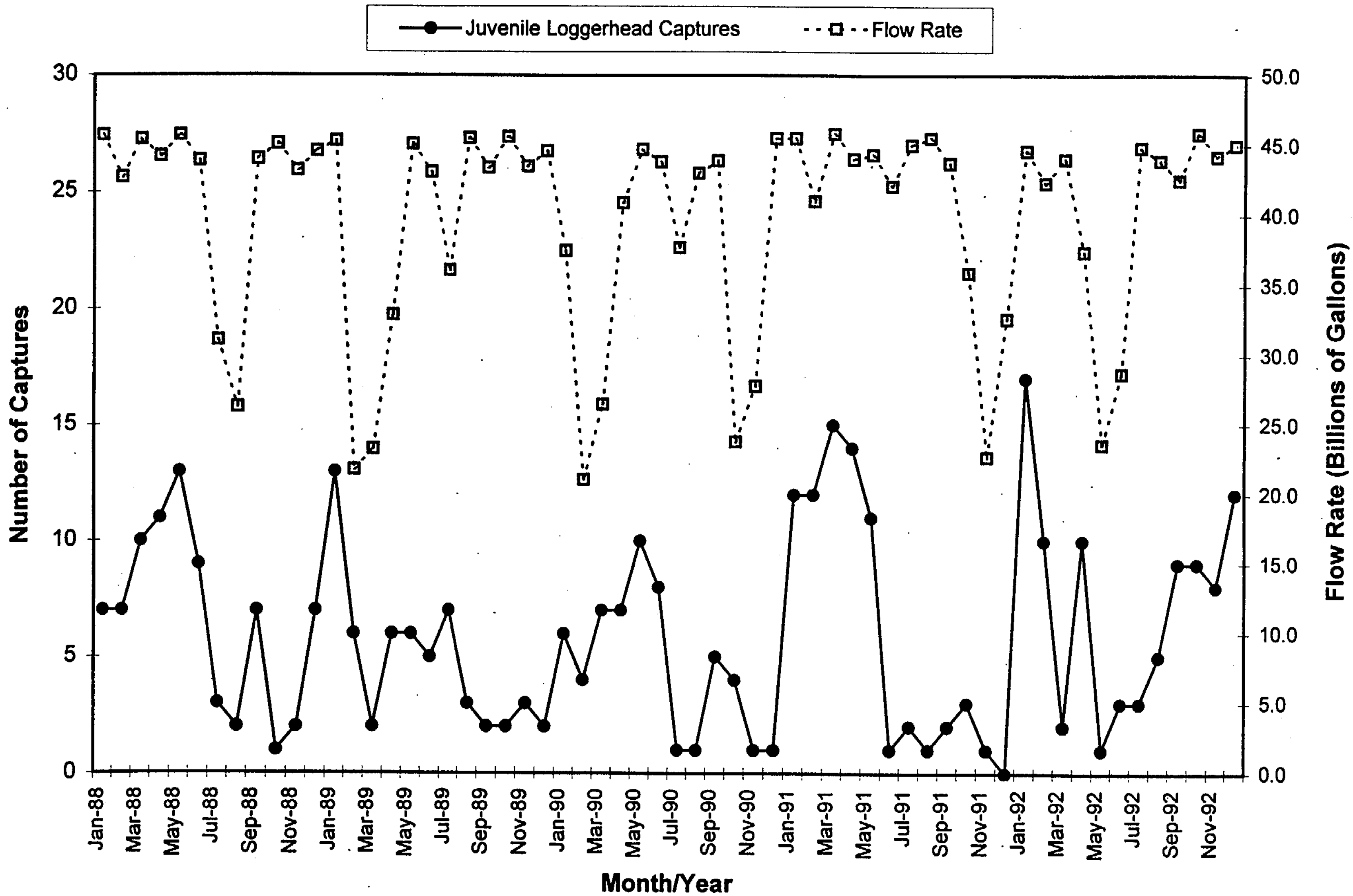


Figure 86. Monthly juvenile loggerhead captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1992.

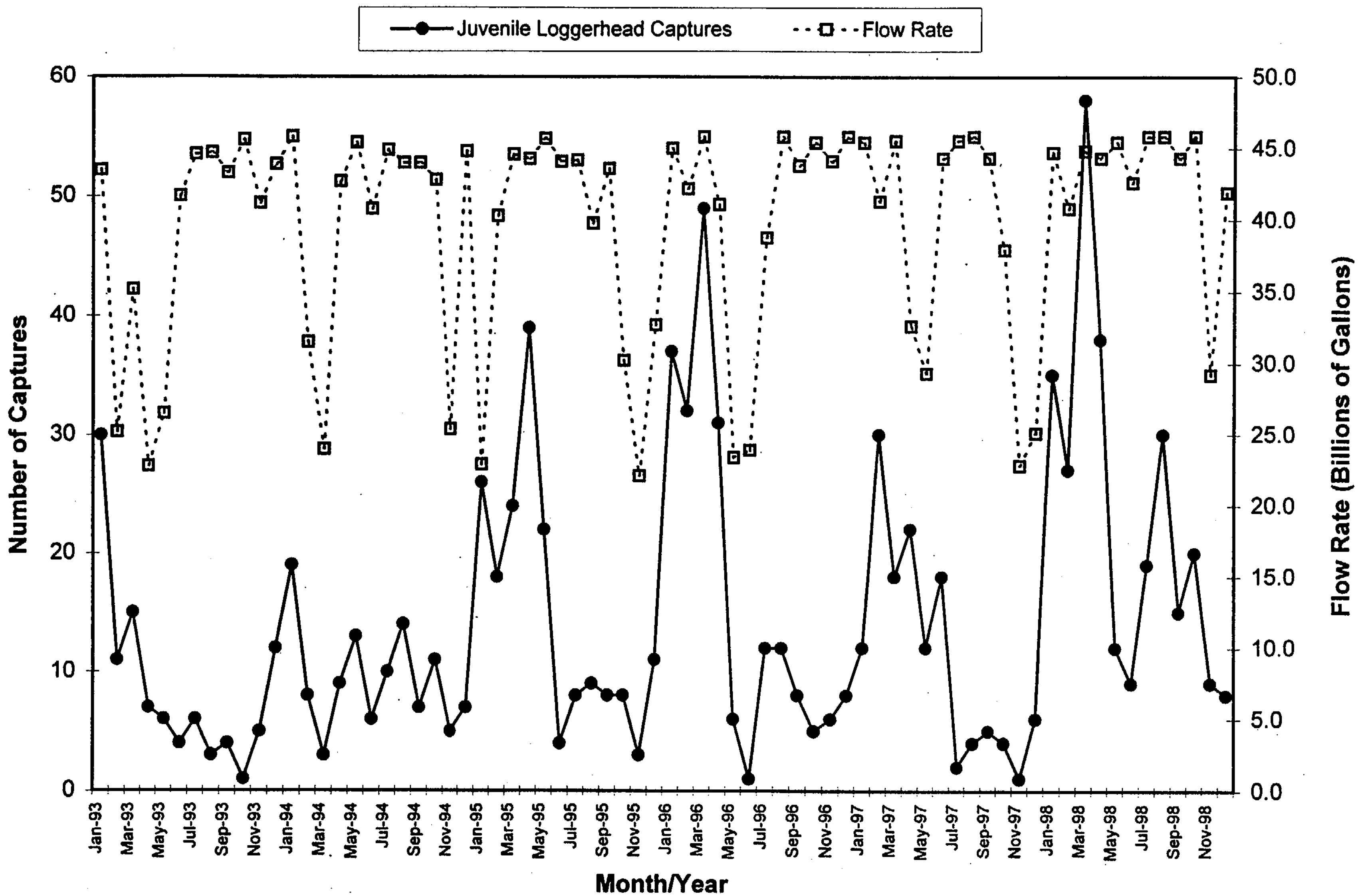


Figure 87. Monthly juvenile loggerhead captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1993 - December 1998.

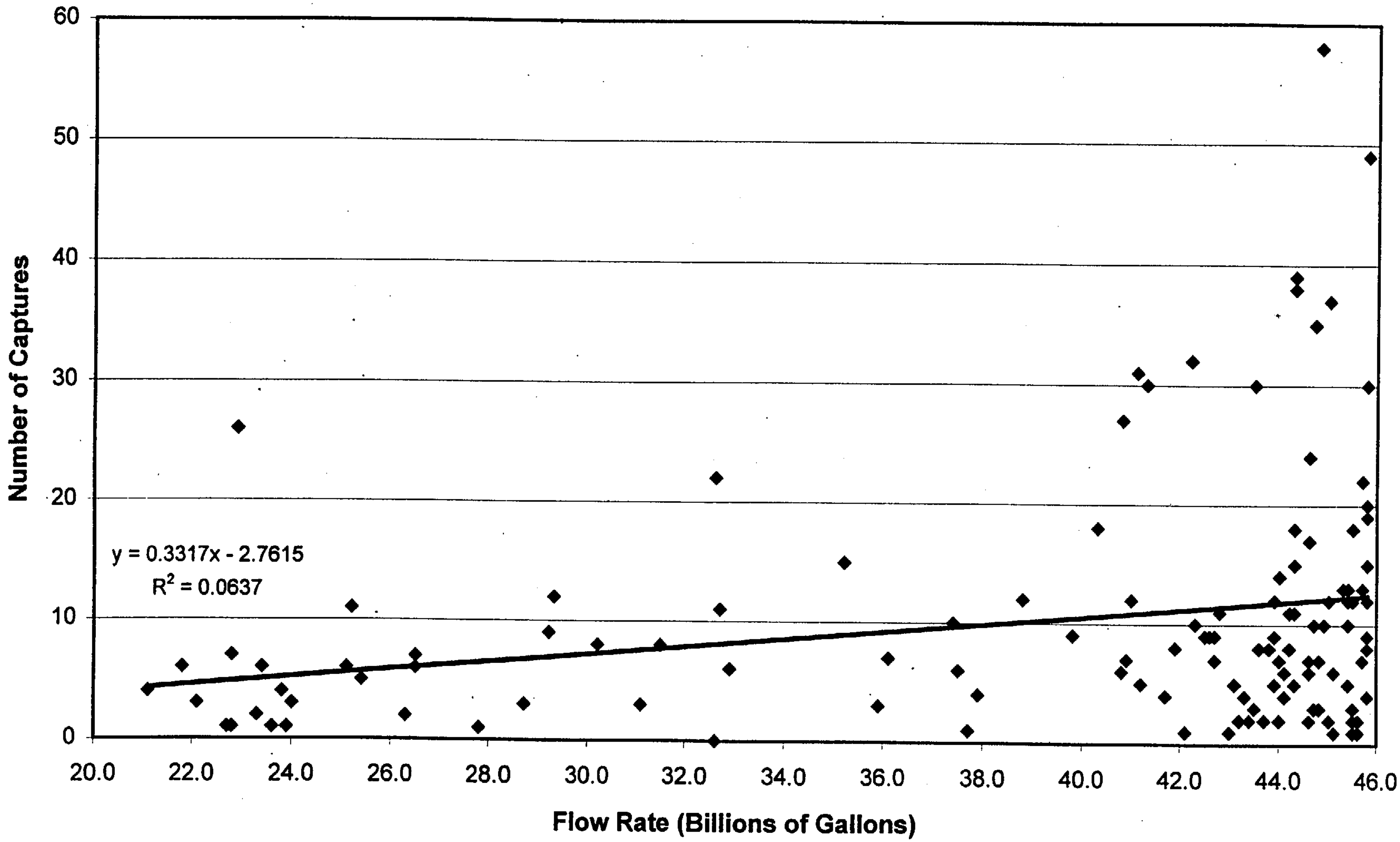


Figure 88. Monthly numbers of juvenile loggerhead captures versus monthly flow rates through circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1998.

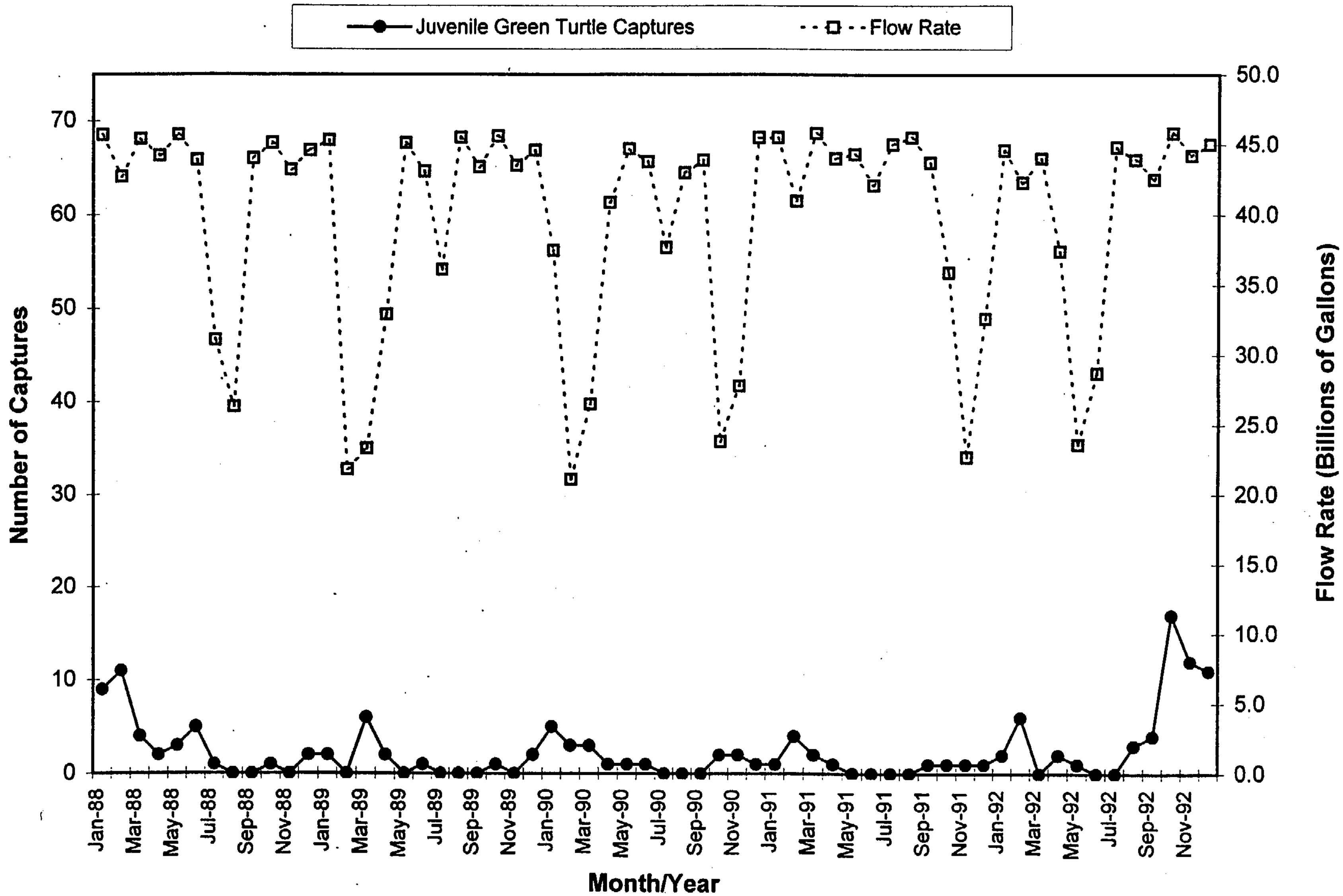


Figure 89. Monthly juvenile green turtle captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1992.

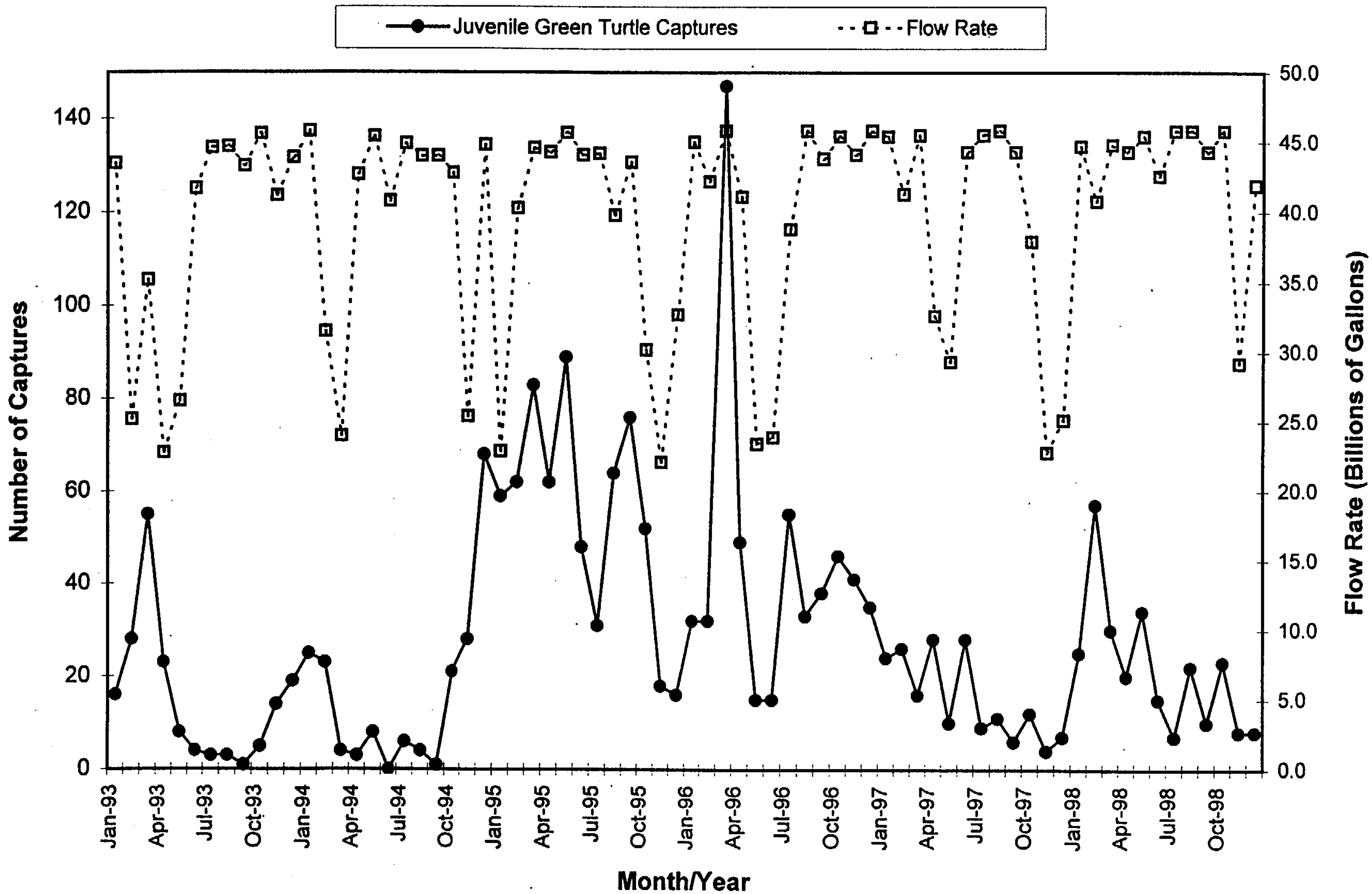


Figure 90. Monthly juvenile green turtle captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1993 - December 1998.

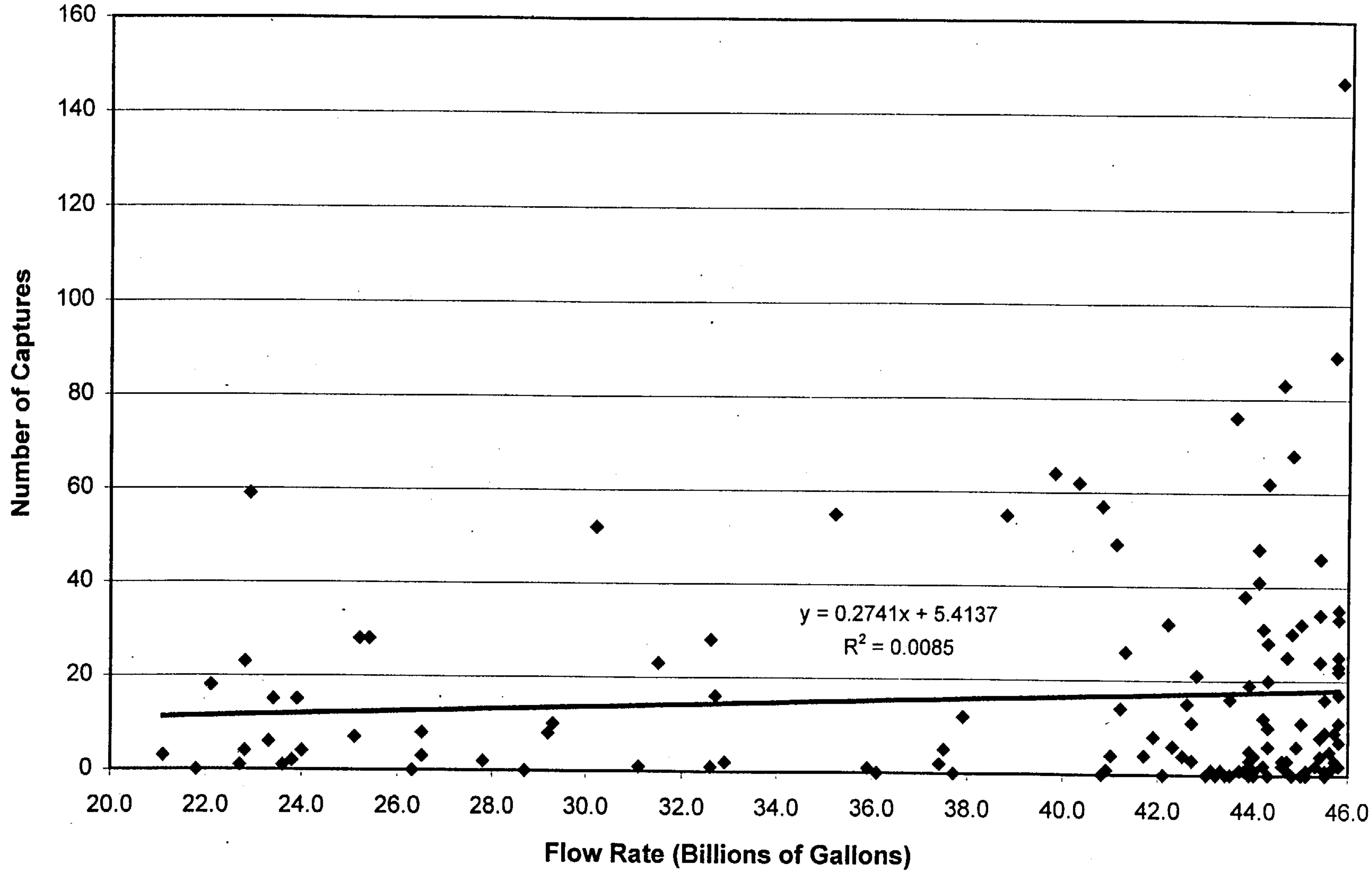


Figure 91. Monthly numbers of juvenile green turtle captures versus monthly flow rates through circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1998.

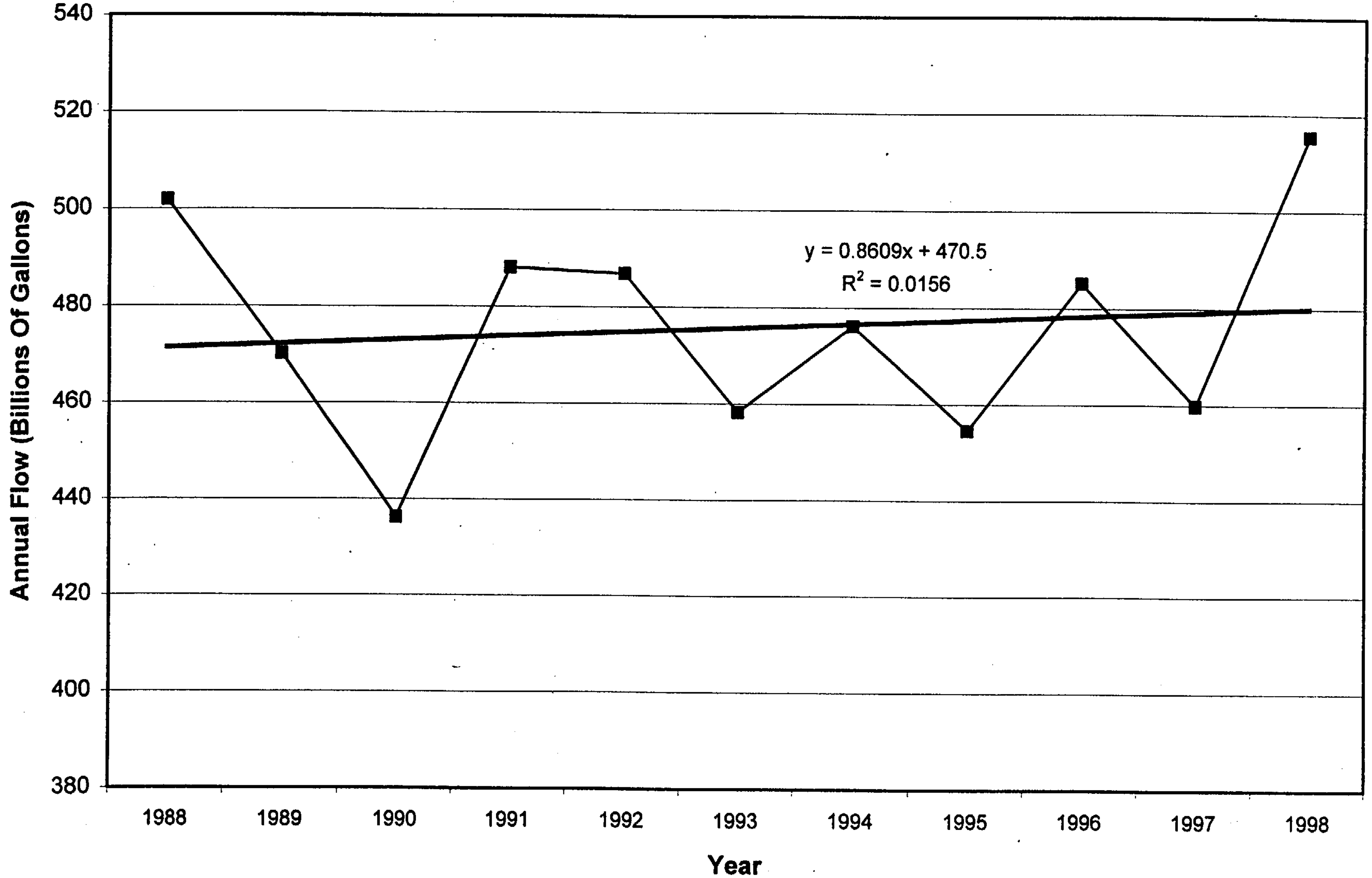


Figure 92. Annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

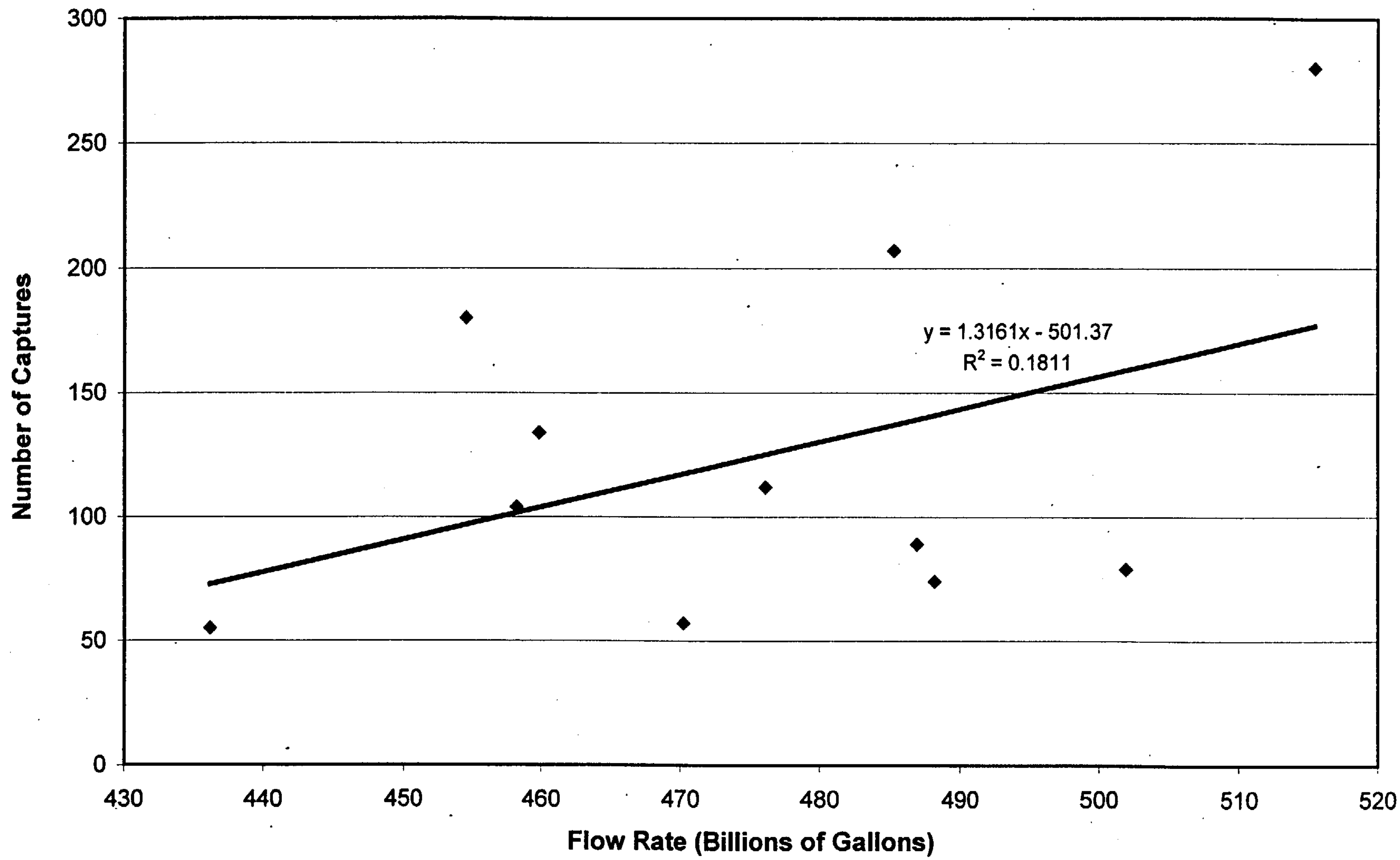


Figure 93. Annual juvenile loggerhead captures versus annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

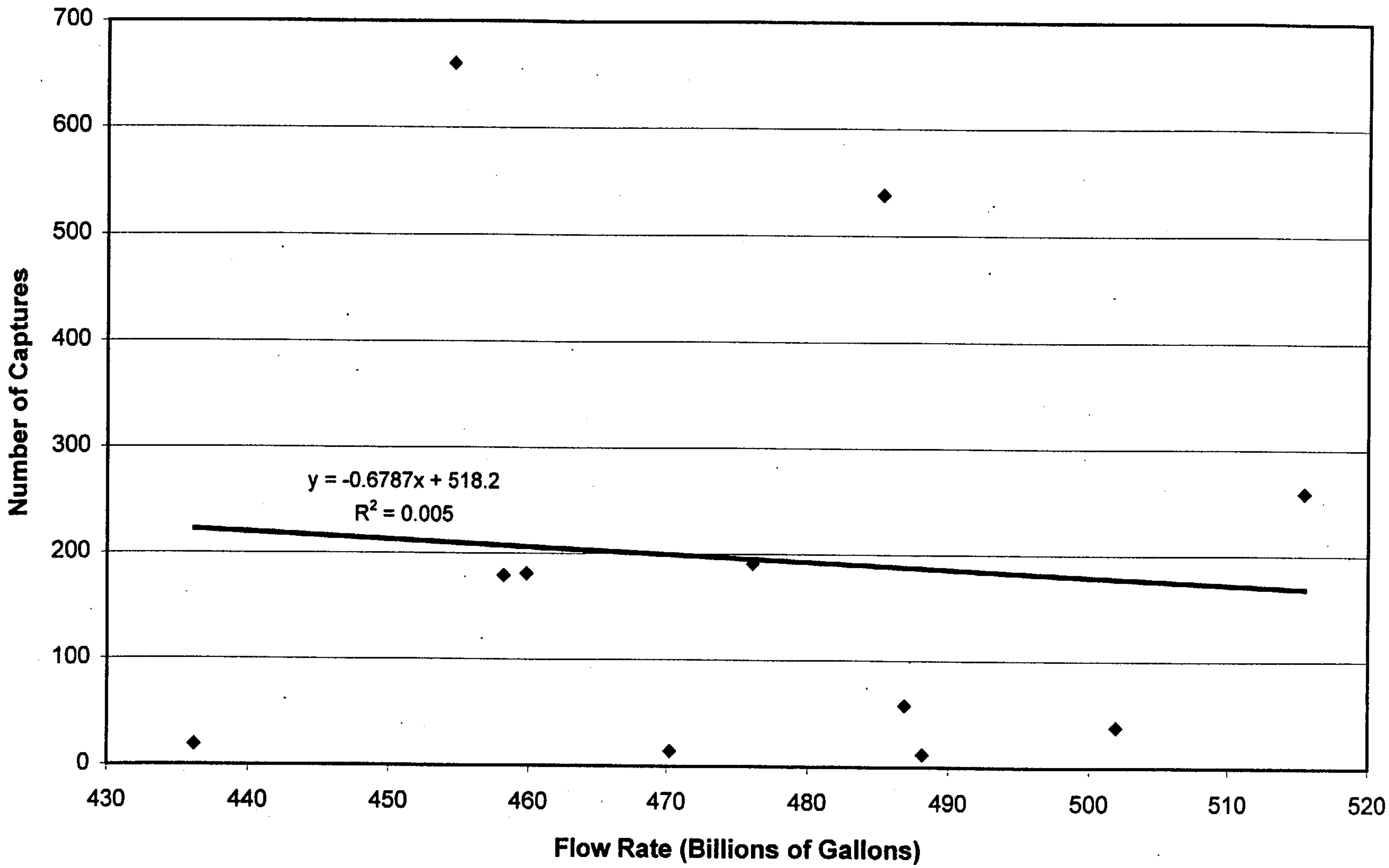


Figure 94. Annual juvenile green turtle captures versus annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

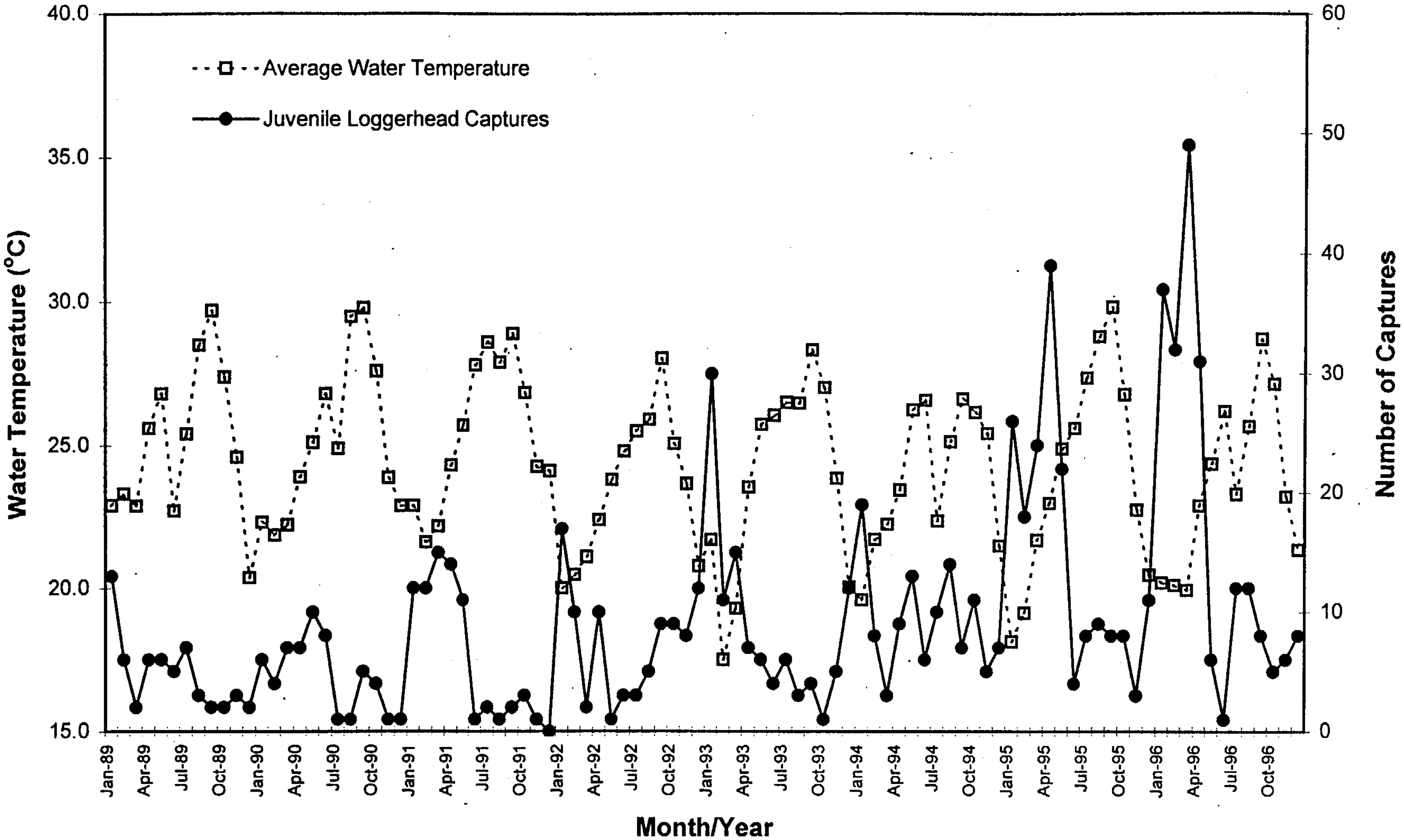


Figure 95. Monthly juvenile loggerhead captures compared to mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

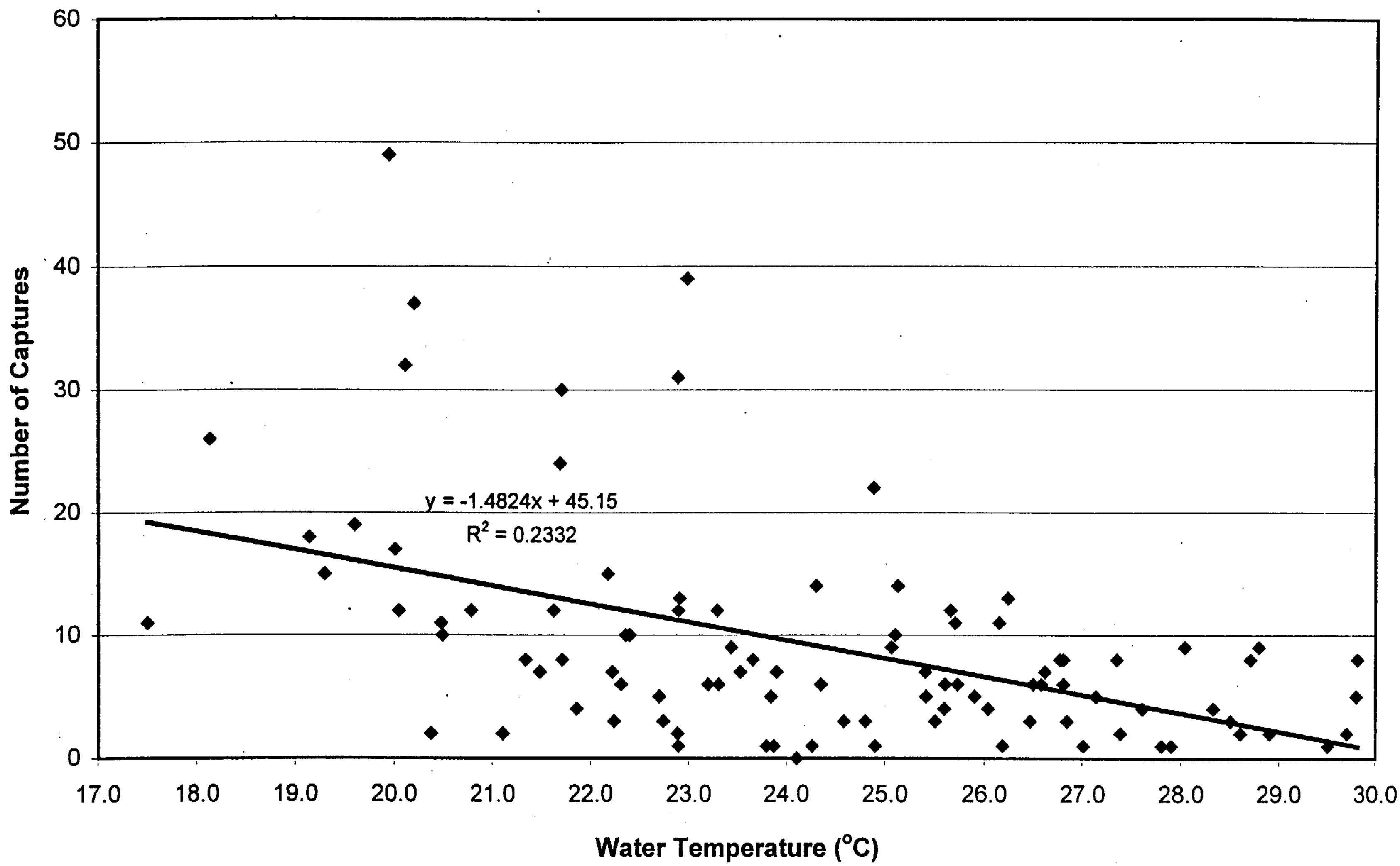


Figure 96. Monthly juvenile loggerhead captures versus mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

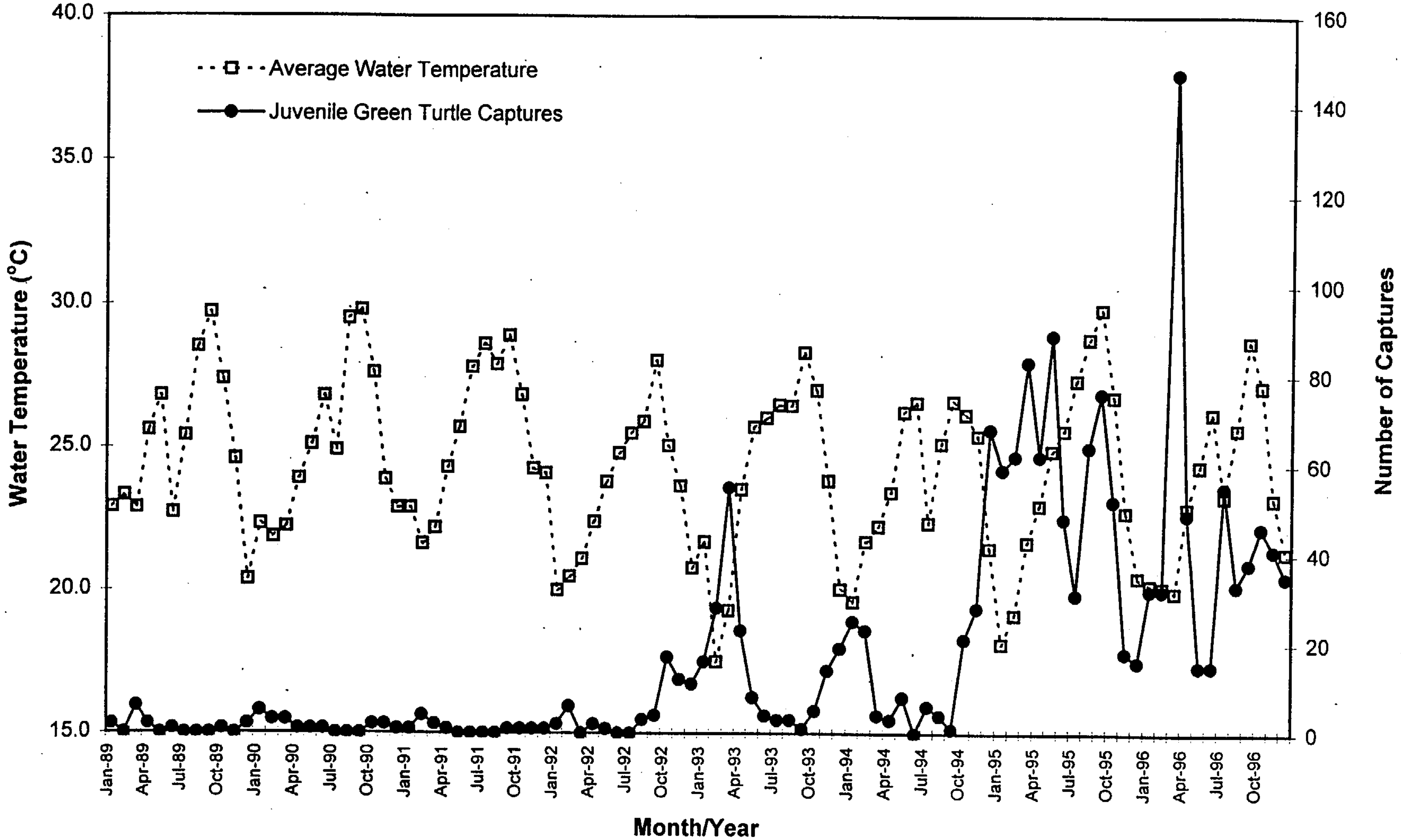


Figure 97. Monthly juvenile green turtle captures compared to mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

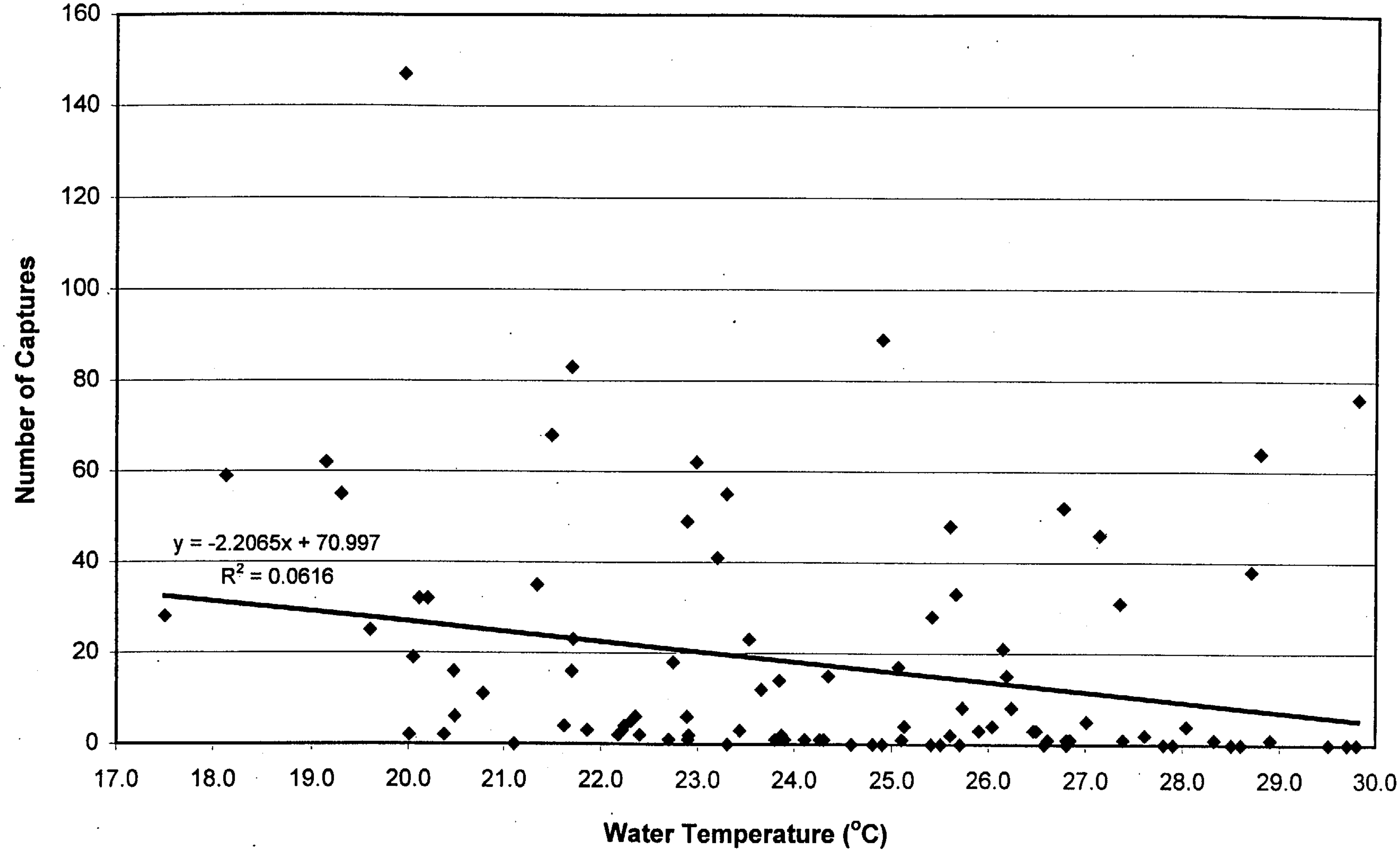


Figure 98. Monthly juvenile green turtle captures versus mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

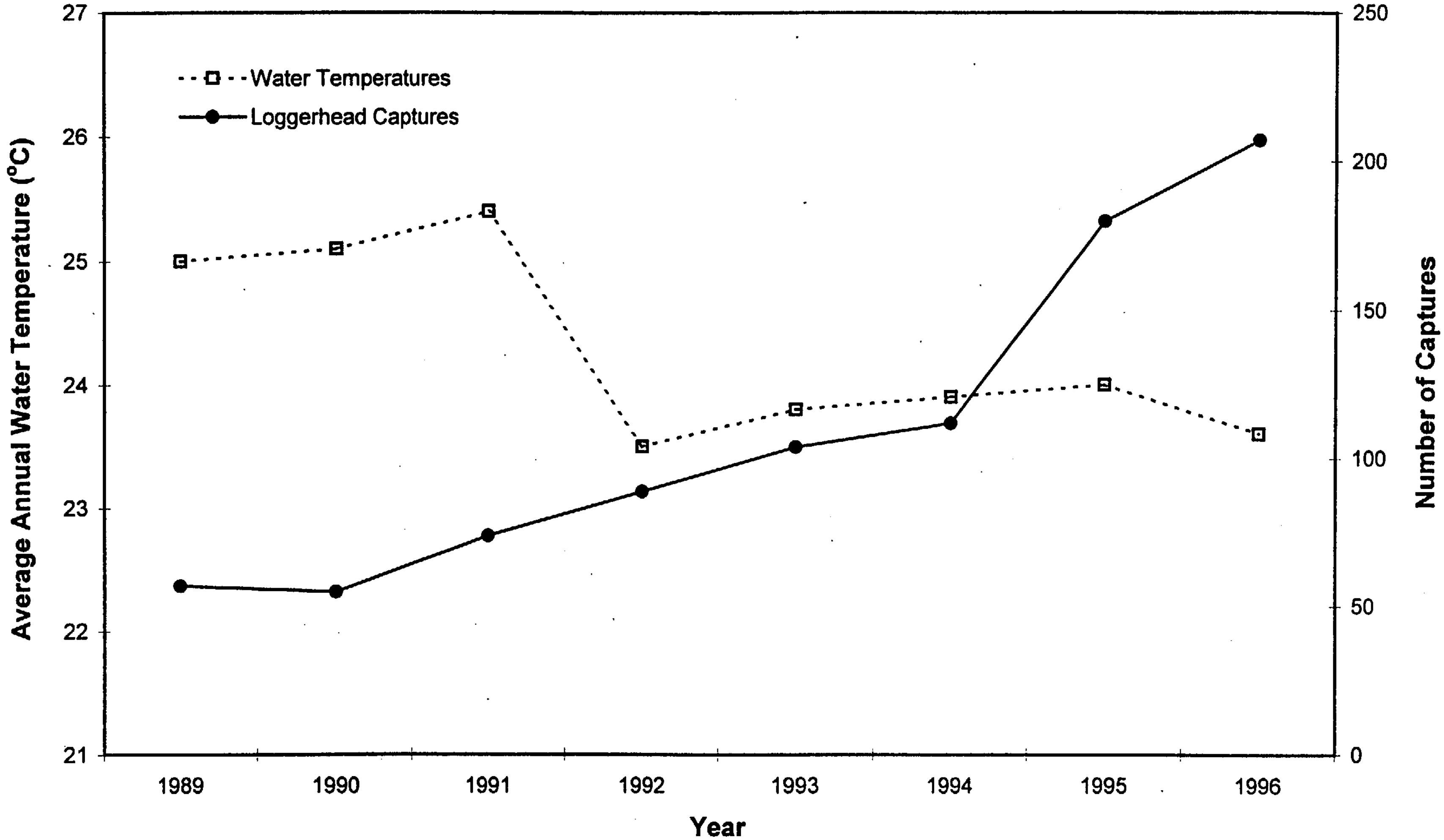


Figure 99. Annual number of juvenile loggerhead captures compared to average annual water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1989-1996.

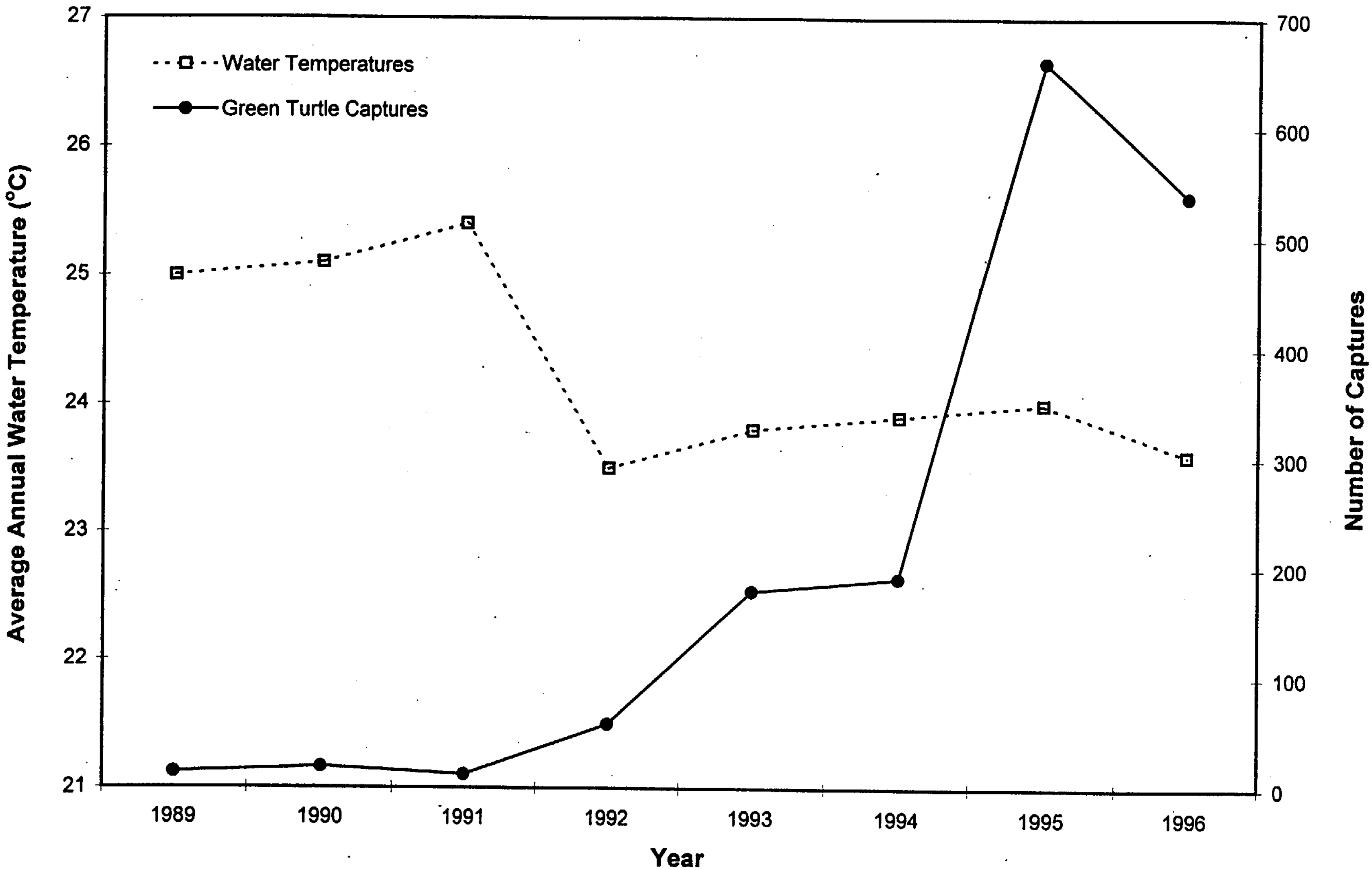


Figure 100. Annual number of juvenile green turtle captures compared to average annual water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1989-1996.

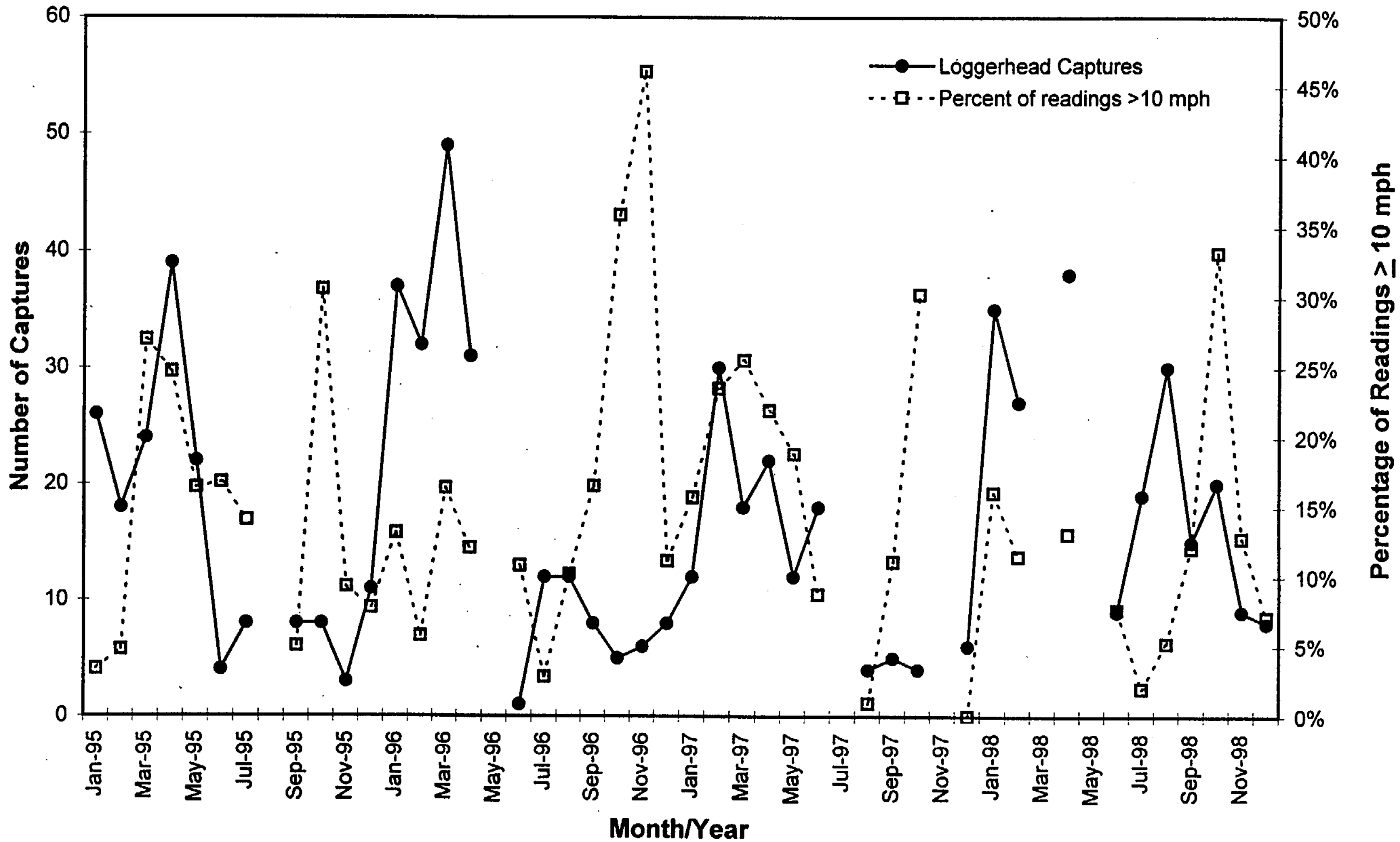


Figure 101. Monthly juvenile loggerhead captures compared to percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

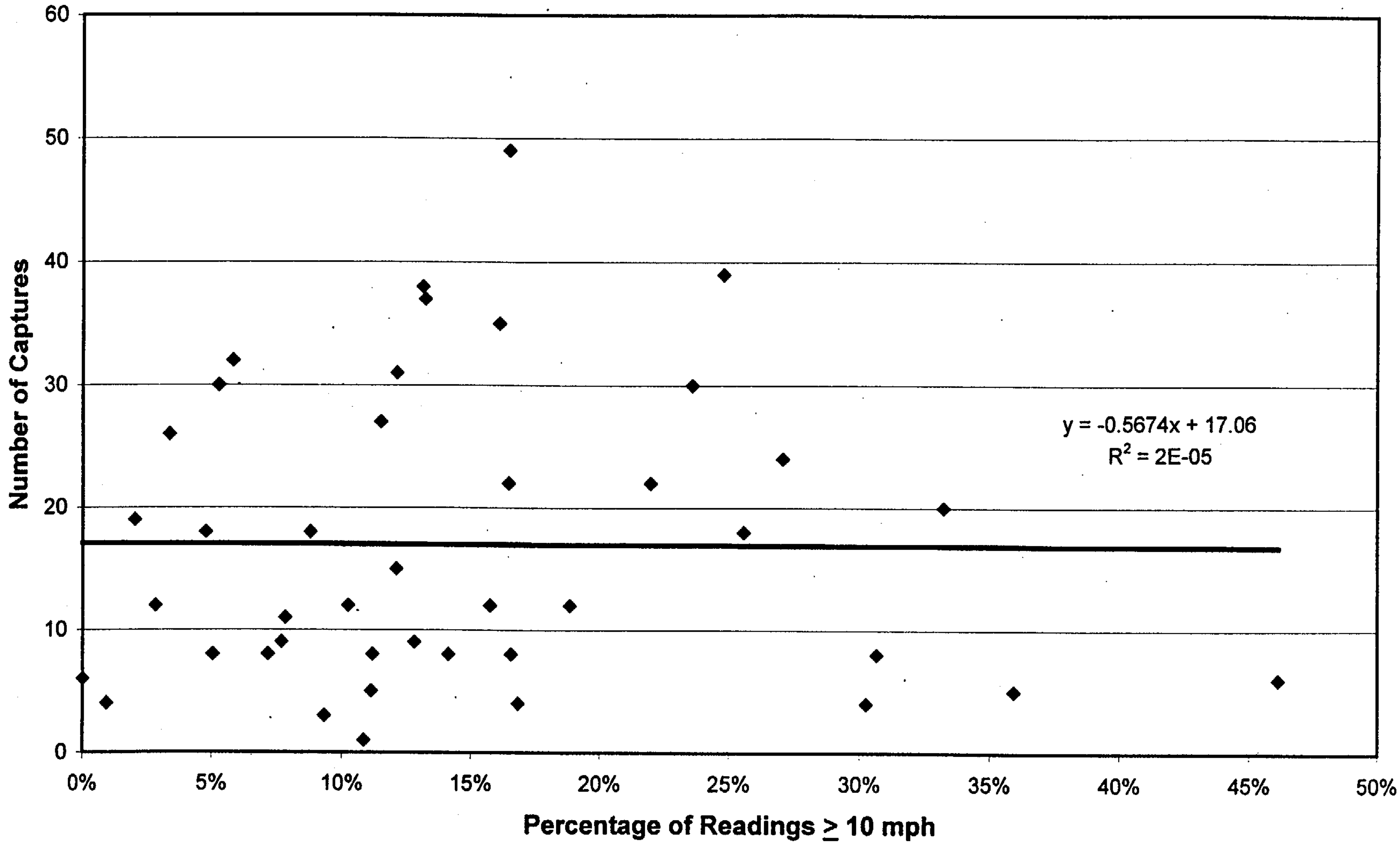


Figure 102. Monthly juvenile loggerhead captures versus percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

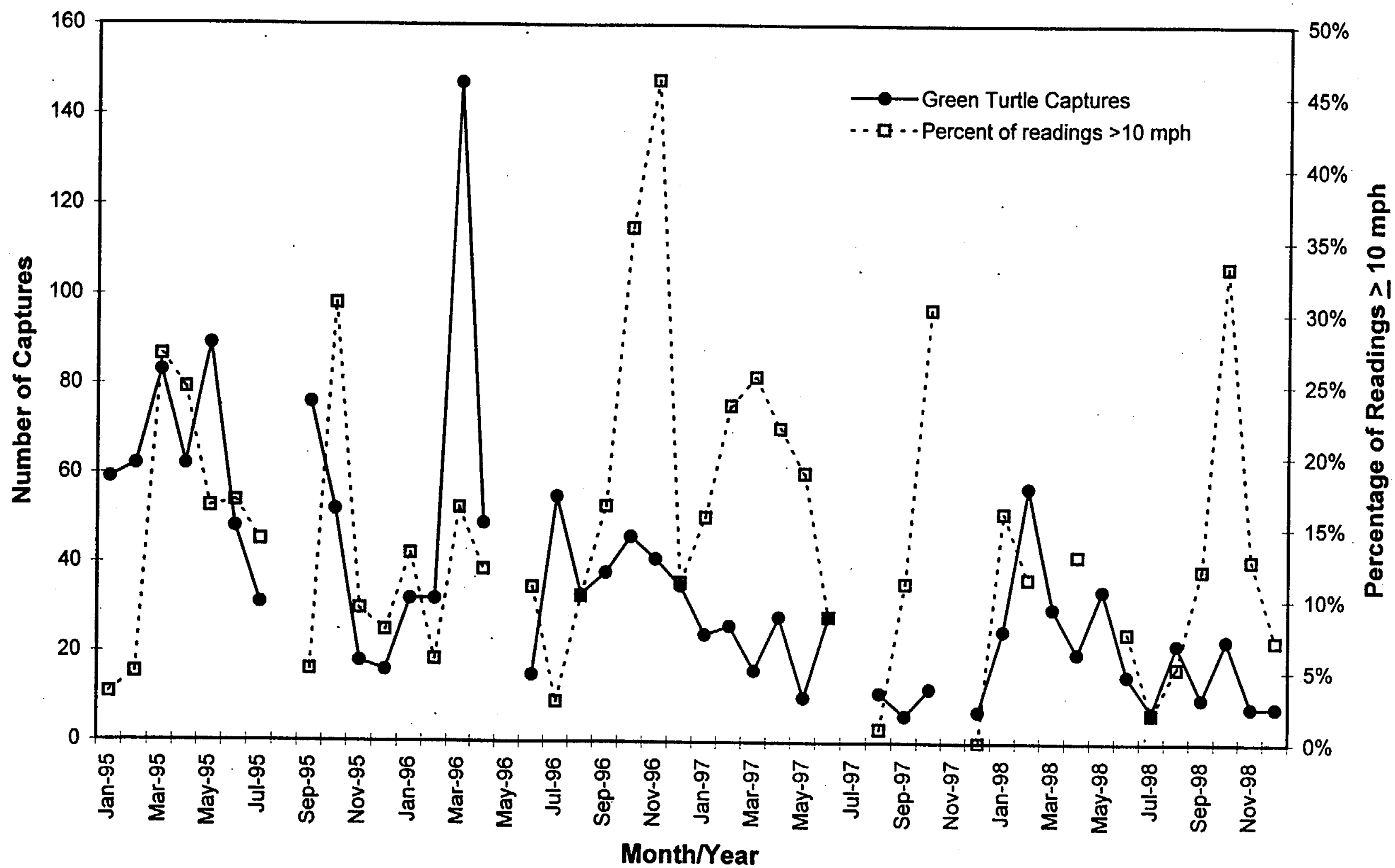


Figure 103. Monthly juvenile green turtle captures compared to percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

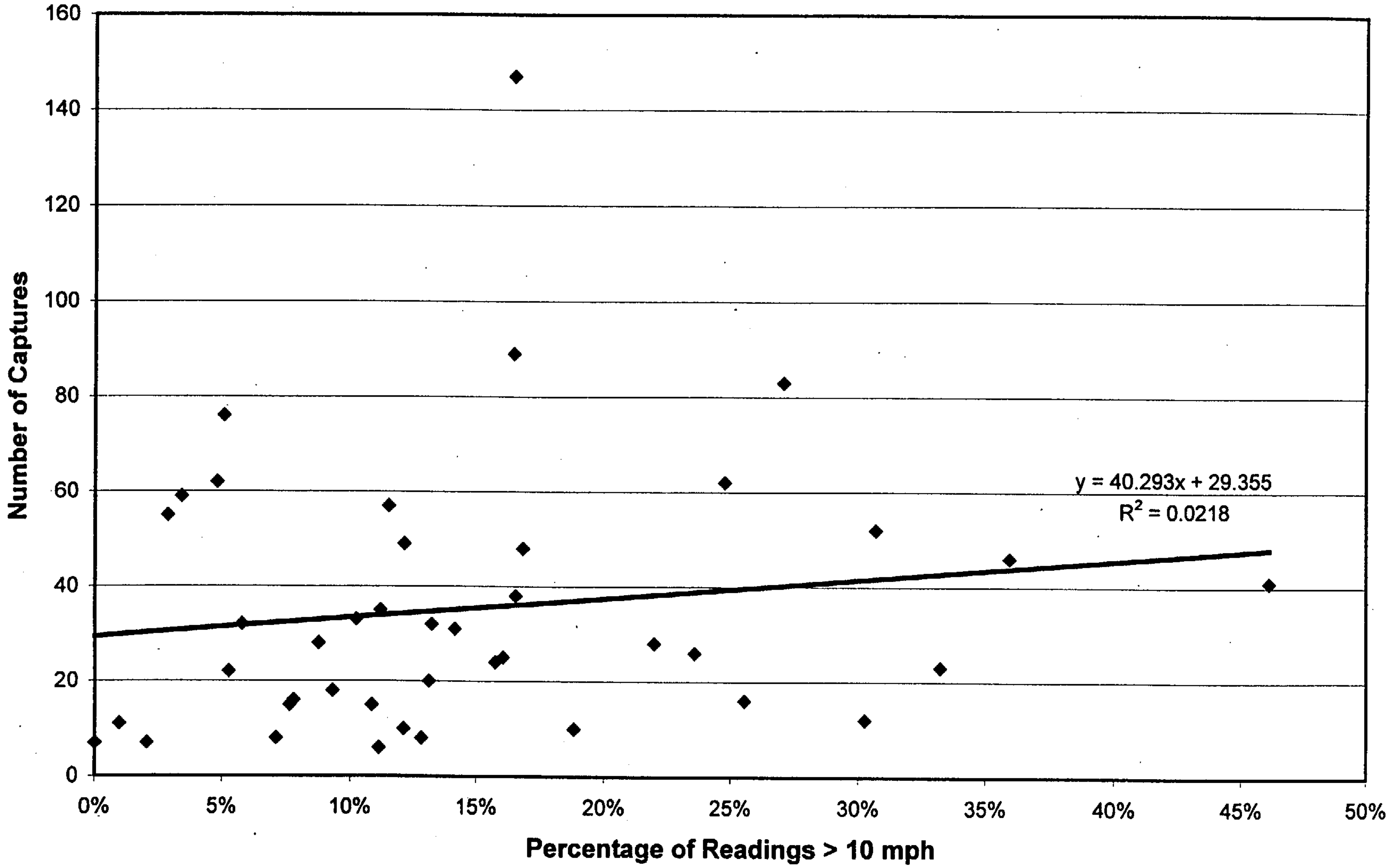


Figure 104. Monthly juvenile green turtle captures versus percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

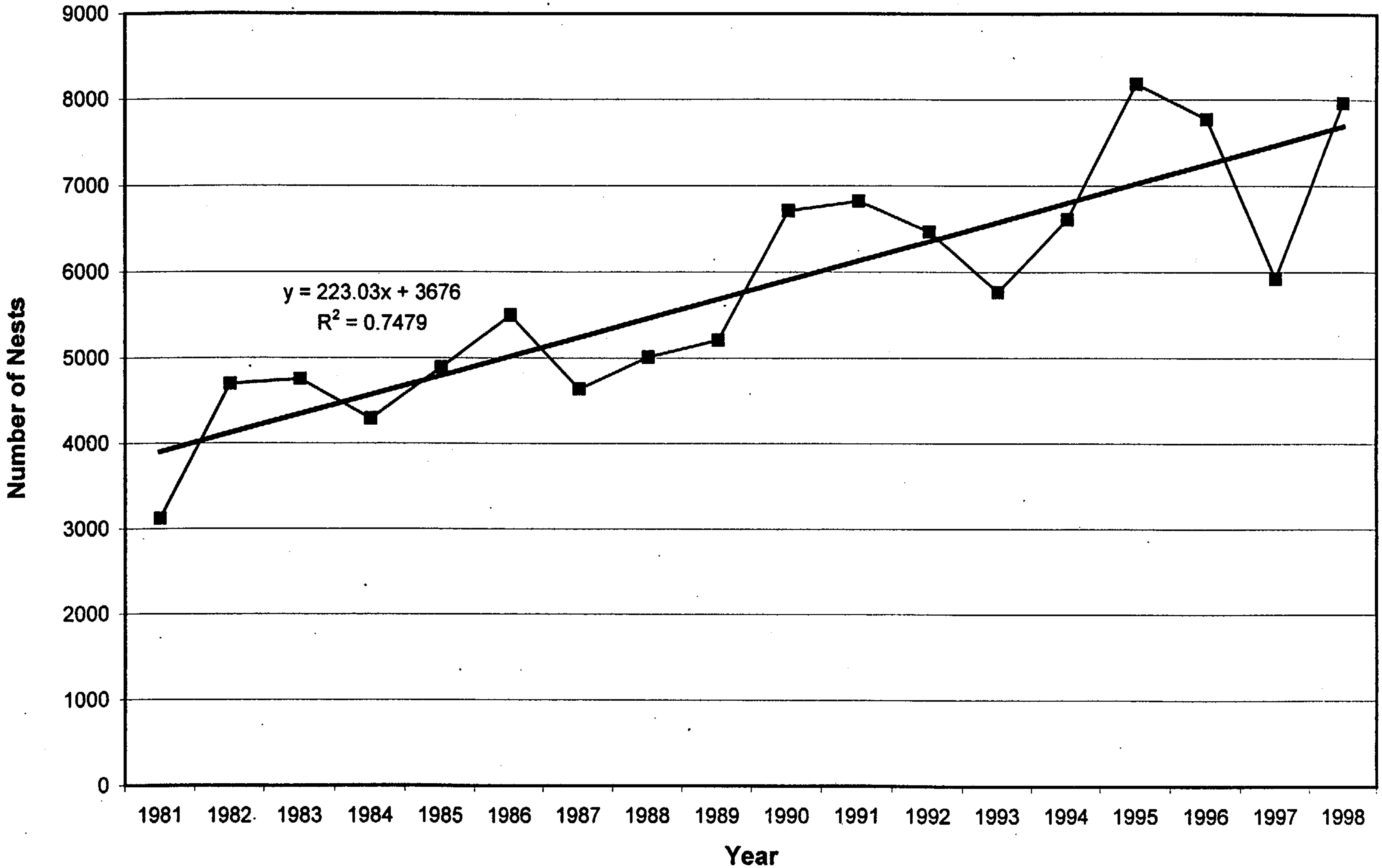


Figure 105. Annual numbers of loggerhead turtle nests recorded on Hutchinson Island, Florida 1981-1998.

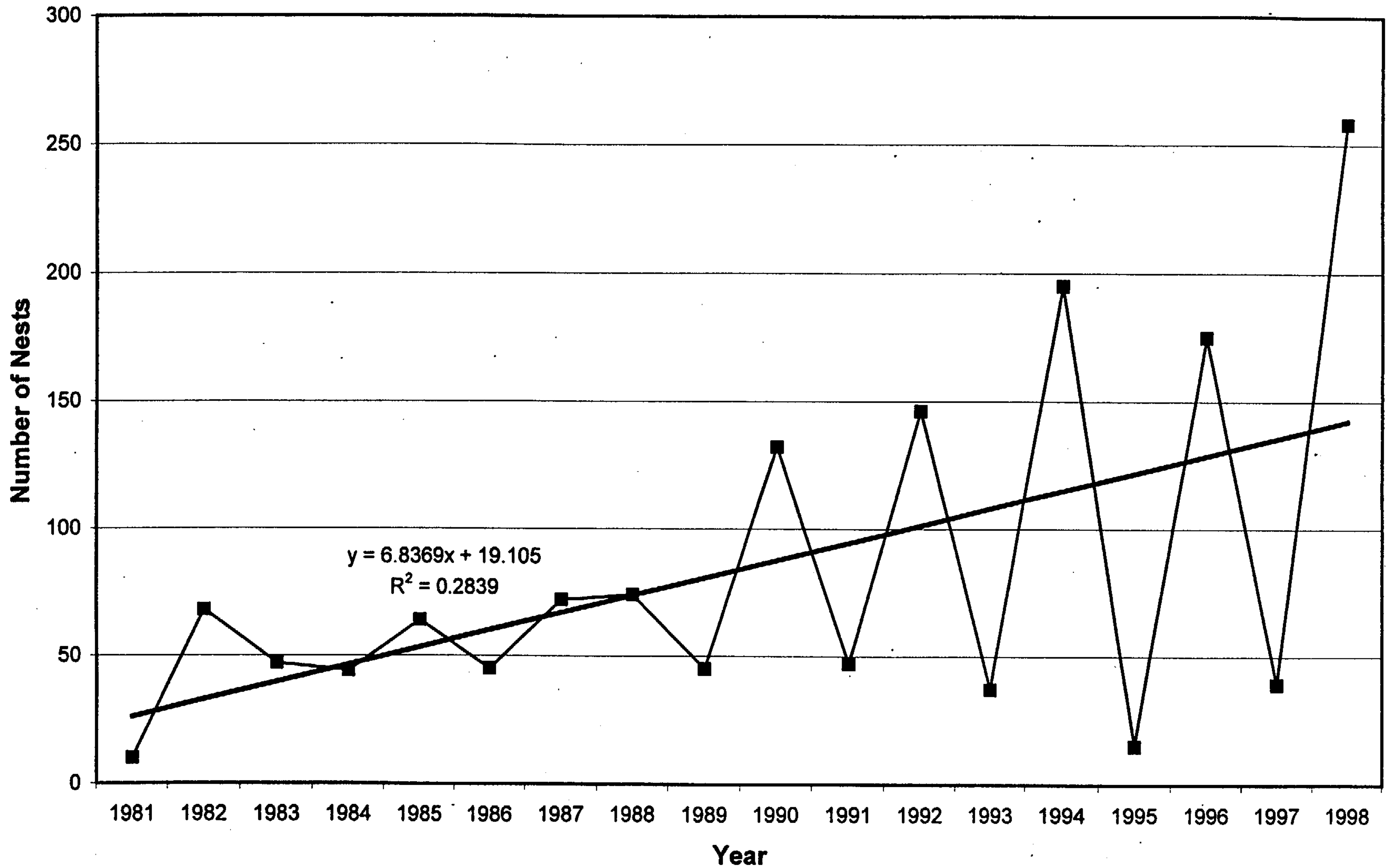


Figure 106. Annual numbers of green turtle nests recorded on Hutchinson Island, Florida, 1981-1998.

Green Turtle Lethal Take Discussion

There were a total of four green turtle mortalities at St. Lucie Plant in 1999. The present National Marine Fisheries Service (NMFS) designated lethal take limit for this species at St. Lucie is 3 or 1.5%, whichever is greater. A total of 190 green turtles were removed from the canal during 1999, yielding a green turtle mortality rate of 2.1% for the year. Three of the four mortalities occurred in September of 1999 following the passage of Hurricane Dennis and Hurricane Floyd. Concurrent with these events, there were large influxes of drift algae that accumulated on the primary barrier net, which forced the lowering of the net for several days. It was difficult to ascertain if any of these three mortalities were directly related to conditions encountered in the canal itself.

Exceeding the Lethal Take Limit requires reinitiating of a Section 7 Consultation between NRC and NMFS. FPL's request for a Section 7 Consultation resulted in a meeting November 10, 1999 with FPL, NRC, NMFS, and Florida Fish and Wildlife Commission (FFWC) personnel. This meeting also satisfied the biannual meeting with these agencies required by the plant Environmental Protection Plan, Section 4.2.2.2.10) c). Data presented by FPL during the November 1999 meeting indicates that over the entire period since consultation was initiated, green turtle mortalities were below the 1.5% level. Individual years (1997 and 1999) have exceeded the take limit and reinitiated consultation. In both 1997 and 1999, higher mortalities were associated with hurricanes and jellyfish influxes. It appears that these essentially random and uncontrollable events caused "spikes" in mortality levels that triggered reinitiating of consultation. Thus, while overall the conservation program is effective in achieving the take limit goals, the trigger to reinitiate consultation is perhaps too sensitive.

FPL proposes that individual year limits be set higher, at 6 green turtles or 3%, with a "lifetime" program limit of 1.5%. In support of the above request, FPL would like to reiterate the effectiveness of the sea turtle protection program at the St. Lucie Plant. This program includes the following current activities:

1. The Canal Capture and Release Program - This program has included over 6,500 turtles that have been captured, biological information recorded, tagged, and released back to the environment. The program has provided an invaluable source of population information for Loggerhead and Green Turtle populations, including immature individuals, on the East Coast of Florida. It also serves as a method of capture and rehabilitation of injured or diseased sea turtles that enter the intake canal.

2. The Beach Nesting Survey Program - This program includes a daily survey of sea turtle nests on Hutchinson Island. In 1999, over 7,400 nests were identified to species and counted. This data provides another invaluable tool toward monitoring the long-term trends of Loggerhead, Green, and Leatherback Turtle reproductive populations in the area.

3. The Public Service Turtle Walk Program - This program included 26 Turtle Walks in 1999 and involved approximately 1,100 members of the public. The program is a highly effective tool toward promoting sea turtle protection awareness.

4. Participation in the Sea Turtle Stranding and Salvage Network - In 1999, FPL responded to approximately 30 sea turtle strandings in the local area. This program supports the monitoring of sea turtle disease, injury, and mortality. If necessary, injured or diseased turtles are transported to rehabilitation facilities where they can be treated and released back to the environment.

In addition to the above programs, FPL has initiated many efforts to reduce plant impact on local sea turtle populations. These efforts include studies to reduce turtle entrapment in the canal as well as the development of methods to reduce residence time and mortalities in the canal. These efforts include several deterrent studies, which were conducted during the early to mid-1980's. Deterrent technologies, such as strobe lights, bubble-curtains, electrical fields, and pneumatic guns were tested, but none proved to be effective in the offshore environment.

Several physical barrier designs and possible deterrents for the ocean intakes were also considered during the 1980's when the average size of turtle captured in the canal was much larger than the small green turtles that have been captured recently. These alternatives posed potential environmental concerns. These concerns include but are not limited to a net or barrier could become a floating "menace" in the Atlantic Ocean, as well as concerns about animals getting impinged on these devices. Previous analysis of those designs indicated that the capital and maintenance costs for a physical barrier system would be prohibitive and could likely cause a reduction in intake canal flow. In that the grid size of such a barrier would have to be even smaller to prevent entrapment today, such a design would appear to be even less feasible. Other investigations included methods of modifying turtle behavior with lights, air bubble curtains, sound, or electrical current so that the sea turtles would not approach or enter the intake structure. These studies were completed in 1985 and were submitted to the NRC by FPL letter L-85-158 dated April 18, 1985.

The most effective technology developed to date has been the installation of the 5-inch mesh barrier net just downstream of the canal headwall. This barrier net, which was installed in 1996, is an effective method of reducing residency time in the canal and therefore, the probability of injury or death to entrapped turtles.

At NMFS request, FPL commissioned a study in 1999 to investigate factors that might be important in the entrapment of sea turtles at the St. Lucie Plant. This effort is an excellent summary of canal capture information to date, plus it includes an analysis of many physical factors in the environment that could effect sea turtle entrapment. This study indicates that increased entrapment rates of turtles are most likely due to increases in sea turtle populations in the area offshore of the plant and not any change in plant operating characteristics.

Based on the information presented above and continuing efforts to reduce plant impact on local sea turtle populations, FPL believes that the Green Turtle Lethal Take Limit should be increased.

FLORIDA POWER & LIGHT COMPANY

APR 1 8 1985

L-85-158

Office of Nuclear Reactor Regulation
Attention: Mr. James R. Miller, Chief
Operating Reactors Branch No. 3
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Miller:

Re: St. Lucie Unit No. 2
Docket No. 50-389
Environmental Protection Plan

In accordance with Section 4.2.2 of the St. Lucie Unit 2 Environmental Protection Plan (Appendix B to Facility Operating Licensing NPF-16), a study to evaluate and/or mitigate turtle entrapment at the intake structure was conducted. On April 11, 1984, Florida Power & Light Company (FPL) hosted an Interagency Task Force Meeting to brief federal and state agencies on the results of the study. In attendance at this meeting were representatives from National Marine Fisheries Service, NRC, Florida Department of Natural Resources, FPL and FPL's consultants. A draft report of the study was provided to each attendee, and distributed to U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service and Florida Audubon Society, for review and comment. Comments were received from National Marine Fisheries Service and Florida Audubon Society.

Attached is the final report which is submitted pursuant to Section 4.2.2 of the St. Lucie Unit 2 Environmental Protection Plan. Based on the finding that an 80% reduction of turtle entrapment cannot be projected using sound and/or light devices, it was recommended during the April 11, 1984, meeting that FPL be allowed to remove entrapped turtles using netting techniques. The National Marine Fisheries Service, the lead federal agency having jurisdiction over sea turtles while in the water, concurred with this recommendation. Therefore, FPL will continue removal of entrapped turtles using netting techniques.

Very truly yours,

for J. W. Williams, Jr.
Group Vice President
Nuclear Energy

JWW/RJS/cab

Enclosure 3

J. R. Wilcox

4/09/85

SEA TURTLE INTAKE ENTRAPMENT STUDIES

I Introduction

In the Final Environmental Statement (NRC, 1982 FES) concerning the operation of St. Lucie Plant Unit No. 2 (Docket No. 50-389), Section 5.7 discusses threatened and endangered species. As documented in this section and in compliance with Section 7 of the Endangered Species Act, the NRC consulted with the U.S. Fish and Wildlife Service (FWS) and the U.S. National Marine Fisheries Service (NMFS) regarding threatened and endangered species. The NRC performed a Biological Assessment (Bellmund, Masnik and La Roche, 1982) and submitted it for review by the FWS and NMFS in December 1981.

This Biological Assessment evaluated the effects of construction and operation of St. Lucie Unit 2 on sea turtles. A revised Biological Assessment, issued on March 24, 1982, and agreed to by the NMFS and FWS, concluded that it was unlikely that any federally endangered and/or threatened species would be detrimentally affected, provided certain programs be conducted by Florida Power & Light Company.

In April 1983, the Environmental Protection Plan (non-radiological), Appendix B to St. Lucie Plant Unit 2 (NRC, 1983) was issued. Section 4.2.2 required a laboratory and field program employing light and/or sound to deter turtles from the intake structures at the St. Lucie Plant. On completion of this program, a final report was to be submitted to the NRC, EPA, NMFS and FWS for their evaluation. This report is being submitted to fulfill this requirement.

II Background

Description of Cooling Water System

The St. Lucie Plant consists of two 850-MW nuclear-fueled electric generating units that use nearshore ocean waters to cool the plant's condensers (NRC, 1982; Figure 4.1). Water for the once-through cooling system enters the plant through three submerged intake structures located about 365 m offshore. Each of the intake structures is equipped with a velocity cap to minimize fish entrapment (NRC, 1982; Figure 4.3). Horizontal intake velocities are less than 30 cm/sec. From the intake structures, the water passes through submerged pipes under the beach and dunes to a 1500-m long intake canal, which transports the water to the plant. After passing through the plant, the heated water is discharged into a 670-m long canal that leads to two buried discharge pipelines. These pass underneath the dunes and beach along the ocean floor to the submerged discharges, located approximately 730 m north of the intake.

Description of Turtle Entrapment

From 1976 when the St. Lucie Plant became operational through 1984, 1135 turtles have been entrapped (Appendix A). In decreasing numerical abundance, the species of turtles involved are: loggerhead turtle (Caretta caretta), green turtle (Chelonia mydas), leatherback turtle (Dermochelys coriacea), Kemp's ridley (Lepidochelys kempi) and hawksbill turtle (Eretmochelys imbricata).

It is believed that turtles voluntarily enter the cooling water system at the velocity cap seeking a dark location in which to hide or sleep, become entrained with the flow of water in the submerged pipes, and enter the open intake canal where they become entrapped. The turtles are generally unharmed by passage through the intake pipes, but must be regularly netted from the open canal and returned to the ocean.

Turtles are removed from the intake canal with large-mesh nets that range from 32 to 61 m in length, 2.7 to 3.7 m in depth and 30 to 40 cm in stretch mesh. Large floats keep the nets at the surface and the absence of weights along the foot ropes allows netted turtles to remain near the surface of the water.

During handling, animals are measured, weighed and tagged, their general health is noted, any injury (recent or old) is recorded, and blood samples are taken for pathology. In the case of dead turtles, an attempt to determine the cause of death is made.

As a result of these captures, an extensive and valuable data base has been developed (See Appendix A). This information has been shared with other organizations such as the Southeast Fisheries Center of the NMFS and the State of Florida Department of Natural Resources (DNR). Based on this data base and others, population estimates are being developed for the east coast of Florida. In addition, recaptures of tagged individuals have permitted geographic range estimates for the loggerhead and green turtles. Tissues from recently dead turtles have been used in a variety of histological and pathological studies. Turtles taken from the intake canal have also been used in research programs conducted by FPL, NMFS and DNR.

III Deterrent Studies

Florida Power & Light Company has conducted four different investigations on deterring turtles. All are based on modifying turtle behavior with light, sound, or electrical current so that they would not approach or enter the underwater intake structures at the St. Lucie Plant.

The contractors who completed each segment of the investigation are as follows:

A. Lights and Bubble Curtains

Applied Biology, Inc. - August 1980

B. Electrical Fields

Environmental and Chemical Sciences, Inc. - November 1981

C. Pneumatic Guns

Environmental and Chemical Sciences, Inc. - March 1983

D. Strobe Lights and Bubble Curtains

University of Maryland - January 1984

Each of these studies are summarized in the following subsections. For complete details of each study, consult Appendices B-E.

A. Lights and Bubble Curtains

Description of Study

This project investigated how the intake structures act as an attractant to marine turtles and evaluated several deterrents. Incandescent lights and bubble curtains were considered the most promising deterrents.

Turtles were tested in a 20 m diameter tank. Three plywood boxes (1 m deep, 1 m wide, 0.8 m high) were placed in the tank to represent the offshore intake structure. All boxes had an open end that allowed the turtles free entry and ample turning space. During various trials, the boxes were illuminated with incandescent lights and the entrance surrounded with a bubble curtain.

Conclusions

1. After initial acclimation to the test tank situation, turtles readily sought out and utilized dark box habitats during resting periods. All but one of the

22 turtles rested inside a box at least a few times, with 75 percent of the individuals regularly entering the box habitats.

2. As a surface relief on the open sandy bottom, the velocity cap may act as an attractant to passing marine turtles.

3. The 100-watt lights used during this study were a useful deterrent at night but were ineffective during the day when ambient solar light negated their effect.

4. Only one test using flashing lights was successfully completed; the effectiveness of flashing lights to startle turtles has potential for further consideration.

5. The bubble curtain was most effective during bright light conditions, probably because bubbles reflecting sunlight were more visible. At night the screen was not as effective; however, coupled with lighting, it might enhance deterrent capabilities.

B. Electrical Fields

Description of Study

The use of a deterrent with a direct, although harmless, physiological effect would probably produce a more dependable response than a passive deterrent such as lights and bubble curtains. Therefore, the use of electrical fields as a deterrent was chosen for investigation because all animals are known to have a physiological intolerance to electrical stimulation.

A review of the scientific literature and discussions with turtle researchers and electrofishing experts revealed that the effects of electrical fields on sea turtles were unknown. However, many studies have shown that other marine animals can be controlled by electrical fields. The experiments conducted for this program examined the response of sea turtles to low intensity AC and DC electrical fields.

The study was conducted in two parts. The first series of experiments tested juvenile turtles and was designed to establish the general scope of subsequent tests. Juveniles were selected for the first phase of the study because they are easy to handle and the tank required for testing could be smaller. The second series of experiments examined the responses of sub-adult turtles to the electrical fields found to be the most effective with juveniles. Sub-adults were the primary focus of the study because they are the size most commonly found in the intake canal.

Test criteria were developed at extremely low voltages and then gradually increased until measurable responses were obtained. This procedure was followed because the sensitivity of the test animals to electrical fields was unknown and the safety of the turtles was of prime concern. Test periods were kept short to reduce fatigue and to prevent learned responses.

Conclusions

1. Marine turtles avoided both AC and pulsed DC electric fields of sufficient intensity.
2. Exposure to low voltage electric fields did not harm the turtles. Turtles did not exhibit learned behavior after repeated exposures to such fields.
3. For a given peak voltage, sine wave AC fields were more effective than pulsed DC in repelling turtles. While there was some variability in the response of turtles to different DC pulse rates, pulse widths and waveforms, no well-defined set of parameters appeared to be superior.
4. There was considerable variation in the responses exhibited by individual turtles to electrical fields. Size was important because larger turtles are

more sensitive. Species variations may exist as there was some indication that green turtles are more sensitive than loggerheads.

5. The field intensity experienced by the head of the turtle may be the most important electrical parameter determining behavior.

6. Under some conditions, turtles entered strong electrical fields and lost motor coordination. At the field intensities studied, the turtles recovered immediately when released from the field with no apparent injury and no apparent learning.

C. Pneumatic Guns

Description of Study

Based on observations of turtle behavior made during the electrical field studies, the use of sound as a potential deterrent was considered. Personnel from DNR also suggested that sharp sounds (e.g. pounding on the side of a tank) may alter turtle behavior.

The hearing ability of sea turtles has been examined only for the green turtle. Researchers found the functional hearing range to be below 1000 Hz with the best sensitivity at 300 to 400 Hz. These values are consistent with data on other species of turtles.

In a series of preliminary field experiments, electronically produced sounds in the 100 to 1000 Hz range were not a viable deterrent to loggerhead turtle movement because sound with enough decibels could not be produced. In order to obtain mechanically produced sounds in this frequency range and with sufficient decibels, seismic profiling air guns were used for further field experiments.

Conclusions

1. Guns fired at 141 Kg/cm^2 (2000 psi) and at 15 second intervals were the most effective deterrent. This produced a sound rise of approximately 120 decibels (at one meter distance) in 1.0 - 1.5 milliseconds. The strongest component of the sound frequency was at 25 Hz, although frequencies in the 300 -400 Hz range were measured.

2. These tests indicated that the exclusionary range of the air guns was about 30 m.

3. These results cannot be converted directly to turtle deterrence at the St. Lucie Plant.

4. Although the air guns are mechanically and electrically simple, the guns and their support equipment require maintenance and accessibility. Therefore, engineering costs, capital outlay and maintenance costs need to be evaluated.

D. Strobe Lights and Bubble Curtains

Description of Study

Light potentially may be used as a barrier to any organism that relies on vision. Researchers have investigated the effectiveness of various light regimes in repelling problem fish from intake structures. Strobe lights, in particular, have been used in conjunction with diversion devices to solve several site specific problems with certain species of fish.

Previous studies have found that the maximal visual sensitivity of green turtles is 502 m (e.g. blue), which is close to the maximum transmission of light in seawater. The studies conducted for this project examined the responses of hatchling loggerheads

to constant monochromatic light of different wavelengths and the response of both hatchlings and subadults to white strobe lights under several experimental conditions.

Conclusions

1. Loggerhead hatchlings showed a slight preference for short wavelength light (i.e. blue) and were attracted to strobe lights in 62.5 percent of all tests. This attraction is consistent with their sea finding behavior as they emerge from their nests.

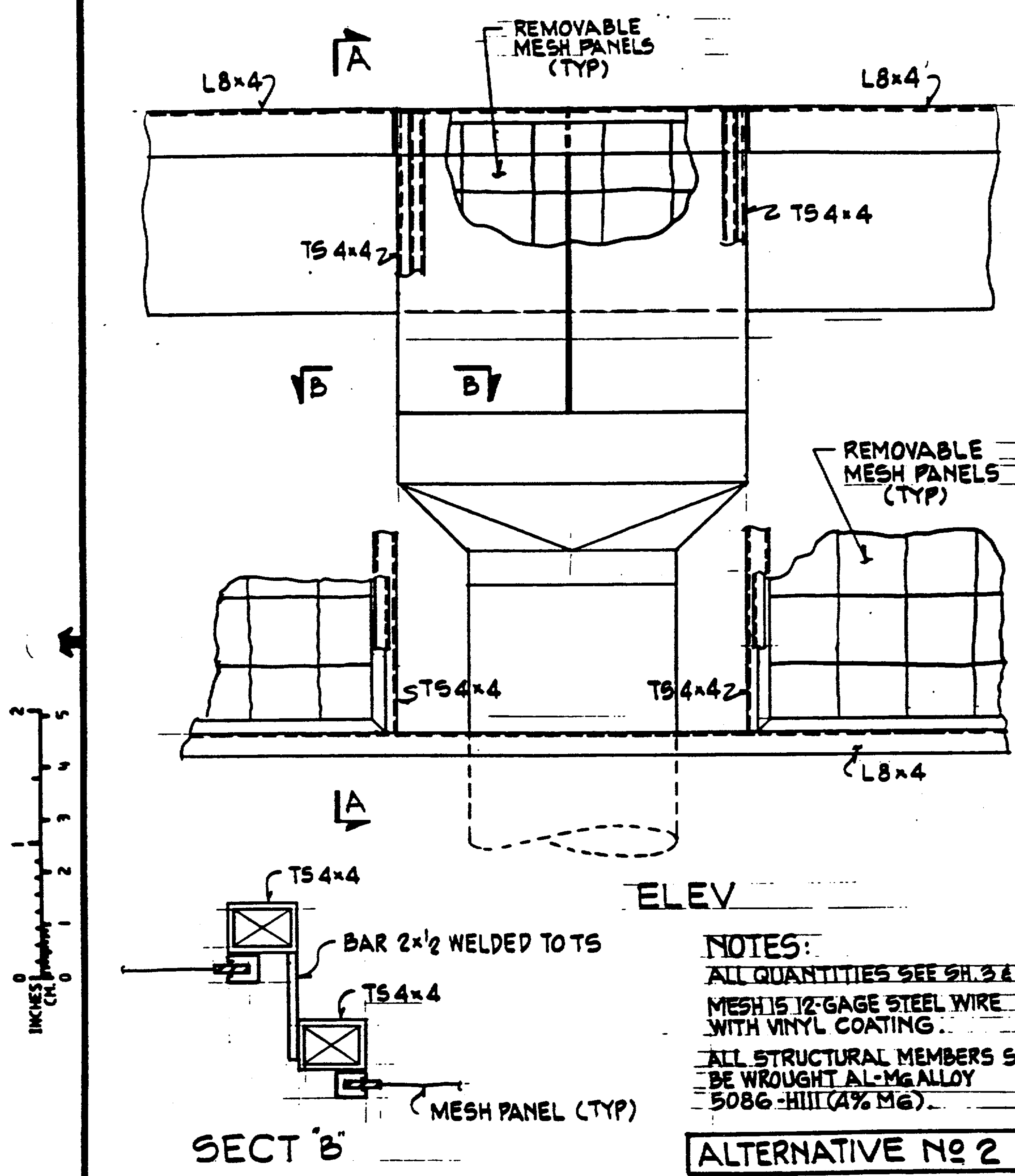
2. Subadults avoided strobe lights in 62.5 percent of all tests. However behavior was highly variable and many were attracted to light when tested again.

3. Strobe lights were more effective in eliciting responses under daylight conditions and the use of an air bubble curtain to increase light scatter had no effects on the turtles response to light.

4. Although the overall reaction of subadult turtles to strobe light was avoidance, all individuals approached the light at least several times. Thus, the applicability of strobe lights in a diversion scheme for marine turtles is limited.

IV Physical Barriers

Florida Power & Light Company has conducted several engineering studies of adding physical barriers to the velocity caps for the ocean intake pipe lines. The purpose of such barriers would be to restrict the entry of turtles into the ocean intake pipes. Several barrier designs have been considered. The details for one of these designs are presented in Figures 1 through 3.



NOTES:

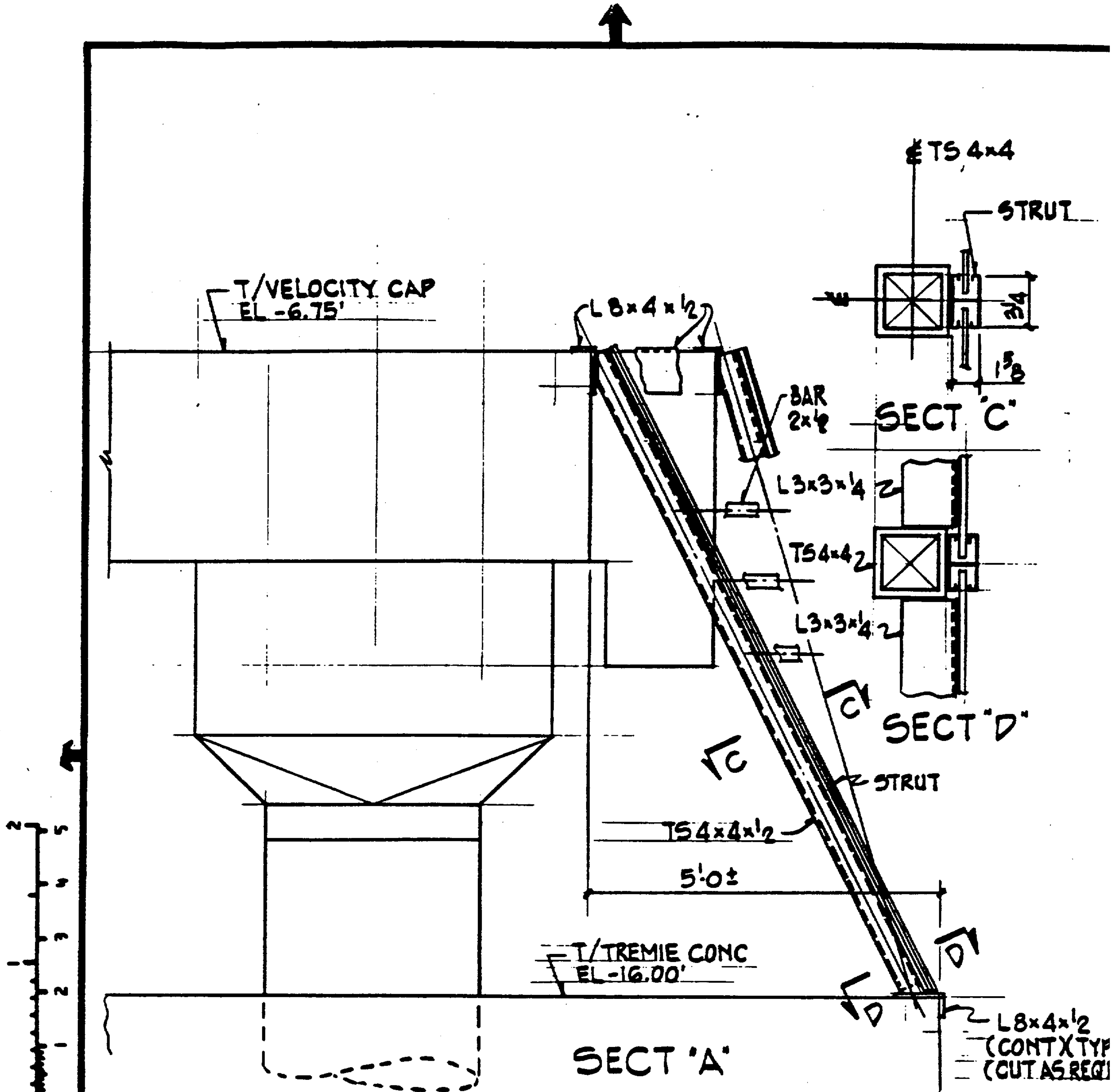
ALL QUANTITIES SEE SH. 3 & 4.

MESH IS 12-GAGE STEEL WIRE WITH VINYL COATING.

ALL STRUCTURAL MEMBERS SHALL BE WROUGHT AL-MG ALLOY 5086-H111 (4% MG).

ALTERNATIVE No 2

EBASCO SERVICES INCORPORATED		FLORIDA POWER & LIGHT COMPANY ST. LUCIE PLANT - UNIT 2 3RD INTAKE PIPELINE-VELOCITY CAP TURTLE DETERRENT STUDY	FIGURE
DIV. CIVIL DR. V.C.	APPROVED		
DATE 9-12-83 CH. T.T.			
SCALE N.T.S.			



QUANTITIES:

TS 4×4×1/2	920 LIN FT
STRUT	1060 LIN FT
BAR 2×1/2	130 LIN.FT
L8×4×1/2	650 LIN.FT
L3×3×1/4	320 LIN.FT
MESH	3850 SQ FT
MESH PANEL BAR	1710 LIN.FT

ALTERNATIVE № 2

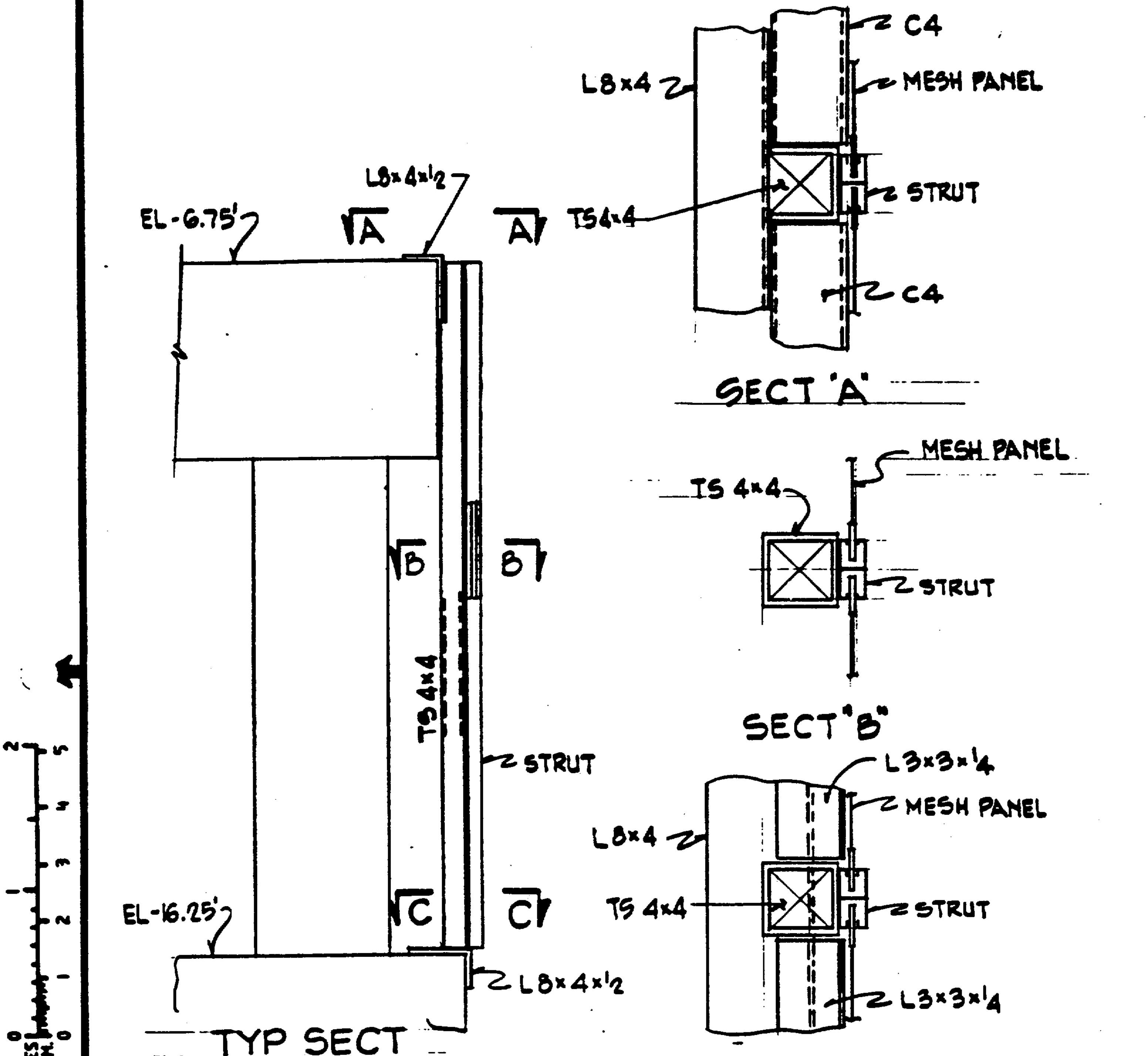
EBASCO SERVICES INCORPORATED

DIV. CIVIL DR. V.C.
DATE 9.12.83 CH. T.T.
SCALE N.T.S.

APPROVED

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT - UNIT 2
3RD INTAKE PIPELINE-VELOCITY CAP
TURTLE DETERRENT STUDY

FIGURE 2



QUANTITIES:

L8×4×½	430 LIN.FT.
TS 4×4×½	240 LIN.FT
STRUT	320 LIN.FT
C4×5.4	210 LIN.FT
L3×3×¼	230 LIN.FT
MESH	2030 SQ FT
MESH PANEL BAR	590 LIN.FT

ALTERNATIVE Nº 2

EBASCO SERVICES INCORPORATED		FLORIDA POWER & LIGHT COMPANY ST. LUCIE PLANT - UNIT #1 VELOCITY CAP (2-REQ'D)	FIGURE 3
DIV. CIVIL DR. V.C.	APPROVED		
DATE 9-12-83 CH. T.T.			

V Discussion

A. Deterrent Studies

Of the four deterrent studies, only the results from the electrical fields and pneumatic air guns were considered positive enough to consider these options for further evaluation. These evaluations were based on scientific results and incorporated considerations such as engineering design, practicality, safety, and costs.

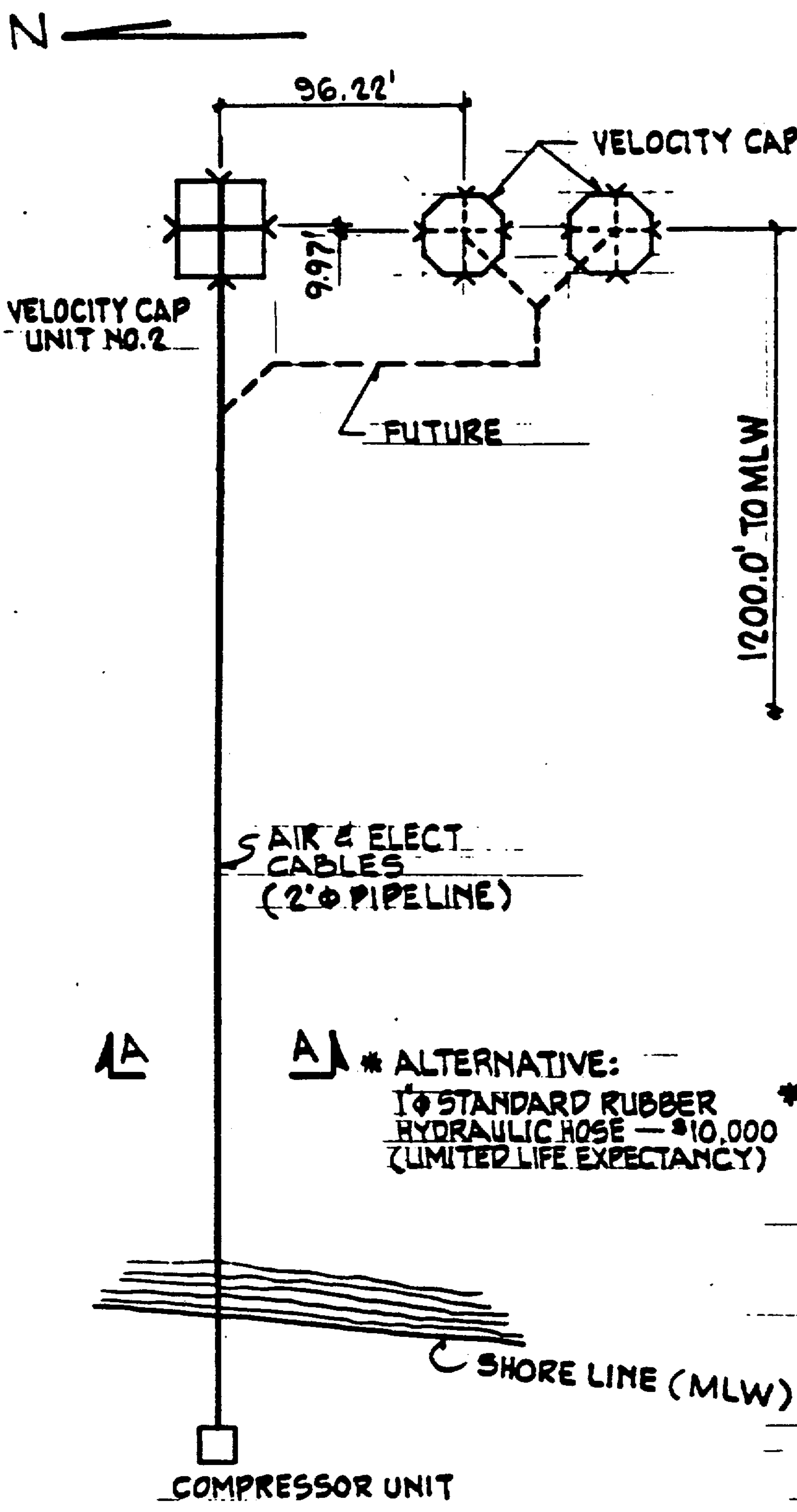
Electrical Fields

For an electrical field to be effective as a turtle deterrent, voltages of approximately 10 VAC/m would need to be maintained around the perimeter of the velocity cap with an extensive array of electrodes. This array would have to be engineered and constructed for a high-energy environment and would require 400-600 A. Maintaining a functional electrode array under severe surf conditions such as experienced at the St. Lucie Plant, was determined to be impractical. Additionally, since the area is used by commerical and sports fisherman, electrical currents could pose significant safety problems. Because of these concerns it was decided that this method of deterrence was not feasible and a detailed engineering and cost evaluation was not made.

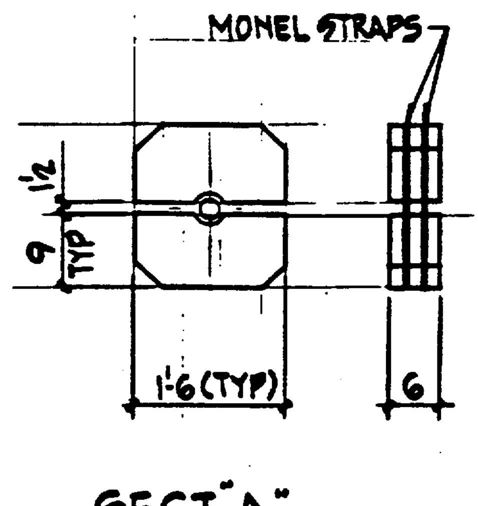
Pneumatic Air Guns

Based on the positive results from field experiments and other preliminary evaluations, a detailed engineering evaluation was undertaken of this deterrent system (Figure 4). This evaluation is briefly discribed below.

Given an the effective deterrent range of about 30 m and the dimensions of the offshore intake structures, it would be necessary to mount a gun on all four sides of the intake structure. Because of the potential long-term dynamic loading from repeated firings, guns would not be mounted on the face of the velocity cap but would need to be suspended away from the structure. Each gun also would require an



* ALTERNATIVE:
1"Φ STANDARD RUBBER HYDRAULIC HOSE — $10,000
(LIMITED LIFE EXPECTANCY)



SECT "A"

(CONC COLLARS TO BEGIN @ ELO
(COLLARS TO BE SPACED @ 5.0'(±
QUANTITIES OF COLLARS SHAL
DEPEND ON PIPE SIZE.

QUANTITIES

1. AIR COMPRESSOR (KA21-30E3)(LITERATURE ATTACHED)
* 2. 2"Φ-3000 PSI PIPELINE (1600 LIN. FT)(LITERATURE ATTACHED)
3. CONTROLLERS & CABLES (MANUAL) FOR 12-ACTIVE & 12-REDUNDANT GUNS
4. SWITCH & MISC ELECT (FOR AUTOMATIC)
5. PAR AIR GUN MODEL 600 B WITH INTERCHANGEABLE CHAMBERS 10 CU. INCHES 8-GUNS @ $8,000 EA
6. CONC BLOCKS PER SECT "A"

NOTES:

ITEMS NO. 1 THRU 4 ARE FOR ALL THREE (3) VELOCITY CAPS.

PIPELINE AND COLLARS SHALL BE NOMINALLY BURIED.

INSTALLATION COST NOT INCLUDED.

EBASCO SERVICES INCORPORATED		FLORIDA POWER & LIGHT COMPANY ST. LUCIE PLANT - VELOCITY CAPS - UNIT #1 & 2 TURTLE DETERRENT STUDY - AIR GUN	FIGURE
DIV. CIVIL DR. VC	APPROVED		
DATE 9-12-83 CH. T.T.	[signature]		
SCALE N.T.S.			

electrical cable to fire the gun and a high-pressure air hose. A shore-based compressor would provide the necessary air at the correct volume and pressure. Air would be conducted offshore through an armored 7 cm diameter hose into an offshore reservoir mounted at the intake structure. A manifold and electrical box would be used to supply air and an electrical signal to each gun. The continuous usage of these guns (i.e. a discharge every 15 seconds) and the potential for failure (i.e. o-rings and electrical connections) would require two backup guns for reliability. Thus, each face of the structure would need three guns for a total of 12 guns on each intake structure. Periodically (6-8 week intervals), all twelve guns would need to be replaced with refurbished equipment.

Because turtles are entering the intake canal through all three intake pipes and air guns would be mounted only on the third and newest intake structure, a system would be needed to separate the turtles drawn in through this pipe from the other two. Thus, to evaluate the effectiveness of the deterrent system, the headwall for the third intake pipe would have to be isolated from the other two intakes with a series of stop logs and heavy-duty screens.

Even with the redundancy described above, the engineers could not guarantee an 80 percent reliability of operation as specified in Section 4.2.2 of the Environmental Protection Plan. The estimated cost (direct and indirect) to determine the reliability of this system under field conditions ranges from a minimum of $720,000 for a 6-month study to $1,053,000 for a 12-month study.

B. Netting Technique

Turtles entrapped in the intake canal of the St. Lucie Plant are caught in large mesh nets and released back into the ocean. Aspects of their biology and status while in the intake canal need to be considered.

Capture Efficiency

A capture/recapture study was conducted from October 1980 through January 1981 to determine the length of time turtles were in the intake canal prior to being captured with the nets and to determine if turtles had any significant weight loss while in the canal.

Eleven loggerhead turtles were captured, tagged, released back into the canal and recaptured. Recapture occurred one to nine times before the individuals were released to the ocean (ABI, 1983; Table H-8). From a total of 32 recaptures, it was found that the elapsed time between capture and recapture ranged from 0.25 to 38 days, with an average of 10.3 days. Twenty-three of the 32 recaptures (72 percent) occurred within 11 days.

Seven of the 11 turtles (average weight 35 kg) were in the canal at least 15 days (range 15 to 90 days, average 44 days) between first capture and subsequent release to the ocean (ABI, 1983; Table H-9). Weight loss during this time ranged from 0 to 2 kg; the average was 0.7 kg. The turtles all appeared to be in healthy condition when released into the ocean.

Injury

The potential for injury during passage through the intake pipe was also a concern. Approximately 7 percent (75 out of 1135) of the sea turtles removed from the intake canal had recent lacerations, abrasions or other injuries that may have resulted from passage through the pipes. Wounds were considered minor in approximately 51 of the entrapped animals and major (deep cuts, broken flippers, etc.) in 24 of the animals. The intake pipes are 3.7 - 4.9 m in diameter, and it appears that the vast majority of the turtles are carried through the pipes without hitting the walls and sustaining injury.

Mortality

Over the nine years of monitoring through December 1984, 73 of the 966 loggerhead turtles (7.6 percent) and 16 of the 157 green turtles (10.2 percent) found in the intake canal were dead. All of the leatherback, the hawksbill and the Kemp's ridley were found alive.

Of the 73 dead loggerheads, 57 individuals (78 percent) were found floating in the canal, either along shore, against the barrier net or, in a few cases, against the bar screens (grizzlies) at the plant. Most of these "floaters" were in advanced stages of decomposition. Of the 16 dead green turtles, 11 individuals were found in the turtle nets or gill nets, three were found floating and information on two is lacking.

To reduce or eliminate mortalities caused by the nets, particularly among smaller green turtles, the turtle nets have been modified so that they are lighter and the fish gill nets were moved from areas where turtles frequent. Reducing mortalities of those turtles which are "floaters" is more of a problem because the causes of death are generally unknown.

The majority (62 percent) of the turtles found alive and released back into the ocean were considered to be in good physical condition, 20 percent were in poor condition and 18 percent were in excellent condition. Criteria used to evaluate condition were weight, activity, parasite coverage and wounds or injury (ABI, 1984; Table D-7). Turtles found dead in the canal (e.g. "floaters") may have been in poor condition prior to entering the canal. Turtles in poor condition could enter the ocean intakes seeking shelter and die from causes unrelated to plant operations.

The cost associated with netting and removing turtles from the intake canal at the St. Lucie Plant is approximately $60,000/yr. This cost is comprehensive and includes all phases of the effort.

C. Engineering Studies

All of the engineering studies have indicated that the capital and maintenance costs for a physical barrier system would be prohibative. The high costs are related to having all work performed under water in the open ocean. There are also costs related to power penalties from additional head losses caused by the barrier and its support system and costs for replacement power when the barrier is being installed. The estimated costs for the installation and maintenance of a barrier system and the related power penalty are outlined in section 6.4.5 of the St. Lucie Unit 2 Final Environmental Statement and, as an upper boundary, could be as high as 65 million dollars.

Based on the high estimated costs, this method of deterrence was considered impractical and eliminated from further consideration.

D. Recommendation

Upon careful evaluation of the practicality, reliability, and costs, of the various deterrent systems, Florida Power & Light feels that the present netting technique is the most practical and cost-effective technique for removing entrapped turtles from the intake canal at the St. Lucie Plant. Advances have been made in reducing the mortality of turtles from netting since the biological opinion was issued in 1982.
It is, therefore, proposed that Florida Power & Light be permitted to continue with the present netting technique for the life of the plant.

VI Interagency Task Force

On April 11, 1984, FPL hosted an Interagency Task Force in Ft. Pierce, Florida. Those invited and those in attendance are listed in Appendix F.

An oral summary of the findings were presented to those in attendance. A draft of this document was passed out for review and comment by the participants. On recommendation of the NRC participant, copies of the document were forwarded to USFWS, EPA, and Florida Audubon Society (Appendix G).

Comments were received from the NMFS and Dr. Peter C. H. Pritchard of the Florida Audubon Society (Appendix H). Verbal and written comments received from the agencies were all supportive of FPL's recommendation to continue netting turtles from the intake canal in lieu of behavioral or physical barriers for exclusion.

VII Appendices

A. Applied Biology, Inc., Sea turtle data base, St. Lucie Plant 1976 - 1983.

B. Applied Biology, Inc. 1980.
Turtle entrainment deterrent study. Final Report to Florida Power & Light Company, P.O. 02380-88260.

C. O'Hara, J. and H. J. Kania, 1981.
Avoidance response by sea turtles exposed to electrical Fields. Environmental and Chemical Sciences, Inc. Final Report to Florida Power & Light Company, P.O. 28171-85794.

D. O'Hara, J. 1983.
Seismic exploration air guns as a tool for sea turtle deterrence. Environmental and Chemical Sciences, Inc. Final Report to Florida Power & Light Company, P.O. 28171-85794

E. Raesly, R. L., J. R. Staufer, Jr., C. H. Hocutt, and D. R. Sager, 1984.
Behavioral responses of loggerhead sea turtles to light. University of Maryland. Final Report to Florida Power & Light Company, P.O. 44089-88612.

F. Participants invited and in attendance of the Interagency Task Force, April 11, 1984.

G. Transmittal letter to agencies, April 18, 1984.

H. Written comments sent by reviewing agencies.

VIII Reference

ABI. 1984. St. Lucie Plant annual non-radiological aquatic monitoring report, 1983. AB-530, Applied Biology, Inc., Atlanta, GA.

ABI. 1983. St. Lucie Plant annual non-radiological aquatic monitoring report, 1982. AB-442, Applied Biology, Inc., Atlanta, GA.

Bellmund, S., M. T. Masnik and G. La Roche. 1982. Assessment of the impacts of the St. Lucie Nuclear Plant on threatened or endangered species. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation.

NRC. 1982. Final environmental statement related to the operation of St. Lucie Plant, Unit 2. Docket No. 50-389.

NRC. 1983. Appendix B to facility operating license No. NPF-16 (Environmental Protection Plan (non-radiological)), St. Lucie Plant, Unit 2.

KEY

SEA TURTLE DATA BASE

Species (Sp)

CC	*Caretta caretta* (loggerhead)
CM	*Chelonia mydas* (green)
DC	*Dermochelys coriacea* (leatherback)
EI	*Eretmochelys imbricata* (hawksbill)
LK	*Lepidochelys kempii* (Kemp's ridley)

Measurements

SLCL	Straight-line carapace length in centimeters
CCL	Curved carapace length in centimeters
CW	Carapace width in centimeters (switched from straight-line to curved on 042881 for loggerheads, 122881 for greens and 041382 for leatherbacks)
PL	Straight-line plastron length in centimeters
TL	Tail length in millimeters (beginning 09/82)
WT	Weight in pounds
Hb	Hemoglobin in grams Hb/100 ml

Sex (S)

M	Male
F	Female (determined by relative tail length in animals where SLCL equals or exceeds 80 cm; determined by blood analysis of testosterone levels in animals equal to or less than 76 cm SLCL)

Relative Condition (C)

1	Excellent	- normal or above normal weight active very few or no barnacles or leeches no wounds
2	Very good	- intermediate good to excellent
3	Good	- normal weight active light to medium coverage of barnacles and/or leeches wounds absent, healed or do not appear to debilitate the animal
4	Fair	- intermediate poor to good
5	Poor	- emaciated slow or inactive heavy barnacle and/or leech infestation debilitating wounds or missing appendages
6	Dead	

Condition Factor (K)

$$K = \frac{\text{Weight in kilograms}}{(\text{SLCL in centimeters})^3} \times 10^5$$

Comments

A Alive, released in ocean (A is assumed unless stated otherwise)
B Dead
C Found floating
D Found on intake screens, baskets, grizzlies or barrier nets
E Found in turtle net
F Found in various stages of decomposition (generally buried)
G Found in fresh condition
- G-1 given to Ross Witham, Fla. DNR
- G-2 given to NMFS
- G-3 given to University of California at request of NMFS
- G-4 alive, given to Miami Seaquarium
- G-5 alive, released back into canal system
- G-6 given to S.N. Wampler DVM for necropsy (or treatment, if alive)
- G-7 alive, given to House of Refuge, Stuart, Fl.
- G-8 alive, given to Florida Institute of Technology
- G-9 alive, given to FPL for entrapment deterrent studies
- G-10 alive, delivered for artificial seagrass studies at Miami Seaquarium

H Cause of death unknown
I Water in lungs
J No water in lungs
K No abnormalities
L Abnormalities (lacerations, emaciated, etc.)
N Released back into intake canal
O Found in fish survey gill nets
P Tagged for identification purposes after death
R Recapture

PANDT3
TBKEY,1

SEA TURTLE DATA BASE

ST LUCIE PLANT

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
EI	030672	A8287		46.0		35.0	37.5		28.0			3	13.0	
EI	092984	NNC536	NNC537	37.0	40.0	36.0	29.5	68	14.0			2	12.5	
LK	020681	B2874	B2875	32.0		31.5	25.5		10.0			5	13.8	
LK	012684	NNC492	NNC493	34.0	36.5	37.0	27.0	69	12.0			2	13.8	
LK	021684	AAH559	AAH560	47.0	50.0	53.0	36.0	100	34.0			3	14.9	
DC	112877	HI2098		142.0		79.5						3		PL=111
DC	030778	HI2187		150.0		82.0					M	3		PL=119,EST1000LBS
DC	030878	HI2165		144.5		93.0						1		PL=113
DC	031378	HI2192		118.5		71.0					F	3		EST450LBS
DC	020381	HI3605	HI3606	124.0		68.0	97.0				M	3		
DC	031381	AAH028	AAH027	134.5		72.5			515.0		M	3	9.6	PL=105
DC	041382	AAH186	AAH187	112.5	119.0	83.0	87.5		290.0			4	9.2	
CM	012777	A6601		20.0		16.0			3.0			3	17.0	
CM	013177	415		27.0		22.0			4.0			3	9.2	
CM	021077	A6602		28.5		18.0	18.5		3.5			3	6.9	
CM	021477			36.0		27.0	31.5		10.0			6	9.7	HK
CM	042177											6		EI
CM	013178	HI2145		56.5		46.0	44.5		40.0			3	10.1	
CM	020978	HI2158		64.0		49.0	56.0					3		
CM	021778	HI2159		26.5		22.0	22.5		5.0			3	12.2	
CM	030378	HI2160		40.0		34.5	31.0					3		EST15LBS
CM	030778	A8288		26.0		21.0	21.5		5.5			1	14.2	
CM	052678			34.5		30.0						6		CFH
CM	020479	HI2295		30.0		24.0	23.0					3		
CM	041379	B1		35.0		29.0	29.0		13.0			6	13.8	EG2IK
CM	062179	HI2335		93.0		70.0	71.0				M	2		EST300LBS
CM	020480	A8289		35.5		28.0	28.0		12.0			5	12.2	
CM	022280	HI3075		40.5		35.0	34.0		18.0			1	12.3	
CM	022280	HI3100		36.0		30.5	30.0		14.5			6	14.1	EG3I
CM	022780	HI3072		44.0		36.0	36.5		29.0			3	15.4	
CM	022880	HI3074		51.5		42.5	45.0		49.0			3	16.3	
CM	030680	HI3112		55.0		45.0	45.0		64.0			3	17.4	
CM	030680	HI3113		24.5		20.5	20.0					3		
CM	030680	HI3115		26.0		21.0	22.0		5.0			6	12.9	EGILP
CM	031080	A8290		23.0		19.5	18.5		3.5			2	13.0	
CM	010881	HI3171	A8300	30.5		24.5	25.5		9.0			3	14.4	
CM	011381	B2791	B2792	25.0		19.0	22.0		5.0			3	14.5	
CM	011381	B2793	B2794	29.0		23.5	25.0		7.5			3	13.9	
CM	011381	B2795	B2796	28.0		23.5	24.0		5.5			3	11.4	
CM	011381	B2797	B2798	27.0		21.5	22.5		5.5			3	12.7	
CM	011481	B2799	B2800	48.5		39.0	40.0		38.0			3	15.1	
CM	011581	B2803	B2804	31.0		26.5	25.5		7.5			3	11.4	
CM	011581	B2805	B2806	26.0		21.5	22.0		5.5			3	14.2	
CM	011681	B2807	B2808	27.0		22.5	22.5		6.0			3	13.8	
CM	011881	B2809	B2810	30.0		26.5	24.0		7.5			3	12.6	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CM	011981	B2815	HI3623	53.5		43.5	43.0		47.0				13.9	A
CM	011981	B2811	B2812	24.0		24.5	25.0					3		
CM	011981	B2813	B2814	29.0		24.0	23.5		7.5			4	13.9	
CM	011981	HI3625	HI3624	47.5		38.0	39.5		36.0			3	15.2	
CM	012181	B2863	B2864	37.5		28.0	30.0		12.0			3	10.3	
CM	012181	B2865	B2866	28.0		24.5	24.5		7.5				15.5	A
CM	012181	B2867	B2868	30.5		26.0	25.5		8.0			3	12.8	
CM	012181	B2869	B2870	31.0		25.0	26.0		9.0			3	13.7	
CM	012781	B2871		28.5		23.0	24.0		7.0			6	13.7	EG1IP
CM	012881	B2872	B2873	31.0		26.0	27.5		9.0			4	13.7	
CM	021381	B2876	B2877	27.0		22.5	22.5		5.0			3	11.5	
CM	021381	B2878	B2879	27.0		21.5	22.5		6.0			3	13.8	
CM	021381	B2880	B2881	29.5		25.0	24.5		8.0			4	14.1	
CM	021581	B2882	B2893	28.5		23.0	23.5		6.5			3	12.7	
CM	021781	B2884	B2885	31.5		25.0	26.5		9.5			3	13.8	
CM	022681	B2886	B2887	29.0		24.0	24.0		6.0				11.2	A
CM	022781	B2888	B2889	32.0		28.5	27.5		9.0			3	12.5	
CM	031081	NNC326	NNC327	27.5		21.5	23.0					5		EST4LBS
CM	040681	AAH010	AAH011						58.0			1		
CM	080581	NNC357	NNC358	32.5		24.5	25.5		9.5			3	12.6	
CM	080681	NNC359		32.0		25.0	25.0		10.0			6	13.8	G10P
CM	122881	NNC401	NNC402	29.5	30.0	26.0	23.5		5.5			5	9.7	
CM	010782	NNC403	NNC404	34.5	35.5	31.0	28.5		11.0			1	12.2	
CM	042082	NNC360	NNC361	26.5	27.0	23.0	22.0		5.0			3	12.2	B080583VEROBEACH
CM	081382	NNC365	NNC366	28.0	30.0	26.0	24.0					1		
CM	082082	NNC367	NNC368	29.5	30.0	25.0	24.5	52	6.0			3	10.6	
CM	110782	NNC376	NNC378	23.0	24.0	22.0	19.0					1		
CM	112182	NNC379	NNC380	27.0	31.0	26.0	24.5	58	4.0			4	9.2	
CM	112282	NNC371	NNC372	28.0	30.5	26.0	24.0		7.5			4	15.5	
CM	120182	NNC381	NNC382	40.5	42.0	38.0	33.0		18.0			3	12.3	
CM	010483	NNC373		41.0	43.5	36.0	33.0	86	17.0			4	11.2	
CM	011083	AAH316	AAH318	57.0	59.5	54.0	47.5	110	48.0	9.5		1	11.8	
CM	011283	NNC398	NNC399	27.0		29.5	24.0	41	6.0			1	13.8	
CM	011383	NNC383	NNC384	32.5	34.5	30.5	27.0	59	9.0			2	11.9	
CM	011583			33.5	35.5	29.0	27.0	55	10.0			6	12.1	CG6L
CM	012583	NNC385		34.5	35.5	31.0	28.0	62	9.5			3	10.5	NNC386?
CM	012583	NNC375		44.0	45.5	39.5	37.0	83	22.0			3	11.7	NNC386?
CM	012683	NNC389	NNC387	33.5	35.5	30.0	27.5	56	10.0			3	12.1	
CM	020983	NNC391	NNC390	33.5	35.5	30.5	27.5	45	10.0			4	12.1	
CM	021983	NNC392	NNC393	25.5	27.0	22.5	22.5		5.0			3	13.7	
CM	022483	NNC394	NNC395	25.0	26.0	22.5	20.5	46	4.0			4	11.6	
CM	022583	NNC396	NNC397	30.5	31.5	27.0	26.0	45	7.0			4	11.2	
CM	030283	NNC407	NNC408	30.0	31.0	26.5	26.0	53	6.0			4	10.1	
CM	030483	NNC373		41.0	43.5	35.5	32.0	79	17.0			6	11.2	EGHR
CM	031783	NNC409		28.0	30.0	28.0	24.0	37	6.5			6	13.4	EG6JKP

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CM	062083	NNC410	NNC411	39.0	41.5	35.0	31.0	75	13.5			2	10.3	
CM	070783	AAH415	AAH416		108.0		84.0				M	4		CW=102,EST250LBS
CM	090983	AAH883	AAH884	97.5	101.0	97.0	77.5	437	218.0		M	1	10.7	
CM	101483	AAH453	AAH454	97.0	99.0	89.5	75.5	483	275.0		M	3	13.7	
CM	110583	NNC412	NNC414	28.0	29.0	.26.0	23.5	50	5.0			3	10.3	
CM	112083	NNC415	NNC416	30.5	32.0	29.0	26.0	51	7.0			3	11.2	
CM	112283	AAH484	AAH483	57.5	63.5	54.5	49.5	117	58.0	8.0		1	13.8	
CM	112383	NNC417		31.0	34.0	29.0	27.0	62	8.0			6	12.2	EG6P
CM	010184	NNC426	NNC427	25.0	27.0	23.5	20.5	43	3.0			3	8.7	
CM	010184	NNC418	NNC419	41.5	43.5	39.0	34.5	76	18.0			2	11.4	
CM	010284	NNC420	NNC421	34.0	36.0	29.5	27.5	63	9.0			4	10.4	
CM	010384	AAH508	AAH509	66.0	72.0	64.0	55.0	131	87.0			2	13.7	
CM	010384	NNC422	NNC423	21.5	23.5	19.5	19.0	36	3.0			2	13.7	
CM	010384	NNC425	NNC424	31.5	33.0	29.0	26.0	57	6.5			2	9.4	
CM	010484	NNC430	NNC431	38.0	40.0	33.5	30.5	67	12.0			2	9.9	
CM	010684	NNC432	NNC434	36.0	39.5	33.0	30.5	60	14.0			1	13.6	
CM	010684	NNC435	NNC436	27.5	29.0	25.0	23.0	50	5.0			2	10.9	
CM	010784	NNC451	NNC452	39.0	41.0	37.0	34.0	58	18.0			1	13.8	
CM	010984	NNC437	NNC438	40.0	43.0	38.0	36.0	78	20.0			4	14.2	
CM	011084	NNC439	NNC440	49.5	53.0	43.0	41.0	85	32.0			3	12.0	
CM	011184	NNC441	NNC442	30.5	33.0	29.5	27.5	40	10.0			3	16.0	
CM	011284	NNC443	NNC444	29.5	31.0	28.0	24.0	46	6.0			4	10.6	
CM	011384	NNC455	NNC454	35.0	37.5	32.5	29.0	53	12.5			1	13.2	
CM	011384	NNC456	NNC457	35.0	38.0	33.5	29.0	59	13.0			3	13.8	
CM	011384	NNC458	NNC459	31.5	33.5	27.0	25.5	52	8.0			2	11.6	
CM	011384	NNC460	NNC462	30.5	33.5	26.5	25.5	43	8.0			2	12.8	
CM	011384	NNC465	NNC464	38.0	41.5	36.0	32.0	70	15.5			2	12.8	
CM	011484	NNC466	NNC467	39.0	42.0	37.5	33.0	65	17.0			3	13.0	
CM	011484	NNC445	NNC446	33.5	35.5	32.0	28.5	65	11.0			1	13.3	
CM	011484	NNC501		27.0	28.5	22.5	22.0	45	5.0			6	11.5	CDG6LP
CM	011684	NNC468	NNC469	42.5	46.0	41.0	36.5	65	25.0			1	14.8	
CM	011684	NNC470	NNC471	37.0	39.0	33.0	30.0	65	10.0			3	9.0	
CM	011784	NNC472	NNC473	50.5	55.0	48.5	41.5	85	42.0			2	14.8	
CM	011984	NNC474	NNC475	35.5	37.5	32.0	29.5	43	11.5			3	11.7	
CM	011984	NNC447	NNC448	22.0	23.0	20.0	18.0	35	3.0			3	12.8	
CM	012084	NNC477	NNC478	32.0	33.0	28.5	25.5	33	8.0			1	11.1	
CM	012084	NNC479	NNC480	27.5	28.0	24.0	22.5	22	5.0			1	10.9	
CM	012084	NNC449	NNC450	31.0	34.0	29.5	26.0	51	10.0			3	15.2	
CM	012184	AAH526	AAH527	57.0	62.0	54.0	48.0	105	52.0			1	12.7	
CM	012184	NNC481	NNC482	31.5	34.0	30.0	27.0	50	10.0			2	14.5	
CM	012284	NNC483	NNC484	43.5	47.0	41.0	36.0	80	21.0			3	11.6	
CM	012384	NNC486	NNC485	26.0	27.5	24.0	22.0	48	5.5			3	14.2	
CM	012484	NNC488	NNC489	24.5	26.0	23.0	20.5	38	4.0			2	12.3	
CM	012584	NNC490	NNC491	28.5	31.0	26.5	24.0	57	7.0			2	13.7	
CM	012584	NNC529	NNC530	47.0	50.5	42.0	37.5	75	26.0			3	11.4	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CM	020184	NNC494	NNC495	36.5	38.5	32.5	29.0	67	12.0			1	11.2	
CM	020184	NNC496	NNC497	47.0	49.5	42.5	37.5	85	25.0			2	10.9	
CM	020384	NNC498	NNC499	31.0	33.5	27.5	25.5	54	8.5			2	12.9	
CM	020784	NNC542	NNC543	54.0	59.0	52.5	45.5	111	46.5			1	13.4	
CM	020784	NNC500	NNC502	37.5	40.0	36.0	32.0	67	15.0			4	12.9	
CM	020884	NNC503	NNC504	31.5	34.0	29.0	26.0	60	9.0			3	13.1	
CM	020984	NNC505	NNC506	36.5	39.5	34.0	30.0	65	13.0			3	12.1	
CM	021084	NNC551	NNC552	65.0	69.5	62.0	51.0	136	81.0			3	13.4	
CM	021084	NNC509	NNC508	25.0	26.5	22.0	21.0	41	4.0			3	11.6	
CM	021584	NNC555	NNC556	48.0	52.0	44.5	39.0	74	32.5			1	13.3	
CM	041384	NNC510	NNC511	29.0	31.0	26.0	23.5	52	7.5			1	13.9	
CM	060584	NNC513	NNC514	29.5	32.0	28.5	24.5	49	7.0			1	12.4	G10A062684
CM	061384	NNC516	NNC517	27.0	29.0	25.0	23.0		5.5			2	12.7	G10A062684
CM	062284	NNC518	NNC519	35.0	39.0	36.5	29.0		15.0			1	15.9	
CM	072484	NNC520	NNC521	26.5	28.0	24.0	22.5	49	5.3			1	12.9	G10
CM	073184	AAH673	AAH674	35.0	37.5	33.0	29.0	58	15.0			1	15.9	G10
CM	080684	NNC522	NNC523	34.0	36.0	30.0	27.0	48	10.0			2	11.5	R,B3853TAGGED 031982
CM	081684	NNC524	NNC525	30.0	32.0	28.0	25.0	44	8.0			3	13.4	
CM	091184	NNC527	NNC528	30.0	32.0	27.0	24.5		7.5			3	12.6	G-10,B091484
CM	100184	NNC538	NNC539	28.5	30.5	28.0	24.5	40	7.0			3	13.7	AD
CM	101184	NNC540	NNC541	37.5	40.5	35.0	30.5	55	14.5			1	12.5	
CM	101384	NNC542	NNC543	26.0	28.0	25.5	23.0	40	5.0			1	12.9	
CM	101684	AAH780		50.5	54.0	48.0	41.0	102	40.0			2	14.1	
CM	101684	NNC551	NNC552	25.5	26.0	23.0	21.0	36	6.0			2	16.4	
CM	101884	NNC574	NNC575	29.5	32.0	28.0	24.5	55	7.0			1	12.4	
CM	112084			46.0	47.3	45.0	38.5		25.0			5	11.7	L(TUMORS),NO TAGS
CM	112484	NNC553	NNC554	25.5	28.0	24.5	22.0		8.5			1	23.3	
CM	112684	NNC555	NNC556	30.5	33.0	28.0	26.0	57	7.0			1	11.2	
CM	112684	NNC557	NNC559	35.0	37.5	31.0	28.5	50	10.0			6	10.6	G6 TREATED,B112784
CM	120384	NNC544	NNC545	28.0	30.0	25.5	23.0	51	5.5			3	11.4	
CM	121384	NNC560	NNC561	30.0	32.0	27.5	24.5	45	7.7			3	12.9	
CM	121484	NNC562	NNC563	26.0	27.5	24.0	22.5	49	5.1			2	13.2	
CC	052076													A
CC	052676													A
CC	070876											3		EST80LBS
CC	070976	131										3		TAG301?,EST40LBS
CC	071376			80.0		60.0						3		EST65LBS
CC	071476	302										4		EST75-80LBS
CC	071576			61.0		45.0						4		EST40LBS
CC	071676	303		63.0		55.0						3		EST80LBS
CC	072776											6		CFH
CC	080376	307		56.5		51.0						3		EST60LBS
CC	080476	308		53.0		46.5						3		EST50LBS
CC	092376			65.0		52.0						4		EST45-50LBS
CC	100676	309		54.0		44.0						4		EST40LBS

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	100776	311		75.0		56.0						5		EST125LBS
CC	102776	312		63.0		54.0						3		EST75LBS
CC	102776	313		70.0		60.0						3		EST125LBS
CC	102776	314		61.0		55.0								A,EST75LBS
CC	102876	315		61.0		51.0						5		EST60LBS
CC	102976	316		104.0		76.0					F	5		EST300LBS
CC	111876	315		61.0		51.0						5		R
CC	112376	317		59.0		50.0						3		EST60LBS
CC	112476			61.0		51.0			76.0			6	15.2	CIKH
CC	112976			60.0		53.0						6		CFH
CC	112976			88.0		66.0					F	6		CFH
CC	121076													A
CC	121576	318		53.5		45.0						4		EST50LBS
CC	121576	319		55.0		43.5						4		EST50LBS
CC	121576	320		53.0		49.0						3		EST50LBS
CC	121576	321		60.0		50.0						3		EST50LBS
CC	121576	323		60.0		53.0						3		EST80LBS
CC	121676	324		54.0		47.0			65.0			2	18.7	
CC	121676	325		60.0		51.0			73.0			4	15.3	
CC	121776	315		59.0		50.0			73.0			5	16.1	R
CC	011977	401		71.0		60.0			170.0			4	21.5	
CC	011977	403		64.0		55.0			90.0			3	15.6	
CC	011977	404		52.0		46.0			50.0			2	16.1	
CC	011977	405		53.0		48.0			55.0			2	16.8	
CC	011977	406		61.5		52.5			90.0			2	17.6	
CC	012077	313	408	69.0		58.0			105.0			2	14.5	R
CC	012077	407		60.0		54.0			85.0			2	17.9	
CC	012177	409		66.0		57.0			110.0			5	17.4	
CC	012177	410		60.0		51.0			73.0			3	15.3	
CC	012177	411		47.0		41.0			38.0			2	16.6	
CC	012177	412		69.0		57.0			88.0			3	12.2	
CC	012177	413		61.0		52.0			53.0				10.6	A
CC	012177	414		58.0		49.0			48.0			3	11.2	
CC	020177	422		59.0		48.0			60.0			4	13.3	
CC	020377	416		58.0		50.0			74.0			3	17.2	
CC	021377													A,EST15LBS
CC	021477	417		71.5		61.0			145.0			3	18.0	
CC	021777	419		69.0		60.5	55.0					2		EST75LBS
CC	021777	421		66.0		57.5	55.0					3		EST65LBS
CC	022777	423		60.5		50.5	46.5		55.0			4	11.3	
CC	022877			49.0		39.0			35.0			6	13.5	CFH
CC	030277	426		60.0		52.0			60.0			3	12.6	
CC	030277	428		68.0		56.0						4		EST90-100LBS
CC	030877	429		61.5		51.5			85.0			4	16.6	
CC	031077	431		56.5		47.5			64.0			2	16.1	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	031177	432		58.5		49.5						3		EST55LBS
CC	031477	433		67.0		56.5	50.0					3		EST90LBS
CC	031777	434		64.0		54.5			68.0			3	11.8	
CC	041377			64.0		55.0						6		CFH,EST80LBS
CC	042177	HI1001		66.0		58.0			115.0			3	18.1	
CC	042177	HI1002		64.0		53.0						3		EST80LBS
CC	042177	433		66.5		56.0						3		R,EST90LBS
CC	042877			70.0		55.0						6		CFH
CC	050677	HI1003		59.0		51.0						3		
CC	060177	HI1572		62.0		53.0						3		
CC	060177	HI1573		53.0		49.0						2		
CC	060277	408		75.0		59.0						3		R
CC	060277	HI1574		62.0		51.0						3		
CC	060577	HI1638		57.0		48.0						3		EST30LBS
CC	070577	HI1857		60.0		53.0						3		EST50-60LBS
CC	070677	HI1860		65.0		57.5						4		EST70LBS
CC	071477	HI1870		58.0		46.0						4		
CC	072077	HI2012		105.5		81.0					M	4		EST350-400LBS
CC	081777	HI2074		65.5								3		EST60LBS
CC	082377	HI2069		59.0		52.0						3		EST50LBS
CC	082377	HI2070		72.0		61.0						4		
CC	090877	HI1875		57.0		49.5						3		EST40-50LBS
CC	090877	HI2071		60.0		53.0						3		
CC	090877	HI2072		54.0		51.0						3		
CC	090877	HI2073		73.0		60.5						3		
CC	090977	HI1876		68.5		56.5						3		
CC	090977	HI1877		53.5		43.5						3		
CC	091077	HI2078		70.5		58.5	55.0					4		
CC	091077	HI2079		67.0		57.5	52.5					3		
CC	091077	HI2080		66.0		57.5	50.5					3		
CC	091077	HI2081		62.5		52.5	48.5					3		
CC	091377	HI2082		68.0		56.5	52.0					3		
CC	091377	HI2083		57.0		52.0	45.5					2		
CC	091477	HI2084		71.0		58.0						4		EST80LBS
CC	091577	HI2085		85.0		68.0	62.5				M	2		
CC	092977			63.5		53.0	48.5		84.0			6	14.9	IL
CC	100377			85.5		64.0					F	6		CFH
CC	100777	HI2086		47.0			45.0					4		
CC	101177	HI2087		60.0								3		
CC	101177	HI2088		53.0								3		
CC	101177	HI2089		74.0								3		
CC	101177	HI2090		63.0		54.5	48.0		84.0				15.2	A
CC	101377	HI2091		57.0		47.0	44.0		59.0			2	14.5	
CC	102077	HI2092		64.0		57.0	49.0					2		
CC	102777	HI2093		59.5		49.0	46.0					2		

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	110877	HI2095		62.0		50.0	49.0					4		
CC	110877	HI2096		54.0		44.0	44.0					2		
CC	110977	HI2097		66.0		54.5	50.0					5		
CC	112977	HI2100		66.5		56.0	52.0					4		EST94LBS
CC	113077	HI2126		79.5		64.0	57.0					5		
CC	120177	HI2099		71.0		60.5	58.0					3		
CC	120277			61.5		52.0	46.0		54.0				12.5	A
CC	120877	HI2128		56.5		48.0	44.0		55.0			3	13.8	
CC	120977	HI2129		62.0		52.0	47.0		77.0			4	14.7	
CC	121277	HI2130		58.0		49.5						5		
CC	010178													A
CC	010278	HI2151										3		
CC	010878	HI2131		55.0		46.0	43.0					4		
CC	010978	HI2132										3		
CC	010978	HI2152		56.0		47.0	43.0		70.0			4	18.1	
CC	010978	HI2153		58.0		50.0	43.5		80.0			3	18.6	
CC	011078	HI2133		52.5		46.0	46.0		49.0			3	15.4	
CC	011078	HI2134		62.0		57.0	46.5		81.0			4	15.4	
CC	011078	HI2135		69.0		59.0	53.5		120.0			3	16.6	
CC	011178	HI2136		58.0		49.0	44.0		61.0			4	14.2	
CC	011378	HI2137		57.0		53.0	44.0		72.0			3	17.6	
CC	012478	HI2138		54.0		46.0	42.0		55.0			3	15.8	
CC	012478	HI2139		55.0		49.0	42.5		64.0			3	17.4	
CC	012478	HI2140		60.0		50.0	45.0		71.0			4	14.9	
CC	012478	HI2141		62.0		53.5	51.0		86.0			3	16.4	
CC	012578	HI2142		49.0		44.0	39.0		48.0			3	18.5	
CC	012678	HI2143		67.0		55.5	51.5		105.0			4	15.8	
CC	012778	HI2154		59.0		52.0	48.5					3		B041578VEROBEACH
CC	012778	HI2155		50.0		49.0	43.0					3		
CC	020178	HI2146		63.0		53.5	47.5					3		
CC	020278	HI2147		60.0		50.0	47.0					3		
CC	020878	HI2156		59.5		50.5	48.0					5		
CC	020978	HI2157		68.0		59.0	53.0					5		EST150LBS
CC	021478	HI2148		71.0		59.5	56.0					3		EST150LBS
CC	021578	HI2149		59.0		51.0	46.0		74.0			3	16.3	
CC	021778	HI2150		65.0		55.5	52.5		92.0			5	15.2	
CC	022878	HI2176		63.5		56.0	50.0					1		EST80LBS
CC	022878	HI2177				53.5	51.0					2		EST75LBS
CC	030178	779		82.0		64.0	63.0					6		DL,UNIVOFFLATAG
CC	030178	HI2178		69.0		57.0	53.0					4		EST90LBS
CC	030178	HI2179		62.0		54.0	48.0					3		EST75LBS
CC	030178	HI2180		61.5		52.5	48.0		75.0			3	14.6	
CC	030178	HI2181		73.0		60.0	56.0					5		EST125LBS
CC	030278	HI2182		55.0		47.5	45.5		68.0			2	18.5	
CC	030278	HI2185		61.5		54.5	48.5		84.0			2	16.4	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	030678	HI2162		54.0		50.0	42.0					2		EST45LBS
CC	030678			64.0		54.0	43.0					3		EST80LBS
CC	030778			93.5		68.0	65.5				F	6		DL,TAGC2798?
CC	030778	HI2186		65.0		53.0	49.0		90.0			3	14.9	
CC	030878	HI2163		78.0		62.0	58.0					3		EST150-200LBS
CC	030878	HI2164		65.0		53.5	49.0					1		EST85LBS
CC	031078	HI2188		59.0		51.5	47.5		73.0			3	16.1	
CC	031178	HI2189	HI2190	65.0		55.0	51.0		83.0			4	13.7	
CC	031378	HI2191		57.5		48.0	45.5		65.0			1	15.5	
CC	031478	HI2193		62.5		55.0	48.0		87.0			3	16.2	
CC	031478	HI2194		55.0		47.0	44.0		61.0			2	16.6	
CC	031578	HI2175										3		
CC	032078	HI2166		72.0		62.0	54.0					1		EST150LBS
CC	032178	HI2195		62.0		51.0	46.0		69.0			2	13.1	
CC	032178	HI2196		64.0		56.0	51.5		38.0			1	15.2	
CC	032178	HI2197		73.5		65.0	56.0					2		EST140LBS
CC	032378	HI2198		67.0		54.0	48.0		70.0			1	13.6	
CC	032378	HI2199		74.0		61.0	56.5					3		EST175+LBS
CC	032378	HI2200		61.5		54.0	47.5		77.0			3	15.0	
CC	033178	HI2172		75.5		61.0	55.0					5		EST90LBS
CC	040678											1		
CC	040778	HI2167		61.0		52.5	46.5		82.0			3	16.4	
CC	040778	HI2168		71.5		59.5	52.5					3		EST130LBS
CC	040778	HI2170		64.5		56.0	52.0					3		EST110LBS
CC	041178	HI2171		69.5		57.0	54.0					4		EST130LBS
CC	041178	HI2173		73.0		63.5	57.5					3		EST170LBS
CC	041278	HI2202		60.5		51.0	46.5		61.0			4	12.5	
CC	041278	HI2203		66.0		54.5	50.0		86.0			4	13.6	
CC	041378			63.0		55.5	50.0					6		CFH
CC	041378	HI2204		69.5		61.5	54.0					4		EST150LBS
CC	041478	HI2205		74.0		64.5	61.5					4		EST160LBS
CC	041478			67.5		56.0	50.5		85.0			5	12.5	
CC	041478	HI2206		69.0		59.0	56.5					4		
CC	041878			70.0		58.0	52.0					6		CFH
CC	041978			70.5		58.0						6		CFH,EST140LBS
CC	041978			71.5		61.0						6		CFH,EST150LBS
CC	042078	HI2207		49.5		42.0	37.5		42.0			4	15.7	
CC	042478			67.0		54.0	52.5		97.0			6	14.6	CFH
CC	042678	HI2208		64.5		56.0	50.0		98.0			3	16.6	
CC	050478			57.0		46.0						6		CFH
CC	051178	HI2209				51.5	47.5		71.0			4		
CC	051678	HI2210		63.0		52.5	47.5		85.0			4	15.4	
CC	060778	HI2226		72.0		62.0	59.5					5		EST160LBS
CC	060778	HI2141				53.0	49.0		67.0			3		R
CC	061378	HI2212		61.5		48.0	45.0		63.0			5	12.3	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	061378	HI2213		67.5		57.5	53.0					4		EST125LBS
CC	061378	HI2214		99.0		76.5	73.0				M	4		EST400LBS
CC	061378	HI2210		63.0		52.0	48.0		69.0			4	12.5	
CC	061578	HI2215		67.0		56.0	53.0		95.0			2	14.3	
CC	061578	HI2216		52.0		45.0	43.0		57.0			2	18.4	
CC	062378	HI2227		58.5		51.0	46.5		76.0			1	17.2	
CC	062878	HI2217		90.5		68.5	68.0				F	3		EST200-250LBS
CC	080278	HI2218		100.0		76.0	75.0				F	4		EST250-300LBS
CC	081078	HI2228		66.5		57.5	52.5					3		EST150LBS
CC	081078	HI2229		67.0		56.5	52.5					3		EST150LBS
CC	081078	HI2230		62.0		53.0	47.5		85.0			3	16.2	
CC	081078	HI2231		67.0		56.0	51.0		97.0			3	14.6	
CC	081178	HI2251		60.5		53.5	47.5		79.0			3	16.2	
CC	081578	HI2219		88.0		70.0	66.0				F	2		EST275LBS
CC	082278	HI2221		83.0		66.5	61.5				F	3		EST250LBS
CC	082278	HI2222		47.0		42.0	38.0					3		EST30LBS
CC	082378	HI2223		50.0		44.0	39.0		50.0			2	18.1	
CC	082478	HI2232		59.0		61.0	57.5					1		EST140LBS
CC	083078	HI2233		61.0		51.0	46.5		83.0			2	16.6	
CC	090178	HI2235		58.5		51.5	45.5		80.0			4	18.1	
CC	101878	HI2224		66.0		55.0	50.5					3		EST105LBS
CC	101878	HI2225		63.0		53.5	49.5		83.0			3	15.1	
CC	101978	HI2252		56.0		48.0	44.0		65.0			3	16.8	
CC	101978	HI2253		76.0		57.5	56.5					4		EST125+LBS
CC	101978	HI2254		72.0		61.0	58.0					3		EST150LBS
CC	101978	HI2255		55.0		50.0	45.5		70.0			3	19.1	
CC	101978	HI2256		81.0		67.5	61.5				F	3		EST250LBS
CC	102078			53.0		51.0	47.0		75.0			6	22.9	EI
CC	102078	HI2257		64.0		58.0	55.0		120.0			2	20.8	
CC	102478	HI2258		60.0		52.0	41.0		78.0			3	16.4	
CC	102478	HI2259		64.5		55.0	49.0		89.0			5	15.0	
CC	102478	HI2260		70.0		58.0	54.0		112.0			4	14.8	
CC	102578	HI2261		57.0		49.0	45.0		65.0			5	15.9	
CC	102678	HI2262		56.5		48.5	46.0		63.0			3	15.8	
CC	102678	HI2236		56.0		50.5	45.5		63.0			3	16.3	
CC	102778	HI2237		75.0		57.5	53.0		130.0			2	14.0	
CC	103178			65.0		57.5	50.5		87.0			6	14.4	DI
CC	110278			63.5		52.5						6		CFH
CC	110278			72.5		57.5						6		CFH
CC	111078			76.0		64.0	58.0					6		CFH
CC	111478	HI1004		91.0		65.0	62.0				M	2		EST205+LBS
CC	111678	HI1005		65.0		55.0	50.0					5		EST60LBS
CC	111778			75.0								6		CFH
CC	111778	HI1368	128								F	6		CFH, TAGGEDONBEACH
CC	111778	HI2238		63.0		55.0	47.0		81.0			5	14.7	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	111778	HI2239		56.5		48.5	43.0		57.0			5	14.3	
CC	111778	HI2240		77.0		65.5	57.5		130.0			4	12.9	
CC	111778	HI2242		67.0		54.0	52.5		98.0			3	14.8	
CC	112878											6		CFH,ESTCL=100
CC	112878	HI2243		57.0		51.0	44.0		67.0			2	16.4	
CC	113078			65.0		56.0	50.5		87.0			6	14.4	EI
CC	113078	HI2244		58.0		51.0	46.0		77.0			2	17.9	
CC	120178	HI2246				51.0	43.0		68.0			2		
CC	120578	HI2276		91.0		65.0	66.0				F	3		EST300LBS
CC	120878	HI2277		57.0		47.0	43.5		80.0			1	19.6	
CC	121678	HI2278		67.0		56.0	53.0		95.0			3	14.3	
CC	010479	HI2263		64.0		56.0	51.0					5		EST80LBS
CC	010579			61.0		48.0						6		CFH,EST70LBS
CC	010679			60.0		50.0	39.0					6		CFH,EST50-60LBS
CC	011079	HI2264		56.0		46.5	46.5		68.0			3	17.6	
CC	011079	HI2265		54.0		47.5	40.5		62.0			4	17.9	
CC	011079	HI2266		60.0		54.0	48.0		83.0			4	17.4	
CC	011079	HI2267		54.0		48.0	43.0		61.0			2	17.6	
CC	011079	HI2268		60.0		51.5	45.0		74.0			3	15.5	
CC	011079	HI2269		63.0		55.0	50.5		97.0			1	17.6	
CC	011079	HI2270		66.5		54.0	51.0		95.0			1	14.7	
CC	011179	HI2271		62.0		50.5	50.0		84.0			3	16.0	
CC	011179	HI2272		62.5		56.0	49.0		89.0			2	16.5	
CC	011179	HI2273		59.5		51.0	47.5		76.0			3	16.4	
CC	011179	HI2274		68.5		58.0	52.0		105.0			4	14.8	
CC	011279			62.5		48.0	45.0					6		E,EST7LBS
CC	011279	HI2275		57.0		47.5	48.0		60.0			3	14.7	
CC	011279	HI2279		71.0		59.0	54.5		115.0			5	14.6	
CC	011279	HI2280		71.0		61.5	56.5		133.0			3	16.9	
CC	013179			64.0		53.0	48.5		92.0			3	15.9	BLACK
CC	013179	HI2281		64.5		54.5	49.0		86.0			4	14.5	
CC	013179	HI2282		66.0		56.5	54.5		119.0			2	18.8	
CC	013179	HI2283		56.0		49.5	43.5		69.0			3	17.8	
CC	013179	HI2284		71.5		60.5	54.5		124.0			4	15.4	
CC	013179	HI2285		69.5		57.5	52.5		105.0			3	14.2	
CC	020179	HI2286		69.0		58.5	52.5		103.0			4	14.2	
CC	020179	HI2287		58.5		48.5	45.0		74.0			3	16.8	
CC	020179	HI2288										5		EST65LBS
CC	020279	HI2289		63.5		55.5	50.0		95.0			3	16.8	
CC	020279	HI2290		64.0		55.5	49.5		90.0			3	15.6	
CC	020279	HI2291		62.0		53.5	47.5		83.0			3	15.8	
CC	020279	HI2292		55.5		47.0	45.5		67.0			3	17.8	
CC	020279	HI2294		52.5		45.0	41.5		55.0			3	17.2	
CC	020479	HI2296		55.5		44.0	43.0					2		BLACK,EST58LBS
CC	020579			63.0		54.5			84.0			6	15.2	DHK

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	020679	HI2297		67.5		57.0	54.0		119.0			3	17.6	
CC	020779	HI2298		77.5		61.0	54.0		150.0			3	14.6	
CC	020879	HI2299		71.5		59.0	55.5		120.0			5	14.9	
CC	021279	HI2300		63.0		55.0	50.0		95.0			4	17.2	
CC	021379	HI2302		89.0		64.5	65.0		.		M	4		EST250LBS
CC	021479	HI2303		67.0		60.0	55.0		111.0			3	16.7	
CC	021579	HI2304		53.0		46.0	42.5		67.0			1	20.4	
CC	021579	HI2305		56.5		47.5	44.5		71.0			1	17.9	
CC	021979	HI2306		64.0		52.0	48.0		85.0			3	14.7	
CC	022079	HI2307		62.0		52.5	48.0		93.0			3	17.7	
CC	022079	HI2308		48.0		50.0	44.0					4		EST60LBS
CC	022179	HI2309		68.5		58.0	53.0		115.0			5	16.2	
CC	022279	HI2310		55.0		47.0	44.0		66.0			3	18.0	
CC	022379	HI2311		69.0		58.0	53.0					3		EST125LBS
CC	022379	HI2312		59.0		50.5	47.5					3		EST60LBS
CC	022679	HI2313		69.0		59.0	52.0		110.0			3	15.2	
CC	022879	HI2141	HI2314	60.5		52.5	50.0		88.0			2	18.0	R
CC	022879	HI2315		60.0		50.5	46.5		87.0			3	18.3	
CC	022879	HI2316		66.5		55.5	52.5		118.0			3	18.2	
CC	030179	HI2317		54.0		44.0	43.0		65.0			3	18.7	
CC	030179	HI2318		69.0		62.0	55.0		125.0			5	17.3	
CC	030179	HI2319		57.0		49.0	44.0		68.0			3	16.7	
CC	030279	HI2320		55.5		49.0	43.5		69.0			1	18.3	
CC	030879	HI2321		57.0		49.0	45.0		78.0			2	19.1	
CC	030879	HI2322		54.0		46.0	42.0		59.0			1	17.0	COVEREDWITHMUD
CC	031579	HI2323		65.5		54.5	50.0		89.0			2	14.4	
CC	032879	HI2302		94.0		64.5	66.0				M	2		R,EST250LBS
CC	032879	HI2324		52.5		44.0	41.5		63.0			1	19.7	
CC	032879	HI2325		58.5		51.0	44.5		61.0			1	13.8	
CC	032979	HI2326		55.0		47.5	45.5					1		EST70LBS
CC	040379	HI2327		63.5		53.5	49.5		95.0			2	16.8	
CC	040379	HI2328		57.0		51.0	49.5		75.0			1	18.4	
CC	040379	HI2329		85.0		67.5	63.0				M	2		EST275LBS
CC	040379	HI2330		52.5		47.5	43.0					2		EST45LBS
CC	040479	HI2331		62.5		54.0	49.0					2		
CC	040479	HI2332		53.5		48.5	43.5		68.0			1	20.1	
CC	040479	HI2333		73.5		59.5	55.0		120.0			2	13.7	
CC	040479	HI2334		64.0		50.0	46.0		82.0			1	14.2	
CC	040479	HI2335		64.0		55.0	51.5					1		
CC	040579			62.5		54.0	48.5		95.0			1	17.7	
CC	040579			71.0		59.5	54.5		125.0			2	15.8	
CC	040579			79.5		61.0	63.0		187.0			4	16.9	
CC	040579			62.5		52.0	49.0		81.0			3	15.0	
CC	040979			73.5		59.0	58.0					4		
CC	040979			83.5		65.5	63.0				F	3		

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	041079	HI2337		84.0		64.0	65.0				F	4		EST200LBS
CC	041079	HI2338		67.0		55.0	53.0		105.0			3	15.8	
CC	060579	HI2351		66.5		55.5	51.5					2		EST85LBS
CC	060679	HI2352		71.0		62.0	57.0		132.0			1	16.7	
CC	062179	HI2354		47.5		41.0	37.0		47.0			6	19.9	EG2IKP
CC	071079	HI2356		52.0		46.5	42.5		49.0			3	15.8	
CC	071079	HI2357		59.5		48.5	48.0		63.0			3	13.6	
CC	071079	HI2376		71.5		60.5	55.5		130.0			5	16.1	
CC	071079	HI2377		59.5		49.0	45.5		75.0			2	16.2	
CC	071079	HI2378		65.0		53.0	48.5		87.0			3	14.4	
CC	071079	HI2379		59.0		48.5	45.5					5		
CC	071079	HI2380		61.5		51.5	49.5		81.0			4	15.8	
CC	071179	HI2381		73.5		63.0	58.5		155.0			3	17.7	
CC	071179	HI2382		56.5		49.0	44.5		60.0			5	15.1	
CC	071179	HI2383		56.0		48.0	43.0		61.0			4	15.8	
CC	071179	HI2384		55.0		50.5	43.5		77.0			2	21.0	NA071779
CC	071279	HI2427		112.0		83.0	83.0				F	3		400+LBS
CC	071379			69.0		53.5	51.5		89.0			6	12.3	IOL
CC	071679			56.5		49.0	44.5		75.0			4	18.9	TAGHI11446?
CC	071779	HI2385		51.0		44.0	42.0					1		EST50LBS
CC	071879	HI2386		58.0		51.0	47.0					2		EST80LBS
CC	071879	HI2387		59.0		51.0	47.0					1		EST75LBS
CC	071979	HI2341		62.5		53.5	47.5		91.0			2	16.9	
CC	071979	HI2342		58.0		50.0	44.5		65.0			5	15.1	
CC	071979	HI2358		54.0		52.0	46.0		54.0			2	15.6	
CC	072479	HI2360		88.5		66.5	68.5				F	3		EST300LBS
CC	072479	HI2359		63.5		55.5	48.5		79.0			3	14.0	
CC	072579	HI2341		65.0		53.0	47.0		92.0			2	15.2	
CC	072679	HI2342										6		CFH
CC	072779	H1355		85.5		65.5	65.0				F	4		UNIVOFFLATAG
CC	072779	HI2468		80.0		60.0	61.0				F	4		TAGGEDONBEACH
CC	073179	HI2343		68.0		58.0	52.0		107.0			3	15.4	
CC	080179	HI2344		55.5		47.5	44.5		69.0			3	18.3	
CC	080279	HI2345		63.0		54.5	50.5		95.0			5	17.2	
CC	080779	HI2346		61.0		52.5	48.5		88.0			3	17.6	
CC	080879			59.5		51.0	46.5		80.0			3	17.2	
CC	080879	HI2363		70.5		55.0	51.0		112.0			5	14.5	
CC	081479	HI2347		69.5		58.5	56.5		105.0			2	14.2	NA082879
CC	081579	HI2361		67.0		57.5	55.0		113.0			3	17.0	
CC	081679	HI2362		53.0		45.5	42.5		57.0			2	17.4	G9A083179
CC	081779	HI2314		61.5		52.0			72.0			6	14.0	CHL
CC	082179	HI2365		75.5		62.5	60.0		145.0			1	15.3	
CC	082179	HI2364		64.5		55.5	51.0		96.0			2	14.5	G9A083179
CC	082379	H279		97.5		75.0	69.5				F	4		UNIVOFFLATAG
CC	082379	HI3406		100.0		73.0	71.0				F	4		TAGHI30467?

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	082479	HI3050		63.0		54.0	48.5		90.0			2	16.3	
CC	082479	HI3049		60.0		54.0	47.0		85.0			2	17.9	
CC	082779											6		CFH,ESTCL=91
CC	082879	HI2347		69.5		58.5	56.5		100.0			3	13.5	NA091479
CC	091079	HI2366		98.0		70.5						6		CHP,EST280-350L[illegible]
CC	091179	HI2878		94.5		72.0	71.5		222.0		F	3	11.9	TAGGEDONBEACH
CC	091479											2		NA092579
CC	091779	HI2247		71.5		55.0	54.5		107.0			3	13.3	G9A100679
CC	091879	HI2349		88.5		71.0	67.5		198.0		F	2	13.0	
CC	092579	HI2248		65.5		55.5	51.5		83.0			2	13.4	
CC	092579	HI3031		95.0		68.5	69.0		255.0		F	4	13.5	NA112779
CC	092579	HI3030		63.5		54.0	51.5		78.0			3	13.8	
CC	100179			73.5		60.0	23.0					6		FH
CC	100479	HI2631		103.0							F	6		FH
CC	100579	HI2367		62.0		52.0	48.0					3		
CC	101079	HI2389		71.5		56.5	53.0		123.0			2	15.3	G9A101879
CC	101079	HI2350		72.5		58.0	54.5		96.0			3	11.4	G9A101679
CC	101179	HI2390		51.5		46.0	40.5		47.0			3	15.6	
CC	101279	HI2393		56.0		44.5	45.0		58.0			1	15.0	
CC	101679	HI2368		69.0		59.0	57.5		112.0			3	15.5	
CC	101779	HI2371		62.0		52.0	48.5		62.0			3	11.8	
CC	101779	HI2370		73.5		61.0	56.0		105.0			3	12.0	
CC	101779	HI2369		62.0		53.5	49.5		73.0			2	13.9	
CC	101879	HI2372		60.0		56.0	52.0		81.0			2	17.0	G9A103179
CC	101979	HI2373		74.0		65.0	59.5		133.0			2	14.9	
CC	102579			76.5		60.5	57.5					6		CHL
CC	102579	HI3047		68.0		56.5	53.5		97.0			4	14.0	G9A103179
CC	110179	HI3048		52.0		46.0	42.0		61.0			3	19.7	G9A110879
CC	110379	HI2396		75.0		61.0	58.5		128.0			5	13.8	G6TREATED
CC	110679	HI3042		52.0		45.0	41.0		57.0			3	18.4	G9A111579
CC	110679	HI2394		66.0		53.0	49.0		87.0			3	13.7	G9A111479
CC	110779	HI2374		60.5		56.0	49.5					2		EST95LBS
CC	110979	HI3052		52.0		45.0	41.0		46.0			5	14.8	
CC	110979	HI3051		52.0		47.5	41.0		44.0			3	14.2	
CC	110979	HI3053		75.0		62.5	56.5		125.0			5	13.4	
CC	111679	HI2395		58.0		51.5	49.0		73.0			3	17.0	
CC	112779	HI2398		67.5		58.0	52.5		105.0			3	15.5	
CC	112779	HI2399		76.5		63.5	57.5		155.0			3	15.7	
CC	113079	HI3076		71.0		62.5	56.0		118.0			4	15.0	
CC	120779	HI3055		60.5		51.5	49.0		80.0			1	16.4	NA121379
CC	120779	HI3054		57.0		50.5	45.0		68.0			2	16.7	
CC	120779	HI3056		56.0		45.0	43.5		63.0			2	16.3	
CC	121379	HI2400		63.5		54.5	50.0		104.0			1	18.4	
CC	121379	HI3057		70.0		60.5	54.0		105.0			4	13.9	
CC	121479	HI3058		70.5		59.0	55.0		118.0			5	15.3	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	121879	HI3077		71.0		58.0	52.5		125.0			5	15.8	
CC	121979	HI3078		53.5		46.5	42.0		62.0			4	18.4	
CC	122179	HI3059		57.5		49.0	44.0		79.0			1	18.8	
CC	122779	HI3101		62.5		52.0	46.5		85.0			4	15.8	
CC	010880	HI3060		65.5		55.5	50.0		118.0			2	19.0	
CC	010880	HI3061		57.0		45.0	43.5		66.0			3	16.2	
CC	010680	HI3062		53.5		46.5	41.5		62.0			1	18.4	
CC	010880	HI3063		58.0		50.5	47.0		85.0			4	19.8	
CC	010980	HI3064		63.0		51.5	48.0		94.0			2	17.1	
CC	010980	HI3065		56.0		48.0	45.0		71.0			2	18.3	STAINED
CC	010980	HI3066		60.5		53.0	47.5		92.0			2	18.8	STAINED
CC	011580	HI3079		68.5		57.5	55.0		115.0			1	16.2	
CC	011580	HI3080		51.5		45.5	41.5		52.0			1	17.3	
CC	011880	HI3081		73.0		62.0	59.0		134.0			2	15.6	
CC	011880	HI3082		71.0		56.0	55.0		115.0			3	14.6	
CC	011880	HI3083		72.0		59.0	56.0		130.0			2	15.8	
CC	012280	HI3084		57.0		48.0	46.0		82.0			3	20.1	
CC	012280	HI3085		58.5		50.0	46.5		77.0			3	17.4	
CC	012480	HI3086		61.0		49.0	47.0		72.0			3	14.4	
CC	012880	HI3087		57.5		48.0	46.0		79.0			3	18.8	
CC	020180	HI3088		62.0		50.5	46.0		83.0			2	15.8	
CC	020180	HI3089		67.5		57.0	52.0		110.0			2	16.2	
CC	020180			68.5		57.5	53.0		115.0			6	16.2	EF
CC	020480	HI3090		60.0		51.5	45.0		68.0			4	14.3	
CC	020780	HI3091				58.0	53.0		97.0			4		
CC	021180	HI3092		57.5		49.5	46.5		76.0			3	18.1	
CC	021180			57.5		49.0	44.5		56.0			6	13.4	OIL
CC	021480	HI3093		60.5		53.0	48.5		90.0			3	18.4	CLEANEDOFF TAR
CC	021480	HI3094		65.0		52.0	48.0		63.0			5	10.4	
CC	021480	HI3095		61.5		52.0	46.5		78.0			2	15.2	
CC	021980	HI3096		56.0		50.0	45.5		81.0			1	20.9	
CC	021980	HI3097				51.0	47.0		69.0			5		
CC	022180	HI3098		71.0		58.0	55.5		107.0			4	13.6	
CC	022280	HI3099		55.0		49.0	44.0		62.0			4	16.9	NA032580
CC	022680	HI3067		62.5		52.5	49.0		88.0			3	16.3	
CC	022680	HI3068		65.5		58.0	51.0		117.0			1	18.9	
CC	022780	HI3069		62.5		51.5	48.0		79.0			4	14.7	
CC	022780	HI3070		74.0		58.5	56.0		124.0			5	13.9	
CC	022780	HI3071		58.5		50.0	48.0		87.0			4	19.7	
CC	022880	HI3073		65.0		52.0	50.5		98.0			1	16.2	
CC	022980	HI3103		47.0		40.5	37.5		48.0			[illegible]	21.0	
CC	030480	HI3106		55.5		49.5	45.5		72.0			1	19.1	
CC	030480	HI3108		60.0		50.5	46.5		77.0			5	16.2	
CC	030480	HI3109		61.0		52.5	48.0		85.0			2	17.0	
CC	030480	HI3105		58.5		49.5	47.5		81.0			[illegible]	18.4	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	030480	HI3104		58.5		51.0	45.0		76.0			3	17.2	
CC	030580	HI3110		63.0		54.0	50.0		90.0			4	16.3	
CC	030680	HI3111		50.5		43.0	39.0		55.0			3	19.4	
CC	030780	HI3114		60.0		49.5	46.5		81.0			1	17.0	NA032180
CC	031080	HI3116		57.5		48.0	45.0		75.0			4	17.9	
CC	031180	HI3117		64.0		53.0	49.5		105.0			1	18.2	
CC	031280	HI3118		63.5		54.5	50.5		103.0			1	18.2	
CC	031280	HI3119		58.0		48.5	46.0		75.0			3	17.4	
CC	031380	HI3120		58.5		53.0	48.0		82.0			1	18.6	
CC	032780	HI3122		60.0		50.5	48.5		86.0			1	18.1	
CC	051380	HI3123	HI3125	93.0		75.0	70.0		300.0		F	1	16.9	
CC	051680	HI3126		86.0		64.5	66.0		235.0		F	2	16.8	
CC	052080	HI5132	HI3153	87.0		65.0	70.0					4		EST275LBS
CC	052280	HI3154	HI3155	65.0		56.0	51.0		100.0			3	16.5	
CC	052880	HI3127	HI3128	73.0		60.5	58.0		135.0			1	15.7	
CC	052880	HI3158	HI3159	70.5		59.5	55.0		128.0			1	16.6	
CC	052880	HI3156	HI3157	65.5		54.0	53.5		91.0			4	14.7	
CC	060380	HI3129	HI3130	62.0		52.5	48.0		83.0			4	15.8	
CC	060380	HI3131	HI3133	61.0		53.0	50.0		80.0			3	16.0	
CC	061080	HI3156	HI3157	67.0		55.0	53.0		101.0			5	15.2	
CC	061280	HI3161	HI3162	104.0		81.5	79.5					3		EST425LBS
CC	061680	HI3134		58.0		51.5	46.0		72.0			6	16.7	CFKP
CC	061780	HI3165		65.0		55.0	54.0		101.0			6	16.7	CFKP
CC	061780	HI3163	HI3164									3		ESTCL=52,EST45LBS
CC	061980	HI3166		77.0		60.0	53.0		85.0			6	8.4	ELP
CC	080680	HI3170	HI3172	59.5		50.0	45.5		51.5			5	11.1	
CC	080680	HI3173	HI3174	60.0		51.0	45.5		65.5			3	13.8	
CC	080680	HI3175	HI3176	59.5		51.0	46.0		71.5			3	15.4	
CC	081880	HI3177	HI3178	62.5		52.0	48.5		69.0			4	12.8	
CC	082780	HI3179	HI3180	57.0		52.0	46.0		72.0			4	17.6	
CC	082780	HI3181	HI3182	53.0		45.0	42.5		61.0			1	18.6	
CC	082780	HI3183	HI3184	60.0		53.0	47.0		73.0			3	15.3	
CC	082880	HI3185	HI3186	88.0		72.0	66.0				M	4		EST250LBS
CC	082880	HI3187	HI3188	76.0		58.0	59.0		147.0			3	15.2	
CC	082880	HI3189	HI3190	68.0		59.0	51.0		117.0			4	16.9	
CC	082880	HI3191	HI3192	55.0		47.0	44.0		66.0			3	18.0	
CC	082980	HI3195	HI3196	59.5		52.5	47.0		70.0			3	15.1	
CC	090380	HI3156	HI3157	67.0		55.0	53.5		85.0			4	12.8	R
CC	090380	HI2369	HI3140	59.0		51.0	47.5		65.0			3	14.4	
CC	090480	HI3141	HI3142	55.0		45.5	42.0		59.0			1	16.1	
CC	090480	HI3143	HI3144	60.0		49.0	46.5		70.0			2	14.7	
CC	090480	HI3146	HI3147	53.5		43.5	42.0		51.0			4	15.1	
CC	090980	HI3201	HI3102	81.5		64.5	63.5		192.0		F	3	16.1	
CC	090980	HI3203	HI3204	64.0		55.0	51.0		85.0			4	14.7	
CC	091980	HI3205	HI3206	51.0		44.5	40.0		45.0			4	15.4	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	092280	HI3168	HI3169	57.5		49.5	46.5		65.0			3	15.5	
CC	092280	HI3148	HI3149	58.0		48.5	46.5		61.0			3	14.2	
CC	092280	HI3150		61.5		51.5	49.5		69.0			4	13.5	
CC	092380	HI3207	HI3208	101.5		72.0	74.5		309.0		F	3	13.4	
CC	092380	HI3209	HI3210	70.0		58.5	55.5		116.0			3	15.3	
CC	092480	HI3211	HI3212	57.0		52.0	44.0		55.0			4	13.5	
CC	092480	HI3213	HI3214	55.5		47.5	45.0		56.0			1	14.9	
CC	092580	HI3215	HI3216	57.5		50.5	46.0		70.0			3	16.7	
CC	092580	HI3217	HI3218	56.0		49.5	44.5		66.0			3	17.0	
CC	092680	HI3219	HI3220	69.5		56.5	53.5		118.0			3	15.9	
CC	092980	HI3226	HI3227	86.5		66.0	67.5		220.0		F	3	15.4	R,ALSOHI3126
CC	100180	HI3228	HI3229	84.0		69.5	66.0		215.0		F	3	16.5	
CC	100180	HI3230	HI3231	55.5		51.0	44.5		55.0			1	14.6	
CC	100880	HI3232	HI3233	92.0		58.0	58.0		215.0		F	3	12.5	
CC	101080	HI3234	HI3235	55.0		47.0	44.0		58.0			5	15.8	NA010981
CC	101480	HI3261	HI3273	67.0		54.0	49.0		86.0			3	13.0	NA121680
CC	101480	HI3263	HI3274	69.0		59.0	54.0		100.0			3	13.8	NA111480
CC	102780	HI3156	HI3157	67.0		55.0	53.5		85.5			5	12.9	
CC	110180	HI3221	HI3276	78.5		62.0	58.0		160.0			3	15.0	NA120880
CC	110680	HI3264	HI3277	55.5		47.0	44.0		57.0			3	15.1	NA121180
CC	111180	HI3262	HI3275	86.0		62.5	64.0		215.0		F	3	15.3	NA111480
CC	112480	HI3236	HI3237	46.5		39.0	39.0		37.0			1	16.7	NA120980
CC	120180	HI3222	HI3238	51.0		43.5	42.0		44.0			3	15.0	NB010681G1,0
CC	120380	HI3278	HI3279			65.0	61.0		180.0		M	3		NA120880
CC	120480	HI3280	HI3281	70.0		61.0	54.5		115.0			4	15.2	NA121280
CC	120580	HI3282	HI3283	61.0		47.5	44.0		56.0			3	11.2	NA121080
CC	120880	HI3284	HI3285	52.5		44.0	41.5		50.0			3	15.7	
CC	120980	HI3286	HI3287	62.5		51.5	48.5		82.0			3	15.2	
CC	121080	HI3289	HI3290	67.0		56.0	51.5		97.0			4	14.6	
CC	121580	HI3291	HI3292	72.5		60.0	53.5		105.0			4	12.5	
CC	010581	HI3239	HI3240	61.5		51.5	47.0		85.0			1	16.6	
CC	010681	HI3241	HI3242	57.5		49.5	45.5		66.0			2	15.7	
CC	010881	HI3243	HI3244	60.0		50.0	48.0		78.0			4	16.4	
CC	011381	HI3245	HI3246	63.0		53.5	49.0		81.0			4	14.7	
CC	011481	HI3247	HI3248	55.0		45.5	43.0		53.5			3	14.6	
CC	011481	HI3249	HI3250	46.0		41.5	37.0		41.0			3	19.1	
CC	011681	HI3296	HI3297	70.0		60.0	56.0		112.0			3	14.8	
CC	011981	HI3294	HI3295	60.5		53.5	47.5		71.0			3	14.5	
CC	012181	HI3601	HI3602	51.0		45.5	41.5		51.5			3	17.6	
CC	012681	HI3603	HI3604	60.0		50.5	47.0		85.0			2	17.9	
CC	020481	HI3607	HI3608	63.5		55.0	49.5		76.0			4	13.5	
CC	020681	HI3609	HI3610	50.0		45.0	42.0		46.0			3	16.7	
CC	021281	HI3315	HI3316	64.0		55.0	51.0		94.0			3	16.3	
CC	021381	HI3317		47.5		41.0	38.0		40.0			6	16.9	DFP
CC	021781	HI3318		83.5		62.5	64.0		170.0		F	6	13.2	DFP

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	021781	HI3319		70.5		53.0	54.5		110.0			6	14.2	DFP
CC	022381	HI3621	HI3622	60.0		51.0	45.0		65.0			5	13.6	
CC	022581	HI3321	HI3322	58.0		50.0	48.0					3		
CC	022781	HI3611	HI3612	56.0		48.5	45.5		68.0			3	17.6	
CC	022781	HI3613	HI3614	52.5		45.0	40.5		49.0			4	15.4	
CC	022781	HI3215	HI3216	58.0		50.5	46.0		75.0			3	17.4	
CC	030681	AAH001	AAH002	56.5		45.5	45.0		59.0			3	14.8	
CC	030881	AAH003	AAH004	53.0		43.5	40.5		55.0			2	16.8	
CC	031581	HI3173	HI3174	58.0		50.0	45.0		59.0			5	13.7	R
CC	031581	AAH029	AAH030	65.0		55.0	51.5		96.0			4	15.9	
CC	033081	AAH007	AAH006	62.5		52.5	49.5		77.0			2	14.3	
CC	033081	AAH008	AAH009	56.0		47.0	44.0		66.0			2	17.0	
CC	040181	AAH031	AAH032	52.0		44.0	41.5		55.0			3	17.7	
CC	040481	AAH033	AAH034		59.0	48.5	44.5		55.0			3		
CC	040681	AAH013	AAH014	51.5	55.5	49.5	44.0		58.0			1	19.3	
CC	040781	AAH015	AAH016	52.0	56.0	45.5	41.0		50.0			4	16.1	
CC	040781	AAH017	AAH018	67.5	75.0	58.0	55.0		109.0			3	16.1	
CC	042281	NNC354	NNC353	57.5	62.0	50.0	45.5		66.0			2	15.7	
CC	042881	AAH051	AAH052	54.5	58.0	56.0	43.0					1		EST55LBS
CC	042981	AAH054	AAH055		57.5	53.5	44.0					1		EST55LBS
CC	042981	AAH056	AAH057		71.0	67.0	50.0					5		EST85LBS
CC	043081	AAH060	AAH059		72.0	73.5	54.0					4		EST115LBS
CC	050481	NNC355	NNC356	57.5	62.0	56.5	46.5		59.0			5	14.1	
CC	050581	AAH035	AAH036		59.5	57.5	45.0					2		EST75LBS
CC	051281	AAH061	AAH062	60.0	65.0	62.0						4		EST45LBS
CC	051481	AAH063	AAH064	62.0	68.0	64.0	49.0		88.0			1	16.7	
CC	052781	AAH065	AAH066	59.0	66.0	67.0	48.5		74.0			3	16.3	
CC	052981	AAH067	AAH068	58.5	64.0	62.0	45.0		54.0			5	12.2	
CC	060381	AAH069	AAH070	69.0	75.0	61.5	55.0		107.0			3	14.8	
CC	060481	AAH071	AAH072	94.5	100.0	91.0	71.5				F	3		EST250LBS
CC	060981	AAD009	AAD010	60.0	62.0	52.5	48.0		68.0			5	14.3	RETAGAAH037&038
CC	061681	AAH073	AAH075	84.0	94.0	82.0	63.0				F	3		EST250LBS
CC	061681	AAH076	AAH077	86.0	94.0	86.0	65.0		210.0		F	2	15.0	
CC	061981	AAH078	AAH080	88.0	94.0	89.5	66.0				F	3		EST225LBS
CC	071681	AAH043	AAH044	51.5	55.5	55.0	41.0		48.0			4	15.9	
CC	081981	H3875	AAH081	85.0	91.5	87.0	69.5		183.0		F	3	13.5	UNIVOFFLATAG
CC	082481	AAH048	AAH049	59.0	63.5	61.0	47.0		62.0			3	13.7	G9
CC	082581	AAH082	AAH083	72.0	78.0	75.0	55.0		118.0			3	14.3	G9
CC	082681	AAH085	AAH086	59.5	64.0	61.5	46.5		68.0			2	14.6	G9
CC	082781	AAH019	AAH020	64.0	70.0	70.5	50.0		75.0			4	13.0	G9
CC	083181	AAH021	AAH022	58.0	60.5	59.5	43.5		52.0			5	12.1	
CC	090381	AAH087	AAH088	60.0	65.0	61.0	45.5		65.0			2	13.6	
CC	091781	AAH050		63.0		55.0						6		FP
CC	122381	AAH086	AAH102	59.5	64.0	62.0	46.5		74.0			2	15.9	R
CC	123081	AAH105	AAH104	51.5	53.5	52.5	41.0		42.0			1	13.9	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	123181	AAH106	AAH107	58.5	64.0	61.0	48.0		60.0			2	13.6	
CC	010482			67.0	71.0	59.0	53.0					6		CFL
CC	010482					64.5	67.5					6		CF
CC	010882	AAH108	AAH109	44.0	48.5	45.0	37.5		31.0			2	16.5	
CC	011282	AAH110	AAH112	48.5	54.0	54.0	40.0		39.0			4	15.5	
CC	011382	AAH113	AAH114	96.5	103.5	95.0	71.5		310.0		F	4	15.6	
CC	012182	AAH115	AAH116	64.5	67.0	64.0	50.0		71.0			2	12.0	
CC	020982	AAH119	AAH120	51.0	56.0	45.0	41.0		33.0			4	11.3	
CC	021282	AAH122	AAH121	56.5	60.5	56.5	43.0		55.0			1	13.8	
CC	021282	AAH124	AAH123	56.5	60.0	58.5	45.0		55.0			2	13.8	
CC	021682	AAH125	AAH126	68.0	72.0	54.0	47.5		98.0			1	14.1	
CC	021682	AAH127	AAH128	51.5	56.0	54.0	40.5		47.0			2	15.6	
CC	021682	AAH129	AAH130	56.0	60.0	58.0	44.0		59.0			2	15.2	
CC	021682	AAH131	AAH132	52.5	56.5	54.0	40.5		44.0			4	13.8	
CC	021782	AAH133	AAH134	57.0	62.5	58.5	46.0		60.0			3	14.7	
CC	021782	AAH136	AAH137	59.5	63.0	59.0	45.0		58.0			3	12.5	
CC	021882	AAH138	AAH139	69.0	73.0	73.5	56.0		110.0			3	15.2	
CC	022582	AAH140	AAH141	43.5	47.5	45.0	36.0		29.0			2	16.0	
CC	030382	AAH142	AAH143	52.0	56.5	57.0	41.0		45.0			2	14.5	
CC	030382	AAH144	AAH145	51.5	57.0	55.0	41.5		41.0			4	13.6	
CC	030482	AAH147	AAH146	96.0	98.5	88.0	64.0		245.0		M	3	12.6	
CC	030482	AAH048	AAH149	61.0	63.5	61.0	46.0		58.0			4	11.6	R
CC	030882	AAH150	AAH151	60.0	64.5	62.0	47.5		68.0			3	14.3	
CC	031082	AAH152	AAH153	58.0	62.0	59.0	45.5		56.0			1	13.0	
CC	031182	AAH154	AAH155	55.0	59.0	61.0	44.0		49,0			4	13.4	
CC	032482	AAH156	AAH157	59.5	65.0	61.5	45.5		68.0			3	14.6	
CC	032582	AAH158	AAH159	61.0	68.5	64.0	48.5		76.0			1	15.2	
CC	032582	AAH160	AAH161	65.0	70.0	67.0	49.5		83.0			2	13.7	
CC	032682	AAH162	AAH163	72.5	80.0	74.5	52.0		115.0			3	13.7	
CC	032982	AAH165	AAH164	62.0	63.0	58.5	44.5		67.0			3	12.8	
CC	033082	AAH166	AAH167	79.5	88.0	81.0	58.0		154.0			2	13.9	
CC	033082	AAH174	AAH175	61.0	68.0	64.5	48.0		70.0			4	14.0	
CC	040182	AAH172	AAH173		76.5	72.5			93.0			3		
CC	040282	AAH168	AAH169	54.0	59.0	60.0	41.5		47.0			5	13.5	
CC	040582	AAH170	AAH171	57.0	63.0	60.0	42.0		58.0			4	14.2	
CC	040682	AAH176	AAH177	81.0	89.5	77.0	65.0		157.0		F	4	13.4	
CC	040882	AAH178	AAH179	57.0	63.0	59.0	44.0		63.0			2	15.4	
CC	040982	AAH180	AAH181	63.5	69.0	66.0	50.0		91.0			1	16.1	
CC	040982	AAH182	AAH183	62.0	67.0	68.0	50.5		76.0			2	14.5	
CC	041182	AAH184	AAH185	48.5	55.0	56.0	32.0		35.0			4	13.9	
CC	041382	AAH189	AAH190	52.5	58.0	55.5	43.5		47.0			3	14.7	
CC	041482	AAH191	AAH192	54.5	59.0	56.0	42.5		47.0			1	13.2	
CC	041582	AAH193	AAH194	58.0	65.5	64.5	47.5		74.0			1	17.2	
CC	041582	AAH195	AAH196	61.0	66.5	62.0	46.0		72.0			4	14.4	
CC	041682	AAH197	AAH198	61.5	69.0	66.0	47.0		73.0			3	14.2	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	042382	AAH199	AAH200	77.0	86.0	84.5	57.0		128.0			4	12.7	
CC	051082	AAH204	AAH205	64.5	69.5	64.0	50.5		75.0			3	12.7	
CC	051282			59.0		49.5	47.5					6		CF
CC	051282			51.5		47.5	44.5					6		CF
CC	051282	AAC537	AAC538	60.5		54.0	49.0					6		CF,ALSOACC539
CC	051282			61.0		49.5						6		CF
CC	051482	AAH206	AAH207	57.0	65.0	61.0	46.0					3		G9
CC	051782	AAH208	AAH209	65.0	72.5	71.0	51.0		91.0			3	15.0	G9
CC	051882	AAH213	AAH214	84.0	97.0	87.0	71.0		240.0		F	4	18.4	
CC	051982	AAH210	AAH211	67.0	72.0	71.0	51.5		102.0			4	15.4	
CC	052082	AAH212	AAH215	65.0	71.5	72.5	49.5		90.0			3	14.9	G9
CC	052082	AAH168	AAH169	56.0	59.0	59.0	41.0		44.0			4	11.4	R
CC	052182	AAH216	AAH220	52.5	56.0	52.0	42.0		39.0			4	12.2	
CC	052182	AAH221	AAH222	50.5	57.0	51.5	42.0		42.0			2	14.8	
CC	052482	AAH223	AAH224	67.5	74.5	74.5	51.5		105.0			3	15.5	
CC	052582	AAH226	AAH227	54.0	60.5	58.5	45.0		61.0			2	17.6	G9A070982
CC	052682	AAH228	AAH230	72.0	81.0	76.0	54.0		98.0			4	11.9	
CC	052682	AAH231	AAH232	56.5	61.5	58.0	46.5		55.0			2	13.8	G9
CC	060782	AAH233	AAH234	58.0	63.5	58.0	46.5		62.0			2	14.4	G9
CC	061082	AAH235	AAH236	64.0	69.0	68.0	49.0		79.0			3	13.7	
CC	061282	AAH237	AAH238	57.0	61.0	58.0	44.0		47.0			4	11.5	
CC	061782	AAH136	AAH137	59.0	63.0	60.0	45.0		57.0			3	12.6	RG9A091782
CC	062182	AAH170	AAH171	58.0	63.0	58.0	42.0		51.0			5	11.9	R
CC	062882	AAH239	AAH240	84.0	91.0	83.0	61.0		157.0		M	4	12.0	
CC	062982	AAH241	AAH243	61.5	69.0	64.5	48.0		76.0			2	14.8	
CC	070182	AAH244	AAH245	52.0	57.5	55.5	41.0		45.0			3	14.5	
CC	070982	AAH246	AAH247	56.5	72.0	70.0	48.5		70.0			4	17.6	
CC	070982	AAH248	AAH249	60.0	64.5	62.0	46.5		58.0			2	12.2	
CC	071482	AAH250	AAH251	64.0	71.0	70.5	49.0		87.5			3	15.1	
CC	071682	AAH252	AAH253	60.5	67.0	64.5	45.5		70.5			3	14.4	
CC	072082	AAH254	AAH255	57.5	62.0	56.0	44.5		53.0			2	12.6	
CC	072782	AAE219	AAE220	65.5	71.5	67.0	49.0		72.0			4	11.6	G9A092282AAE221
CC	080782	AAH257	AAH258	55.5	62.0	61.0	44.0		50.0			5	13.3	
CC	082082	AAH115	AAH116	63.0	69.0	63.0	48.0		56.0			6	10.2	RDG6L
CC	090182	AAH259	AAH260	49.0	54.5	54.0	39.0	101	39.0	7.5	M	2	15.0	
CC	090182	AAH261	AAH262	51.5	60.0	58.0	42.0	125	53.0	11.5	F	2	17.6	
CC	090282	AAH263	AAH264	54.0	58.5	56.0	40.5		50.0			2	14.4	
CC	090382	AAH265	AAH266	61.5	72.0	70.0	52.0	150	90.0			3	17.6	
CC	090982	AAH267	AAH268	68.5	72.0	62.0	52.0	122	86.0	8.1		2	12.1	G9
CC	092282			93.5							M	6		DF
CC	092382	AAH269	AAH270	54.0	60.5	60.5	42.0	98	48.0	6.9	F	3	13.8	
CC	092882	AAH271	AAH272	62.5	70.0	66.0	47.0	140	76.0	9.2	F	4	14.1	
CC	093082	AAH275	AAH274	59.0	65.0	62.0	46.0	105	58.0	5.3	F	4	12.8	G9
CC	100582	AAH263	AAH264	53.0	58.0	55.5	39.5		49.0	8.0		3	14.9	R
CC	100682	AAH244	AAH245	52.5	58.0	55.0	41.0	99	40.0	6.4	F	4	12.5	R

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	101582	AAH276	AAH277	54.5	60.0	58.0	41.0	108	45.0	7.7	M	3	12.6	
CC	102582			80.5	87.0	58.0	61.0				F	6		CDL,EST130LBS
CC	102682	AAH279	AAH280	65.5	74.5	69.0	50.0	165	78.0	7.7	M	4	12.6	
CC	103182											6		CDF,EST50LBS
CC	103182											6		CDF,EST50LBS
CC	103182											6		CFLD,EST40LBS
CC	103182											6		CFDH,EST60LBS
CC	110282											6		CFDH,EST60LBS
CC	110882											6		CFDH,EST80LBS
CC	111582	AAH281	AAH282	70.5	77.5	73.0	55.0	185	94.0			5	12.2	
CC	112282	AAH166	AAH167	78.0	88.0	81.5	67.0		148.0			2	14.1	R
CC	122482				73.0	70.0						6		DFH,EST75LBS
CC	010383	AAH283	AAH284	93.0	100.0	99.5	68.0	470	260.0	6.5	M	3	14.7	
CC	010383	AAH285	AAH286	69.5	77.0	73.0	54.5	215	107.0	8.8	M	2	14.5	
CC	010383	AAH287	HI3188	76.5	82.0	75.5	59.0		123.0	6.7		4	12.5	R,3187REMOVED
CC	010383	AAH289	AAH290	64.0	69.5	64.5	50.0	135	78.5	6.7	F	4	13.6	
CC	010383	AAH291	AAH292	53.5	59.0	58.0	42.5	100	57.0	9.7	F	2	16.9	G9
CC	010383	AAH293	AAH294	74.5	81.0	77.0	53.5	176	110.0			4	12.1	
CC	010483	AAH295	AAH296	86.5	96.0	86.0	64.0	182	240.0		F	3	16.8	
CC	010483	AAH297	AAH298	71.0	77.0	73.0	56.0	149	109.0			2	13.8	G9
CC	010483	AAH300	AAH299	85.5	93.0	84.0	65.0	181	210.0		F	3	15.2	
CC	010483	AAH301	AAH302	66.5	71.0	70.0	51.0	139	89.0	7.7	F	2	13.7	
CC	010583	AAH303	AAH304	66.0	71.0	69.0	54.5	135	94.0	9.7	M	3	14.8	G9
CC	010583	AAH306	AAH305	56.5	61.0	59.5	46.5	126	61.0	10.2	F	1	15.3	G9
CC	010783	AAH307	AAH308	63.5	69.0	62.5	50.0	134	82.0	11.0	F	3	14.5	
CC	010783	AAH309	AAH166	79.0	87.0	81.0	59.0	159	150.0	8.6		3	13.8	R,ALSOAAH167
CC	010783	AAH310	AAH311	71.0	78.0	70.0	54.0	149	109.0	8.4	F	4	13.8	
CC	011083	AAH312	AAH313	56.0	60.0	58.0	44.0	114	56.0			4	14.5	G9
CC	011083	AAH314	AAH315	64.0	68.0	64.0	50.5	154	85.0			3	14.7	G6TREATED
CC	011083	AAH319	AAH320	85.5	90.5	81.0	60.5	399	200.0		M	3	14.5	
CC	011083	AAH322		68.5	75.0	70.0	52.5	162				5		EST85LBS
CC	011083	AAH321	AAH325	70.0	76.0	72.0	56.5	147	125.0			3	16.5	
CC	011183	AAH326		65.0	70.5	67.5	54.0	145	93.0			3	15.4	
CC	011183	AAH327	AAH328	57.5	63.5	61.0	46.5	128	61.0	9.9	F	3	14.6	G9
CC	011183	AAH329	AAH330	59.5	65.0	60.0	47.0	148	72.0			1	15.5	G9
CC	011183	AAH331	AAH332	51.0	62.0	59.0	43.5	125	60.0			4	20.5	G9
CC	011283	AAH333	AAH334	86.0	97.0	89.5	64.0	305	225.0		M	4	16.0	
CC	011383	AAH335		73.5	79.0	77.0	57.5	149	130.0			5	14.9	
CC	011883	AAH336	AAH337	65.5	71.0	66.5	51.5	143	90.0			1	14.5	
CC	011883	AAH338		83.0	93.0	82.0	62.0	225	172.0		M	4	13.6	
CC	011983	AAH339	AAH340	63.0	67.0	64.0	50.5	133	72.0	8.8	F	3	13.1	
CC	011983	AAH341	AAH342	60.0	64.5	62.0	47.5	116	60.0	8.6		2	12.6	
CC	011983	AAH343	AAH344	68.0	73.5	70.5	54.0	142	140.0	7.7	F	3	20.2	A103183CORESNDNC
CC	012583	AAH345	AAH346	60.5	64.0	63.0	48.5	130	69.0			3	14.1	
CC	012683	AAH347	AAH348	67.5	72.5	72.0	55.0	120	87.0	5.0	F	4	12.8	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(Continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	012683	AAH349	AAH350	58.0	63.0	63.0	47.0	131	65.0	6.8		4	15.1	
CC	012783	AAH351	AAH352	53.5	59.0	57.0	42.5	102	51.0			4	15.1	
CC	012783	AAH353	AAH354	58.5	63.5	59.5	47.0	120	58.0			4	13.1	
CC	012883	AAH356		71.0	77.0	70.0	55.0	158	89.0	11.0	M	3	11.3	
CC	013183	AAH357	AAH358	73.0	79.0	70.0	58.0	158	128.0	8.4	F	3	14.9	
CC	013183	AAH359	AAH360	51.0	58.0	56.0	40.0	123	52.0			4	17.8	
CC	020283	AAH361	AAH362	72.0	79.0	75.0	56.0	165	120.0			3	14.6	
CC	020783	AAH363	AAH364	57.0	63.0	60.0	44.5	120	43.0			2	10.5	
CC	020783	AAH367	AAH366	58.5	65.0	63.0	47.0	108	71.0			4	16.1	
CC	020883	AAH368	AAH369	61.0	66.0	64.0	48.0	138	73.0			3	14.6	
CC	020983	AAH370	AAH371	65.5	69.0	70.0	50.5	142	96.0	8.1	M	4	15.5	B102983CUMBISLGA
CC	021483	AAH372		63.5	70.0	66.0	48.5	119	86.0			4	15.2	G6TREATED
CC	021883	AAH373		64.5	70.0	69.0	50.0	152	90.0	9.4	F	4	15.2	
CC	022583	AAH374		60.5	65.0	61.5	48.0	142	72.0	6.4	M	3	14.7	
CC	022583	AAH375	AAH376	50.5	57.0	55.0	40.0	82	41.0			1	14.4	
CC	022583	AAH378	AAH377	66.5	75.0	70.5	51.0	155	104.0			3	16.0	
CC	022883	AAH379	AAH380	63.0	69.0	69.0	52.0	124	85.0			4	15.4	
CC	022883	AAH381	AAH382	58.0	62.0	61.0	45.0	116	59.0			3	13.7	G9
CC	022883				73.0		48.0					6		CF,EST85LBS
CC	031183	AAH383	AAH384	59.0	65.0	59.0	46.0	146	64.0			4	14.1	
CC	051083	AAH385	AAH386	73.0	78.0	73.5	60.0	135	122.0	11.2	F	3	14.2	
CC	051183	AAH389		51.0	58.5	53.0	41.0	105	47.0			2	16.1	G9A092183
CC	051283	AAH395	AAH396	63.0	70.0	66.5	49.0	142	88.0	10.3		1	16.0	
CC	051383	AAH397	AAH398	58.5	63.5	63.0	43.5	134	63.0	8.9	F	4	14.3	
CC	060683	HI2475	AAH399	83.5	91.0	84.0	63.0	190	177.0	9.9	F	3	13.8	TAGGEDONBEACH
CC	060683	AAH400	AAH401	69.5	76.0	70.5	54.0	143	100.0	11.5	F	1	13.5	
CC	061483	AAH402	AAH403	52.0	57.5	56.5	40.0	104	55.0	9.0	F	2	17.7	G9A092183
CC	061483			75.5	81.0	75.0	55.0		115.0			6	12.1	EL
CC	062183	AAH405		91.0	98.0	89.5	70.0	296	216.0		F	3	13.0	
CC	062283	AAH404	AAH406	87.5	97.5	80.5	66.0	239	226.0		F	3	15.3	
CC	062483	AAH407	AAH408	59.5	65.5	62.5	47.0	106	60.0			4	12.9	
CC	070683	AAH409	AAH410	56.5	61.0	60.0	44.0	121	63.0	6.0	F	3	15.8	G9A081683
CC	070683	AAH411	AAH412	67.0	73.0	68.0	51.5	154	84.0	5.7	F	4	12.7	
CC	071283	AAH417		94.0	107.0	90.0	74.0		280.0		F	3	15.3	
CC	072283	AAH420	AAH421	53.5	58.0	56.0	41.0	132	56.0	8.6	F	4	16.6	
CC	072783	AAH422	AAH423	61.5	66.5	63.5	48.5	132	68.0			3	13.3	
CC	072883	AAH424	AAH425	84.5	93.0	87.0	61.5		190.0		F	2	14.3	
CC	072983	AAH427		63.0	70.0	62.5	47.0	136	74.0			3	13.4	G9A101083
CC	080383	AAH428	AAH429	63.5	70.0	65.0	49.5	154	83.0	8.6		3	14.7	
CC	080983	AAH430	AAH431	66.5	71.0	66.5	49.5	175	80.0			3	12.3	
CC	081183	AAH432	AAH440	70.0	76.5	73.0	53.0	157	116.0			3	15.3	
CC	081383	AAH441	AAH443	84.0	92.0	86.0	62.0	210	150.0		M	3	11.5	
CC	081883	AAH444	AAH445	59.5	63.5	63.0	46.0	115	61.0	9.0	F	3	13.1	
CC	081883	AAH341	AAH342	60.0	65.0	63.0	47.0	128	61.0			3	12.8	RG9A101083
CC	090283	AAH446	AAH447	94.0	99.0	93.0	70.0		275.0		F	3	15.0	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	090283	AAH448	AAH449	93.0	101.0	95.5	73.5		341.0		F	3	19.2	
CC	090683				73.0	68.0						6		DH,EST80LBS
CC	090783	AAH879	AAH870	57.0	64.0	58.0	46.0	111	65.0			3	15.9	TAGAAH880?
CC	090783	AAH881	AAH882	70.0	76.0	72.0	57.0	122	102.0			2	13.5	
CC	091283											6		DFH,EST60LBS
CC	092883	AAH885	AAH886	59.0	67.0	64.0	47.0	130	70.0			4	15.5	G9A112183
CC	093083	AAH887	AAH888	70.0	79.0	72.5	55.0	147	110.0			2	14.5	G5TRANSMITTER
CC	100483	AAH889	AAH890	65.5	71.5	69.5	52.0	129	82.0	10.1		4	13.2	
CC	100583	AAH891	AAH892	64.0	69.0	66.5	47.5	141	75.0			4	13.0	
CC	100683	AAH894	AAH893	51.5	56.5	54.5	40.0	115	48.0			3	15.9	G9A112183
CC	101383	AAH896	AAH895	42.5	46.0	44.0	33.5	83	28.0			3	16.5	G9A112183
CC	101383	AAH897	AAH898	59.5	66.5	62.5	48.0	141	70.0			4	15.1	G9A112183
CC	101383	AAH451	AAH452	61.5	67.0	64.0	49.0	143	69.0	9.7	F	4	13.5	
CC	101483	AAH456	AAH455	49.5	54.5	55.0	40.0	107	38.0	9.3	F	3	14.2	
CC	101583	AAH457	AAH458	80.5	87.0	79.5	63.5	185	165.0		F	5	14.3	G6TREATED
CC	101883	AAH460	AAH459	54.0	57.5	57.5	43.0	121	50.0	9.0	F	4	14.4	
CC	101983	AAH462	AAH461	71.5	77.0	74.5	56.0	162	117.0	7.8	F	3	14.5	
CC	102183	AAH464	AAH463	60.5	66.0	64.0	50.0	134	78.0	8.9	F	1	16.0	
CC	102183	AAH465		81.0	89.0	84.0	61.0		182.0		F	5	15.5	
CC	102483	AAH457	AAH458	80.5	87.0	79.5	63.5	185	165.0		F	4	14.3	R
CC	102583	AAH466	AAH467	60.5	66.0	61.0	48.0	132	66.0	9.0		4	13.5	
CC	102683	AAH469	AAH470	75.0	81.0	77.0	57.0	165	127.0	7.5	F	3	13.7	
CC	102683	AAH471	AAH472	50.0	56.0	53.0	39.0	101	42.0	7.0	F	3	15.2	
CC	102683	AAH473	AAH474	81.0	89.0	80.0	57.5	255	160.0	9.0	M	2	13.7	
CC	110583	AAH475	AAJ001	60.0	69.0	64.0	48.0	115	78.0			4	16.4	
CC	110983	AAH476	AAH477	61.0	67.5	63.5	47.0	136	74.0	8.2	F	2	14.8	
CC	111183	AAH478	AAH428	64.0	69.5	64.0	48.0	154	75.0			2	13.0	RG9101083
CC	111383	AAH479	AAH480	52.0	58.0	55.0	41.0	135	51.0			3	16.5	
CC	111583	AAH481	AAH482	56.0	62.5	60.5	46.0	102	54.0	11.9	F	4	13.9	
CC	120183	AAH485	AAH487	46.5	51.0	50.5	38.0	74	35.0	10.1	F	3	15.8	
CC	120683	AAH488	AAH489	68.0	74.5	70.0	58.0	146	97.0	10.4		2	14.0	
CC	120883	AAH490	AAH286	71.5	77.0	72.0	57.0	221	110.0	8.7	M	4	13.7	R
CC	121683	AAH491	AAH492	61.5	66.5	65.0	52.5	140	85.0			1	16.6	
CC	121683	AAH493	AAH494	52.0	58.0	56.0	42.0	105	45.0	10.0	F	4	14.5	
CC	122083	AAH495	AAH496	57.0	64.0	59.0	46.5	134	68.0	8.9	M	2	16.7	
CC	122183	AAH497	AAH498	73.5	81.0	76.0	58.5	181	124.0	9.9	F	3	14.2	
CC	122383	AAH499	AAH500	89.0	96.0	87.0	62.0	495	200.0		M	4	12.9	
CC	122783	AAH501	AAH420	53.5	57.5	56.5	40.0	127	45.0	6.6	F	4	13.3	R
CC	122883	AAH502	AAH503	67.5	73.5	71.0	52.0	174	108.0			2	15.9	
CC	122983	AAH428	AAH478	64.0	69.0	64.5	47.0	146	73.0	6.6		3	12.6	R
CC	123083	AAH504	AAH505	83.5	91.0	80.5	59.5	242	200.0	8.0		2	15.6	
CC	010184	AAH506	AAH507	60.0	66.0	64.0	48.0	125	78.0			3	16.4	
CC	010484	NNC428	NNC429	55.0	56.0	49.0	45.0	104	40.0			1	10.9	
CC	010484	AAH511	AAH510	67.0	71.0	68.5	51.5	134	88.0			4	13.3	
CC	011084	AAH356		70.5	78.5	71.0	53.5	153	94.0			4	12.2	R

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CLL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	011284	AAH514	AAH515	53.5	58.5	56.0	42.0	127	49.0	8.3	M	4	14.5	
CC	011284	AAH516	AAH517	85.5	93.0	86.0	67.0	240	205.0		F	4	14.9	
CC	011384	AAH518	AAH519	60.5	65.5	62.5	45.0	122	53.0			5	10.9	STAINED
CC	011684	AAH521		56.0	61.0	59.0	42.5	142	58.0			4	15.0	
CC	011684	AAH522		75.0	81.0	77.5	59.0	170	115.0			5	12.4	
CC	011784	AAH525		59.5	66.0	63.5	45.0	128	64.0			4	13.8	
CC	012284	AAH528		73.5	82.0	76.0	56.0	150	118.0			4	13.5	
CC	012584	AAH531	AAH532	58.5	64.0	57.5	46.0	141	60.0	7.3	M	4	13.6	
CC	013184	AAH533	AAH534	62.0	67.5	63.0	46.5	182	72.0			3	13.7	STAINED
CC	020184	AAH535	AAH536	53.5	58.0	56.5	41.5	115	48.5			2	14.4	STAINED
CC	020284	AAH537	AAH538	51.0	57.0	55.0	38.0	113	38.5			4	13.2	STAINED
CC	020684	AAH539	AAH540	63.5	70.0	65.0	49.5	164	76.0	9.4	M	3	13.5	
CC	020784	AAH544	AAH545	69.0	77.0	72.0	55.5	115	100.0			4	13.8	
CC	020884	AAH546	AAH547	50.5	57.0	51.5	40.0	100	47.0	7.2	F	4	16.6	
CC	020984	AAH548	AAH549	73.0	80.0	78.0	56.0	186	130.0			2	15.2	
CC	021484	AAH553	AAH554	51.5	58.0	54.0	40.5	99	50.0	9.5	F	1	16.6	
CC	021584	AAH557	AAH558	50.0	55.0	52.5	38.5	101	41.0	9.6	F	3	14.9	
CC	021684	AAH561	AAH562	55.5	62.0	60.5	43.5	115	58.0			2	15.4	
CC	022184	AAH563	AAH564	69.5	75.0	74.0	54.0	146	125.0	7.3	F	3	16.9	
CC	022284	AAH565		63.5	70.0	64.0	48.5	132	91.0			3	16.1	
CC	030184	AAH567	AAH568	63.5	70.5	67.5	50.5	155	91.0	10.6	F	2	16.1	
CC	030284	AAH550	AAH569	48.5	55.0	50.0	38.0	116	38.0	8.0	F	1	15.1	
CC	031284	AAH570	AAH571	68.0	75.0	72.0	53.5	112	98.0			1	14.1	
CC	031484	AAH572	AAH573	47.0	51.0	51.0	37.0	99	31.0	7.5	F	4	13.5	
CC	031684	AAH565		64.0	70.0	64.0	49.0	140	86.0			3	14.9	R
CC	032184	AAH574	AAH575	59.0	66.5	64.0	48.5	146	75.0	10.0	M	1	16.6	
CC	041784	AAH576	AAH577	59.0	64.0	63.0	47.0	120	70.0	8.0	F	2	15.5	
CC	043084	AAH428	AAH478									6		RCF
CC	052184	AAH578	AAH579	62.0	65.0	63.0	46.0	135	65.0			4	12.4	
CC	052984	AAH580	AAH581	52.5	63.0	62.5	44.5	151	69.0			2	21.6	G10A062684
CC	052984	AAH582	AAH583	56.0	63.0	59.5	46.5	105	66.0			1	17.0	G10A062684
CC	052984	AAH584	AAH585	86.5	96.0	89.0	69.0	190	260.0		F	1	18.2	
CC	053084	AAH586	AAH587	93.5	100.0	90.0	70.5	227	290.0		F	2	16.1	
CC	053084	AAH588	AAH589	88.0	97.0	86.0	70.0	257	258.0		F	2	17.2	
CC	053184	AAH590	AAH591	54.0	60.0	57.0	40.5	127	55.0			3	15.8	G10A062684
CC	060184	AAH592	AAH593	55.0	62.0	59.0	44.5	128	67.0			2	18.3	G5A061184
CC	060484	AAH594	AAH595	58.0	62.0	61.0	46.5	137	68.0	8.0		4	15.8	
CC	060584	AAH578	AAH579	62.5	66.5	63.0	46.5		66.0	7.9		4	12.3	R
CC	060584	AAH602	AAH603	57.0	63.0	61.0	45.5	132	56.0	11.1		2	13.7	
CC	060584	AAH596	AAH597	72.5	79.5	76.0	58.0	140	125.0	9.2		3	14.9	
CC	060584	AAH598	AAH599	68.5	75.0	74.5	53.5	181	118.0	11.5		3	16.7	
CC	060584	AAH600	AAH601	56.5	62.0	56.5	45.0	132	59.0	11.4		2	14.8	
CC	060584	AAH604	AAH605	55.5	63.5	61.0	44.0	120	62.0			2	16.5	G10A062604
CC	060584	AAH606	AAH607	54.0	60.0	61.0	43.0	100	66.0	10.2		2	19.0	
CC	060584	AAH608	AAH609	58.5	64.0	63.0	43.0	117	59.0	7.2		4	13.4	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	060584										F	6		CF LARGE
CC	060684	AAH610	AAH611	64.5	70.0	67.5	49.0		78.0	11.0		3	13.2	
CC	060684	AAH612	AAH613	55.0	60.0	58.0	43.0		57.0	10.2		3	15.5	
CC	060684	AAH614	AAH615	88.0	97.0	84.0	69.0		228.0		F	2	15.2	
CC	060684	AAH616	AAH617	72.5	78.0	76.0	58.5		127.0			3	15.1	
CC	060784	AAH618	AAH619	51.5	58.0	55.5	40.5		50.0	9.5		3	16.6	
CC	060884	AAH620	AAH621	64.0	69.0	65.0	49.0		83.0	10.9		3	14.4	
CC	060884	AAH622	AAH623	85.5	92.0	84.0	60.0	400	173.0		M	2	12.6	
CC	061284	AAH624	AAH625	78.0	80.0	72.0	55.5	153	115.0	10.0		3	11.0	
CC	061384	AAH626	AAH627	88.5	98.0	87.0	66.5		207.0		F	3	13.5	
CC	061484	AAH628	AAH629	88.5	96.0	89.0	69.5		230.0		F	2	15.1	
CC	061484	AAH630	AAH631	65.5	72.0	70.0	49.0		90.0			3	14.5	
CC	061984	AAH632	AAH633		100.0	91.0			233.0		F	3		CL=92APPROXIMATE
CC	061984	AAH634	AAH635		71.0	65.0			74.0	8.8		4		CL=66APPROXIMATE
CC	062084	AAH636	AAH637	46.5	52.0	51.0	38.0		40.0	11.5		1	18.0	
CC	062684	AAH639	AAH640	52.0	60.0	57.0	41.5		53.0	9.5		2	17.1	
CC	062984	AAH643	AAH644	65.5	73.0	68.0	51.5		97.0			2	15.7	
CC	062984	AAH645	AAH646	54.5	65.0	62.0	44.0		62.0			3	17.4	
CC	071084	AAH651	AAH652	62.5	69.5	63.5	49.0		84.0			1	15.6	
CC	071184	AAH653	AAH654	61.5	69.0	66.0	47.0		76.0			3	14.8	
CC	071184	AAH655	AAH657	62.0	68.0	67.0	50.5		87.0	10.5		3	16.6	
CC	071984	AAH658	AAH659	85.5	96.0	88.0	66.5		230.0		F	3	16.7	
CC	072384			60.0		61.0						6		B,F,H
CC	072484	AAH660	AAH661	70.5	77.0	73.0	53.0	127	113.0			3	14.6	G-10
CC	072584	AAH662	AAH663	52.0	57.0	56.0	40.0	95	52.0			3	16.8	G-10
CC	072684	AAH664	AAH665	88.0	97.0	85.0	69.0	249	240.0		F	2	16.0	
CC	072684	AAH666	AAH667	83.0	95.0	84.0	66.5	207	220.0		F	1	17.5	
CC	073184	AAH675	AAH676	85.5	94.5	85.0	65.5	204	195.0		F	2	14.2	
CC	073184	AAH670	AAH672	71.5	76.5	75.0	53.5	158	99.0			4	12.3	
CC	073184	AAH668	AAH669	88.0	94.0	90.0	69.0	254	255.0		F	3	17.0	
CC	080284	AAH677	AAH679	73.0	79.0	78.0	54.5	190	138.0			2	16.1	G-10
CC	080384	AAH608	AAH609	57.5	63.0	62.0	43.5	117	70.0			3	16.7	R,REMOVED 060584
CC	080784	AAH647	AAH648	65.0	70.5	66.0	46.5	180	75.0			4	12.4	
CC	080884	AAH680	AAH682	71.0	76.0	74.0	53.5	135	108.0			4	13.7	
CC	080984	AAH683	AAH684	84.5	95.0	84.0	65.5	176	180.0		F	3	13.5	
CC	081584	AAH685	AAH686	88.0	98.0	85.5	67.0	200	185.0		F	4	12.3	
CC	081584	AAH688	AAH689	74.5	81.0	73.5	55.0	185	125.0	9.5		2	13.7	
CC	081584	AAH690	AAH691	53.5	60.0	56.0	43.5		56.0	10.0		2	16.6	
CC	081584	JI6363	AAH692	93.5	108.0	101.0	77.0	267	330.0		F	3	18.3	R
CC	081584	AAH693	AAH694	60.0	67.0	63.0	44.0	122	80.0	11.0		2	16.8	
CC	081684	AAH695	AAH696	60.5	68.5	67.0	48.0	115	77.0	10.5		2	15.8	
CC	081684	AAH697	AAH698	59.0	66.5	62.5	45.5	143	76.0			3	16.8	
CC	081684	AAH699	AAH700	86.0	94.5	85.0	67.5	240	240.0		F	3	17.1	
CC	081984	AAH649	AAH650	60.0	66.0	65.0	45.0	129	68.0			4	14.3	
CC	082084	AAH630	AAH631	65.5	73.0	70.0	49.0	148	92.0			3	14.9	R,REMOVED 061484

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Sex	Relative Condition	Condition Factor	Comments
CC	082084	AAH701	AAH702	53.0	56.0	58.0	42.0	105	53.0			2	16.1	
CC	082184	AAH703	AAH704	73.5	80.0	75.0	58.0	222	134.0	11.5		2	15.3	
CC	082184	AAH705	AAH706	94.5	101.0	89.5	75.5	240	280.0		F	4	15.0	
CC	082784	AAH707	AAH708	85.5	93.0	88.0	64.0	420	260.0		M	2	18.9	
CC	082984	AAH709	AAH710		76.5	73.5	55.5	140	102.0			[illegible]		
CC	082984	AAH711	AAH712	75.0	82.0	78.0	56.0	192	127.0			2	13.7	
CC	082984	AAH713	AAH714	69.5	77.0	73.0	51.5	128	114.0			2	15.4	G-10
CC	083084	AAH715	AAH717	62.5	69.0	69.5	49.5	115	90.0			2	16.7	G-10
CC	083084	AAH718	AAH719	55.0	62.0	60.0	44.0	115	60.0			2	16.4	G-10
CC	083084	AAH720	AAH721	59.5	65.5	64.5	46.5	133	73.0			2	15.7	G-10
CC	083084	AAH722	AAH723	50.5	56.0	55.5	42.0	119	47.0			2	16.6	G-10
CC	091084	AAH741	AAH742	101.0	106.0	93.5	72.0	270	300.0		F	4	13.2	
CC	091084	AAH738	AAH739	77.0	84.0	81.5	60.0	130	147.0			2	14.6	
CC	091184	AAH743	AAH744	79.0	87.5	81.0	60.0	190	155.0	9.5		3	14.3	
CC	091184	AAH745	AAH746	60.0	66.0	63.0	48.5	95	67.0	6.5		4	14.1	
CC	091184	AAH747	AAH748	86.0	97.5	98.0	69.0	160	260.0		F	3	18.5	
CC	091284	NNC529	NNC530	94.0	102.0	93.5	72.0	200	300.0		F	2	16.4	
CC	091284	AAH749	AAH750	62.0	67.0	65.0	49.0	110	77.0	11.5		3	14.7	
CC	091384	NNC532	NNC533	64.0	71.0	63.5	49.0	156	94.0			3	16.3	
CC	091384	NNC534	NNC535	59.5	66.0	65.0	48.5	99	76.0			4	16.4	
CC	091784	AAH751	AAH752	64.0	71.0	66.0	50.0	140	90.0	13.5		4	15.6	
CC	091784	AAH753	AAH754	67.5	73.0	69.0	51.0	155	88.0			4	13.0	
CC	091884	AAH755	AAH756	53.0	60.0	58.0	42.0	90	50.0	10.5		4	15.2	
CC	092184	AAH757	AAH758	62.0	70.0	65.0	49.0	150	82.0			4	15.6	
CC	092584	AAH759	AAH760	94.0	99.5	96.0	72.0	250	290.0		F	4	15.8	
CC	092684	AAH761	AAH762	66.0	74.0	72.5	55.5	137	98.0			4	15.5	
CC	092984	AAH763	AAH764	50.5	55.5	55.0	40.0	85	51.0			4	18.0	
CC	100184	AAH765	AAH766	75.5	84.0	80.0	59.5	142	145.0	12.5		3	15.3	
CC	100184	AAH767	AAH768	79.0	83.5	81.0	61.5	211	155.0			4	14.3	
CC	100284	AAH769	AAH770	57.0	63.0	58.0	45.0	100	65.0			4	15.9	L,G6,TREATED
CC	100384	AAH771	AAH772	50.0	56.0	53.0	37.5	87	42.0			4	15.2	
CC	100484	AAH773	AAH774	69.0	74.0	71.0	55.0	145	95.0	10.0		4	13.1	
CC	100584	AAH775	AAH776	70.0	77.0	71.0	55.5	172	115.0	9.5		1	15.2	
CC	101384	AAH778	AAH779	59.0	66.0	65.0	48.0	111	75.0			4	16.6	
CC	101784	AAH781	AAH782	85.0	96.0	86.0	65.0	256	210.0		M	2	15.5	
CC	102284	AAH783	AAH784	51.5	57.0	53.0	40.5	109	51.0	9.5		3	16.9	
CC	102384	AAH785	AAH786	60.5	67.0	61.0	45.5	142	74.0	11.0		3	15.2	
CC	110184	AAH789	AAH790	60.5	66.0	64.5	46.5	127	68.0	7.0		3	13.9	
CC	110184	AAH787	AAH788	41.5	47.0	43.5	33.5	99	24.0			1	15.2	
CC	110684	AAH791	AAH792	68.0	75.0	68.5	52.5	174	96.0	11.5		3	13.8	
CC	111584	AAH793	AAH794	61.0	67.0	65.0	50.5	120	79.0	12.5		4	15.8	
CC	111684	AAH795	AAH796	87.0	94.0	86.0	67.0	190	238.0		F	5	16.4	L(OLD)
CC	112684	AAH797	AAH798	72.5	80.0	72.0	56.5	155	134.0			1	16.0	
CC	112784	AAH799	AAH800	56.0	62.0	57.0	42.5	107	56.0			4	14.5	
CC	112984	AAH801	AAH802	75.0	82.0	79.0	59.0	128	110.0			4	11.8	

SEA TURTLE DATA BASE

ST LUCIE PLANT
(continued)

Species	Date	Tag #1	Tag #2	SLCL (cm)	CCL (cm)	CW (cm)	PL (cm)	TL (mm)	WT (lbs)	HB (gm/100 ml)	Se	Relative Condition	Condition Factor	Comments
CC	113084	AAH803	AAH804	66.0	74.0	72.0	53.5	125	105.0			4	16.6	
CC	120384	AAH805	AAH806	55.0	59.0	59.0	49.0	131	62.0			2	16.9	
CC	120484	AAH807	AAH808	58.5	64.0	55.0	46.0	138	75.0	9.6		1	17.0	
CC	120484	AAH809	AAH810	66.0	72.5	65.0	50.5	168	92.0			2	14.5	
CC	120484	AAH811	AAH812	72.0	79.0	73.0	57.5	174	125.0			3	15.2	
CC	120684	AAH813	AAH814	63.0	70.0	55.0	49.0	127	88.0	12.5		1	16.0	
CC	121084	AAH815	AAH816	52.0	56.0	54.0	42.0	85	51.0			1	16.5	
CC	121284	AAH817	AAH818	56.0	62.0	60.0	45.0	131	57.0	10.0		1	14.7	
CC	121884	AAH819	AAH820	55.0	61.0	61.0	43.0	120	64.0			1	17.4	

TURTLE ENTRAINMENT DETERRENT STUDY

AB-290

TURTLE ENTRAINMENT DETERRENT STUDY

AUGUST 1980

Prepared for

FLORIDA POWER & LIGHT COMPANY

APPLIED BIOLOGY, INC.

ATLANTA, GEORGIA

TURTLE ENTRAINMENT DETERRENT STUDY

INTRODUCTION

Florida Power & Light Company's nuclear-powered St. Lucie Plant on Hutchinson Island, Florida, has a once-through cooling system utilizing nearshore ocean water. During the four years of plant operation, over 400 marine turtles have been entrained into the intake canal by the cooling water intake system. The loggerhead turtle (Caretta caretta) constituted 95 percent of those turtles entrapped in the intake canal, with green turtles (Chelonia mydas), 4 percent, and leatherback (Dermochelys coriacea) and hawksbill turtles (Eretmochelys imbricata) found occasionally. These turtles are protected by state and Federal endangered species statutes and must be removed unharmed from the canal.

The cooling system draws in ocean water through two submerged, 3.2-m-diameter, vertically oriented intake pipes, which empty into an open intake canal 1220 m long and 100 m wide. Each of the two vertical intake pipes, located 365 m offshore, has a velocity cap, which produces a moderate horizontal current. Most pelagic fish instinctively orient themselves against such a current and thus avoid entrainment. Turtles, however, apparently do not avoid the intake structure and may be attracted to it. Those turtles approaching too closely are unable to swim against the current and are swiftly swept through the intake pipes into the intake canal. Once in the canal, turtles must be netted and transported to nearby beaches for release.

The present study was designed to determine whether the intake structure acts as an attractant to marine turtles and, if so, to test possible deterrents that would inhibit the animals from approaching the intake structure. Lights and bubble screens were considered the most promising deterrents and thus were the primary concern of this study.

MATERIALS AND METHODS

Loggerhead and green turtles were net captured in the St. Lucie power plant intake canal and held in a 4-m-diameter holding pool for 1 to 7 days before being tested. All turtles were fed fish daily while in captivity.

The turtles were tested in a tank at the Miami Seaquarium. This tank is a 10-m-diameter, 3-m-deep, open concrete structure. A slight counterclockwise current was created by the water filtering system. Low-level background illumination from nearby security lighting enabled observers to follow turtle movements at night.

One or two turtles were normally introduced into the test tank at about 1400 hours and allowed to acclimate to test tank conditions for 10 hr before observations were begun. Results from the first 24 hr of observations (Table 1) were considered control data with the deterrent tests constituting the second 24-hr period. Following testing, the turtles were transported back to Hutchinson Island and were released on the beach.

Three plywood boxes (1 m deep, 1 m wide, 0.8 m high) were placed in the test tank to represent the offshore intake structure. All boxes had an open end allowing the turtles free entry and ample turning space. The box habitats were placed equidistant around the tank perimeter with the opening facing down current so that a turtle had to swim against the water current to enter a box. The boxes were painted differently to test possible preference for a light or dark silhouette. One was painted all black (Box A), a second was all white (Box B), and the third was all white except the inside back panel which was black (Box C).

Test Trials

ABI personnel observed 14 trials using 20 subadult loggerhead and 2 green turtles (Table 2). Trial 1 consisted of observing the behavior of turtles restricted to the test tank environment. After 24 hr, two large plastic trash cans were placed on the tank floor and the response of the 2 individuals to these large stationary objects was recorded. Trials 2 and 3 utilized the three box habitats and served as the baseline or control period for comparison with later tests. In Trial 4, small underwater lights were mounted in two of the three boxes as a preliminary test for light deterrent effects. For Trials 5 through 7, a 12-volt, 100-watt white fountain light was mounted in the upper rear margin inside each box with the light beam flooding the box floor. Two boxes, one of which contained two lights, were used during Trials 8 through 14. A flashing unit (5 sec on, 20 sec off) was incorporated into the light system for Trials 10 and 11. During these tests, light measurements were recorded in footcandles using a Inter Oceans Systems illuminance meter.

A bubble screen deterrent was tested in Trials 12 through 14. Two 3.5-ft sections of 1-in. PVC pipe, drilled every inch with 3/16-in. holes and connected to a 3.7-cfm electric air compressor, were placed 1 ft in front of each open box. In Trial 14, a longer section of pipe surrounded each box in a bubble screen on three sides. The fourth side was adjacent to the tank wall.

The time each turtle spent swimming plus the duration and location of each resting period were recorded. The number of times an individual entered any of the boxes during a 12-hr period was computed as an entry rate. Incidental notes included aggressive interactions, feeding, basking, and any unusual activity. Test tank water temperatures were also recorded.

RESULTS AND DISCUSSION

Five individuals of the 22 tested failed to enter the boxes frequently enough during the first 24-hr control period to justify their inclusion in the deterrent portion of the tests. Two turtles were released before conclusion of the testing period because of marked aggressive behavior. Observations on the remaining 15 turtles are discussed below.

Preliminary observations on the acclimation of turtles to the test tank situation were conducted during Trial 1. When placed in the tank, two turtles initially swam actively and randomly about the tank, often colliding with the tank wall. After several hours, they settled into an

intermittent pattern of slow swimming around the tank perimeter and resting on the bottom. When large plastic trash cans were placed in the tank, the turtles rested adjacent to or with a portion of their bodies within the cans. Often a turtle would lay against a structure with one flipper wedged under it. This was an apparent attempt to maintain a stationary position against the water current while resting.

Before comparisons of box entry rates from control and test periods could be made, it was necessary to establish that the turtles' behavior and box utilization did not alter significantly over the 48-hr observation period. Though the sample size was too small for statistical analyses, the box entry rates were similar for the first 24-hr and the second 24-hr observation periods during Trials 2 and 3 (Table 3). No apparent behavioral change occurred after the initial acclimation period, thus indicating that any subsequent behavioral changes during testing periods were a result of the testing situation.

Aggressive interactions among turtles being tested simultaneously produced a nonquantifiable effect on box habitat utilization. Often the box occupant chased off an approaching individual and immediately re-entered the box, thereby increasing the occupant's box entry rate. Increased box utilization as an attack avoidance maneuver was evident on at least one occasion when a subordinate turtle retreated into a box after a severe interaction. Concurrently, in Trial 7, aggresive interactions intensified at night when lighting reduced the acceptability of the boxes as escape habitat. No aggressive interactions occurred in the two

trials involving a subadult loggerhead and a juvenile green turtle. During Trial 14, both turtles were observed resting together in the same box on several occasions.

Lighted Boxes

Trial 4, run with small underwater lights, was a preliminary test for a possible deterrent effect of lights. Such an effect was observed at night (Table 4) and led to the installation of 100-watt lights in each of the boxes.

Of the nine turtles used in light deterrent Trials 5 through 11, four turtles did not enter the boxes sufficiently during the control period to continue the test, and two were released early because of marked aggressive behavior (Table 2). Trials 6 and 7 were successfully run with one light in each of the three boxes. Prior to Trial 9, one box was removed from the tank and its light was mounted in one of the remaining boxes to increase the light intensity. Only Trial 11 was successfully completed using flashing lights. No significant differences in light deterrent effects were apparent between the differing modes of testing and, therefore, all light test results have been combined for purposes of discussion (Table 4). Statistical analysis of the data was not possible due to the high variability of the turtles and the small number of tests successfully completed.

Illuminance readings for ambient light and box interior illumination are given in Table 5. During the day the lights minimally increased the

illumination inside the box relative to ambient light. Lighting during the day probably did not alter the light-dark silhouette perceived by an approaching turtle. At night, however, the lighted box interior presented sharp contrast against the low ambient light.

Lighting the boxes had no apparent deterrent effect on the turtles during the daylight hours because the illuminated box interior was darker than the surrounding tank environment and provided an attractive resting site. The average box entry rates for all turtles tested were about the same for control and test periods (7.0 and 7.8, respectively; Table 4).

At night the lights had a deterrent effect on turtles approaching the boxes. The nighttime average entry rate for all turtles tested decreased from 9.8 during the control period to 1.5 for the light tests (Table 4). Two of the four turtles tested never entered a lighted box at night. On two occasions during the flashing light tests a turtle was about to enter a box when the light flashed on, causing the turtle to veer off and swim past the box. Twice, turtles were resting in the boxes at night when the lights were first turned on. Neither turtle reacted to the sudden light, nor did they leave their respective boxes with any haste.

Bubble Screen Tests

Three bubble screen deterrent tests were run. Because of their availability, two of the five turtles tested were juvenile green turtles (A-8290 and HI-3075; Table 2). Turtle HI-3075 never entered a box during

the entire 48-hr observation period and, therefore, has been excluded from test data computations.

Although the bubble screens reduced box entry rates during both day and night testing situations, they were most effective during daylight hours (Table 4). Three of the four turtles tested did not reenter a box during the day once the bubbling system was installed. During the test, the box entry for the fourth individual was reduced to one-half the rate of the daytime control period.

The effectiveness of a bubble screen to deter turtles may be greater during the day than at night because of the screens higher visibility during the day. The sunlight reflecting from the air-water interfaces of the bubbles probably appears to the turtles as a translucent barrier of reflective light. This barrier would not be as visually impressive at night and may help to explain the screens decreased effectiveness at night.

The percentage of total time individuals spent at rest and the average duration of each rest interval varied widely (Table 1). Both parameters showed a significant increase at night (Wilcoxon's signed-rank test, P=0.05). The average amount of time spent resting by all individuals was 47.7 percent during the day and 66.3 percent at night. The average duration of each resting period for all individuals combined was 22.6 minutes during the day and 31.2 minutes at night. The longest resting period, 105 minutes, occurred during the day.

No significant correlation was found between ambient water temperatures and either the duration of each resting period or the amount of total time spent resting by each individual (linear regression; r^2=0.190 and r^2=0.028, respectively). The temperature range encountered during this study, 18.5° to 28.5°C, is probably well within the turtles' normal operating range and would not be expected to significantly alter their activity level.

Comparison of entry rates for each of the three differently painted boxes showed no significant preference for any one box throughout the observation period (Friedman test, P=0.05). Individuals often exhibited a temporary preference for a particular box, utilizing it exclusively for several hours before entering a second box. Changing the position of the boxes in the test tank appeared to have no effect on their attractiveness to the turtles.

CONCLUSIONS

After initial acclimation to the test tank situation, turtles readily sought out and utilized the dark box habitats during resting periods. All but one of the 22 turtles rested inside a box at least a few times, with 75 percent of the individuals regularly entering the box habitats. This suggests that the velocity cap presents a surface relief on the sandy bottom offshore of the power plant that acts as an attractant to passing marine turtles and that they actively enter the intake pipe.

The 100-watt lights used during this study were a useful deterrent at night but were ineffective during the day when ambient solar light negated their effect. Although only one test using flashing lights was successfully completed, their effectiveness in startling turtles warrants further consideration.

The bubble screen was most effective during bright light conditions, probably due to its increased visibility as each bubble reflects the sunlight. At night the screen is not as effective; however, coupled with lighting, it might produce increased deterrent capabilities.

The combined installation of lights and a bubble screen around a velocity cap may help to reduce turtle entrapment. The logistics of installation and applicability of such structures offshore are not within the realm of this investigation. Also, the effects of such modifications on other biotic communities in the immediate vicinity of the intake structure would need evaluation before installation of such devices is considered.

TABLE 1

AVERAGE DURATION OF EACH RESTING PERIOD AND THE PERCENTAGE OF TOTAL TIME SPENT RESTING BY INDIVIDUALS DURING DAY AND NIGHT CONTROL PERIODS

Trial	Turtle tag number	Day: Average minutes per stay	Day: Percentage total time resting	Night: Average minutes per stay	Night: Percentage total time resting	Mean water temperature (°C)
3	HI-2247	4.2	2.6	7.8	11.2	28.5
	HI-3030	14.2	56.1	14.5	73.2	
4	HI-2350	10.3	42.1	14.6	42.9	26.0
	HI-2389	12.5	44.6	17.7	60.1	
5	HI-3047	18.6	67.0	45.9	97.9	25.8
	HI-2372	9.5	32.6	17.5	65.3	
6	HI-3048	27.9	80.3	39.2	87.1	24.7
7	HI-2394	42.0	67.0	54.5	90.9	25.7
	HI-3042	34.3	74.6	34.6	89.2	
8	HI-2395	37.3	87.0	50.0	78.4	24.8
9	HI-2398	26.3	47.7	35.0	77.8	22.0
10	HI-3056	53.3	66.7	62.1	65.9	22.1
11	HI-3062	21.0	15.5	21.3	47.2	21.8
12	HI-3089	23.6	36.1	27.5	41.5	18.5
13	HI-3102	23.3	20.3	53.2	92.9	21.0
	HI-3075	20.0	5.8	33.0	26.2	
14	HI-3114	17.8	61.8	21.3	77.3	25.0
	A-8290	10.9	51.4	12.5	68.2	
	Average	22.6	47.7	31.2	66.3	

TABLE 2

SUMMARY OF TESTING SITUATIONS
AUGUST 1979 - MARCH 1980

Trial number	Date begun	Mean water temperature (°C)	Number turtles tested	Turtle tag number	Test	Comments
1	28/8/79	-	2	HI-2364 HI-2362	Preliminary observation	
2	12/9/79	27.5	2	HI-2878 HI-2347	Boxes only	
3	3/10/79	28.5	2	HI-2247 HI-3030	Boxes only	
4	15/10/79	26.0	2	HI-2350 HI-2389	Small underwater lights	HI-2389 released due to marked aggressive behavior
5	29/10/79	25.8	2	HI-2372 HI-3047	Lighted boxes	Test discontinued due to poor box utilization
6	5/11/79	24.8	1	HI-3048	Lighted boxes	
7	12/11/79	25.7	2	HI-2394 HI-3042	Lighted boxes	HI-2394 released due to marked aggressive behavior
8	27/11/79	24.8	1	HI-2395	Lighted boxes	Test discontinued due to poor box utilization
9	3/12/79	22.3	1	HI-2398	Lighted boxes	Test discontinued due to poor box utilization
10	17/12/79	22.5	1	HI-3056	Lighted boxes-flashing	
11	15/1/80	21.8	1	HI-3062	Lighted boxes-flashing	
12	12/2/80	18.5	1	HI-3089	Bubble screen	
13	25/2/80	19.8	2	HI-3102 HI-3075*	Bubble screen	Poor box utilization by HI-3075
14	18/3/80	25.0	2	HI-3114 A-8290*	Bubble screen	

*Green turtle.

TABLE 3

BOX ENTRY RATES DURING THE 48-HR OBSERVATION PERIOD FOR TRIALS 2 AND 3

Trial	Turtle tag number	Day: 1st 12-hr period	Day: 2nd 12-hr period	Night: 1st 12-hr period	Night: 2nd 12-hr period
2	HI-2878	1	0	1	1
	HI-2347	15	8	7	6
3	HI-2247	2	2	15	14
	HI-3030	36	36	28	29
	Average	13.5	11.5	12.8	12.5

TABLE 4

BOX ENTRY RATES (THE NUMBER OF TIMES AN INDIVIDUAL ENTERED A BOX DURING A 12-HR PERIOD)

Trial	Turtle tag number	Day		Night		Testing situation
		Control	Test	Control	Test	
2	HI-2878	0.6		1.1		Boxes only
	HI-2347	14.2		6.5		
3	HI-2247	1.8		11.9		Boxes only
	HI-3030	33.0		30.2		
	Average	12.4		12.4		
4	HI-2350	5.3	17.7	7.8	5.7	Small underwater light
6	HI-3048	7	7	4	0	100-w light
7	HI-3042	10	6	18	3	100-w light
	HI-2394	8	13	12	*	
9	HI-2398	5	6	7	0	100-w light
11	HI-3062	5	7	8	3	100-w light - flashing
	Average	7	7.8	9.8	1.5	
12	HI-3089	3	0	6	3	Bubble screen
13	HI-3102	6	0	9	4	Bubble screen
14	HI-3114	7	4	13	9	Bubble screen
	A-8290	6	0	4	4	
	Average	5.5	1.0	8.0	5.0	

*Turtle was released before completing nighttime test.

TABLE 5

ILLUMINANCE VALUES FOR EACH LIGHTED BOX HABITAT[a]

		Illuminance values (footcandles)					
		Box A		Box B		Box C	
Time	Lights	Outside	Inside	Outside	Inside	Outside	Inside
Day	off	300	5.2	360	32	370	25
	off			395	96	455	125
	on	320[a]	9.6	1240	212	335[a]	62
				395	120	455	135[c]
Night	on	1.3	24.5	0.8	22.5	3.0	8.4[b]
				0.7	38.0	3.1	70[c]

[a]A 100-watt light is mounted within each box except where noted otherwise.

[b]Box in tank wall shadow.

[c]Value is low relative to other boxes due to misalignment of light in relation to probe placement.

[d]Two 100-watt lights.

AVOIDANCE RESPONSES BY SEA TURTLES
EXPOSED TO ELECTRICAL FIELDS

PREPARED FOR
FLORIDA POWER & LIGHT COMPANY

by

JAMES O'HARA, Ph.D.
and
HENRY J. KANIA, Ph.D.

ENVIRONMENTAL & CHEMICAL SCIENCES, INC.
ATLANTA, GEORGIA

NOVEMBER, 1981

TABLE OF CONTENTS

INTRODUCTION

Sea turtles have been observed in the intake canal of the Florida Power & Light Company's St. Lucie Plant since the facility became operational. These turtles are entrained with cooling water drawn from the Atlantic Ocean through two vertical intake structures located 365 m offshore and fitted with velocity caps to reduce vertical currents. Intake water passes through a buried pipe before emerging into the open, 1500-m long intake canal. It is believed that the turtles voluntarily enter the intake pipes seeking a dark hole in which to hide or sleep. The turtles are unharmed by passage through the intake pipes, but they must be regularly netted from the canal and returned to the ocean.

Marine turtles are protected under the Endangered Species Act; therefore Florida Power & Light Company has been concerned with the need to discourage them from entering the intake pipes. To achieve this goal, the company is sponsoring research to find effective and safe turtle deterrents. This paper presents the results of part of this research.

BACKGROUND

Past investigations of turtle deterrents have been limited. Observational studies have shown that lighting the inside of boxes reduced the frequency of entry by turtles seeking shelter (ABI, 1980). However, this method was only effective at night when the lighting contrast was greatest. Bubble screens in front of the boxes reduced the frequency of turtle entry during the day (ABI, 1980). No studies of the combined

effect of these potential deterrents have been conducted, and the potential for attraction and subsequent entrainment of other marine forms from lights or bubbles is unknown. Since results differed for night and day periods, further consideration of these methods as effective deterrents was suspended.

Lights and bubble screens are passive deterrent methods because turtles can choose to enter or not enter. The use of a method with a direct, although harmless, physiological effect would probably produce a more dependable response. Therefore, the use of electrical fields as a deterrent was chosen for investigation because all animals are known to have a physiological intolerance to electrical stimulation.

A review of the scientific literature, and discussions with turtle researchers and electrofishing experts, revealed that the effects of electrical fields on sea turtles were unknown. However, many studies have shown that other marine animals can be sufficiently controlled by electrical fields to justify consideration of this methodology as a means of keeping turtles away from the intakes. Electrical currents have been used to stimulate movement in freshwater fishes (Whitney and Pierce, 1957; Ellis, 1975), marine fishes (Groody et al, 1952, Klima, 1972; Seidel and Klima, 1974) and invertebrates (Phillips and Scolaro, 1980). Electrical barriers for fishes have been deployed in both natural (McLain and Nielsen, 1953) and industrial (O'Leary, 1981) locations. Several successful

field applications of electric fish barriers have been developed from laboratory studies (Maxfield et al, 1970) or prototype systems (Northrop, 1981).

This paper presents the results of preliminary studies on the use of electric fields as a turtle deterrent. The purpose of these experiments is to examine the response of sea turtles to low intensity electrical fields and to obtain data which would help to evaluate the practicality of using electrical fields to prevent turtles from entering the St. Lucie Plant intake structures.

METHODS AND PROCEDURES

This study was conducted in two parts. The first series of experiments used juvenile turtles and was designed to establish the general scope of the tests to be conducted on sub-adults. Sub-adults were the primary focus of the study because they are the size most commonly found in the intake canal. Juveniles were selected for the first phase of the study because they are easy to handle and the tank required for testing could be smaller. In addition, the testing equipment did not require the high electrical capacities anticipated for the larger test tank. The second series of tests examined the responses of sub-adult turtles to the electrical fields found to be most effective with the juveniles.

Test criteria were developed at extremely low voltages which were gradually increased until measurable responses were obtained. This pro-

cedure was followed because the sensitivity of the test animals to electrical fields was unknown and the safety of the turtles was of prime concern. Test periods were kept short to reduce fatigue and to prevent learned responses to test procedures.

Juvenile Turtle Tests

Source of Test Turtles

Twenty-one juvenile loggerhead turtles, *Caretta caretta*, ranging in size from 12 to 19 cm carapace length (Table 1), were obtained from Dr. David Owens of Texas A & M University, College Station, Texas. The turtles were transported by air freight to Atlanta, Georgia, and driven to the testing facility at Edisto Beach, South Carolina. The turtles were held in large shaded plastic wading pools containing water with a salinity of 27 ppt. Turtles were fed to refusal twice daily with freshly caught fish (mostly anchovies) and green leaf vegetables. At the end of the experimental period, the turtles were released at a nearby beach.

Test Equipment

Juvenile turtles were tested in a 1 x 2 m rectangular tank (Figure 1) constructed of cement blocks and lined with a 6 mil thick black polyethylene film. The tank was located under an elevated building which provided shade at all hours of the day. Water depth in the tank was 25 cm. Water temperature during the study ranged between 25.0° and 27.5°C with a mean of 26.3°C. Water for the tank was pumped from a large tidal creek adjacent to the test facility and well water was added to achieve the desired salinity.

A single stainless steel wire electrode was positioned vertically midway along each side of the tank (Figure 1) to produce an electric field across the width of the tank. The electrodes extended to the bottom of the tank. Single wire electrodes were used rather than multi-wire or plate type electrodes to limit the electrical current requirements. A fiberglass screen barrier (Figure 1) was placed around the electrodes to prevent the turtles from entering the high intensity field near the electrodes and to direct them to the middle of the tank where the electrical field was more uniform.

Electrical Parameters

Both 60 Hz AC sine wave voltages and pulsed DC voltages with various pulse rates, shapes and widths were tested. The AC voltages used ranged from 20 to 50 volts. These voltages were produced by an isolation transformer receiving input from an autotransformer connected to the 120 volt laboratory line voltage. AC voltages were measured with a Keithley Model 160 Digital Volt Meter. Consistant with standard practice, all AC voltages are reported as root mean square (rms) values rather than peak instantaneous voltage of the sine wave. These rms values were converted to peak values by multiplying rms x 1.41 when comparisons with DC peak values were made. Generally, however, rms values are used for ease of discussion.

Two shapes of pulsed DC voltages were tested ranging in amplitude from 50 to 85 volts. One was a truncated sine wave which was tested at two pulse widths while the other was a capacitive discharge wave. The

truncated sine waveforms were generated by a commercially available freshwater electrofishing device (Smith-Root Type VI Electrofisher, Smith-Root Company, Vancouver, Washington) connected to the laboratory power system. A high wattage variable resistor placed in series between the electrodes and the output of the Smith-Root Electrofisher was used to adjust the voltages to the electrodes. The capacitive discharge pulses tested were generated by a system consisting of a high capacity variable voltage DC power supply, a mechanical commutator driven by a variable speed motor, and a set of capacitors charged by the power supply through a large inductor. Pulse voltages were set by the output of the power supply, pulse width by the capacitor bank, and pulse frequency by the speed of the commutator motor. Pulsed DC voltages were measured at the electrodes with a calibrated Healthkit Model 10-4105 oscilloscope. All pulsed DC voltages are reported as peak values.

In addition to the waveforms discussed above, which were used throughout the experiments, two other waveforms were examined in single experiments. For one test, a 60 Hz AC sine wave voltage was applied to the electrodes through the mechanical commutator resulting in a pulsed AC waveform. In another test, two banks of capacitors and two power supplies were used and the commutator was wired to produce bimodal capacitive discharge pulses.

The shape of the electrical fields generated in the test tank were measured with a probe consisting of two parallel 1 cm^2 stainless steel plates placed 10.0 cm apart and connected to the digital volt meter or

oscilloscope. Measurements were made at the midpoint between the electrodes and at 10 cm intervals from the electrodes in the middle and along the sides of the test tank.

Test Procedures

For each of 19 combinations of electrical and test characteristics (Table 2), ten juvenile turtles were tested. Turtles were selected randomly, without replacement, from the holding tank and used in tests no more than twice in one day. Several tests were repeated with different sets of turtles to verify the replicability of the experimental results.

Juvenile turtles were tested individually for five minutes. Each turtle was placed in one end of the test tank and allowed to enter or avoid the electrical field at the mid-line. Power was applied to the electrodes only when the turtle was swimming toward the center of the tank. Each successful pass through the field was recorded. For each avoidance, or "turnback", from the electrical field, the distance of the turn from the electrodes was measured and recorded. The behavior of the turtles as they entered or passed through the field was also noted. The results from the ten, five-minute tests were pooled and the total number of attempts to cross the tank, the number of turnbacks, the percentage of turnbacks, and the mean distance to the turnback were calculated.

Sub-adult Turtle Tests

Source of Test Turtles

Sub-adult loggerhead turtles weighing 60 to 80 pounds are the most commonly found turtles in the intake canal and therefore are the turtles of most concern to Florida Power & Light Company. For this portion of the study, only nine turtles near the appropriate size were available. They ranged in weight from 32 to 140 pounds (Table 1). Four loggerhead turtles were captured in the St. Lucie Plant intake canal by Applied Biology, Inc. personnel, one loggerhead and one green turtle (*Chelonia mydas*) were obtained from Mr. Ross Witham of the Florida Department of Natural Resources Laboratory at the Hutchinson Island House of Refuge Museum, and one loggerhead and two green turtles were obtained from Mr. John Fletemeyer of Nova University, Ft. Lauderdale, Florida. These turtles were maintained in two holding pools at the Florida Oceanographic Society laboratory in Stuart, Florida. The turtles were held for only a few days and were not fed. All green turtles and the House of Refuge loggerhead were subsequently returned to the suppliers. The other loggerheads were tagged and released.

Test Equipment

The sub-adult turtles were tested in an indoor 1.3 x 5.0 m rectangular channel that connected the two concrete pools in which the turtles were kept prior to testing. The turtles were constrained to the channel by temporary concrete block walls. Water depth in the tank was maintained at 48 cm. Water was pumped into the holding pools and test chamber from

the Indian River. The salinity of both the test water and the water in the holding pools was 22 ppt and temperatures ranged from 24.0° to 27.0°C with a mean of 25.9°C.

Electrodes, consisting of two nested U-shaped stainless steel wires, were placed against the walls midway in the test tank. The electrode configuration differed from the single wire electrode used for the juvenile turtle tests because of space limitations. The test chamber for the sub-adults was too narrow to allow for a barrier to direct the turtles away from the intense electrical field created immediately adjacent to a single wire electrode. Increasing the effective area of the electrode made a protective barrier unnecessary.

A vertical electrical field was used for one test. This field was created by using two horizontal single-wire electrodes, one on the bottom and one just below the water surface, with both extending the full width of the channel.

Electrical Parameters

For the sub-adult studies, the choice of electrical characteristics was based on the results of the juvenile tests with emphasis placed on AC and 60 pps DC voltages. The AC voltages tested ranged from 5 to 20 volts in a 60 Hz AC sine wave. These voltages were produced by an arc welder connected through a high capacity autotransformer to the 240 volt laboratory power supply. AC voltages were monitored with the digital volt meter.

The pulsed DC voltages tested ranged from 10 to 25 volts and consisted of a truncated DC sine wave with pulses generated by the Smith-Root Type VI Electrofisher used in the juvenile turtle study. A variable resistor was used in the circuit to control the applied voltage. Only a 1 ms pulse width was used because the juvenile turtle tests showed that response did not vary appreciably with pulse width. Voltages were measured with the calibrated oscilloscope and the electric field was measured in the same way as in the smaller test tank.

Test Procedures

Based on the results of tests with juvenile turtles, fatigue and learning were not considered to be complicating factors. Accordingly, each sub-adult turtle was tested with several combinations of electrical characteristics (Table 3) during a single test period, which was generally one day. The nine sub-adult turtles were tested in the same way as the juveniles except that they were kept in the test tank until ten attempts had been made to swim the length of the tank at each voltage.

The sub-adult turtles were transferred to the test tank from the holding pools with as little disturbance as possible and allowed to acclimate for several hours before the tests were started. Normally, the turtles would slowly swim up and down the 5 m long channel. During testing, when a turtle approached the limits of the electrical field (about 1.5 m from the electrodes), the current was applied to the electrodes and the response of the turtle was noted. Each test was continued until the

turtle made ten attempts to cross the electrical field. The distance from the electrodes to the point of turnback, if it occurred, was measured from the plane of the electrodes to the head of the turtle. As with the juvenile turtles, the behavior of the sub-adults as they entered or passed through the field was recorded and the total number of attempts, the number of turnbacks, the percentage of turnbacks, and the mean distance to the turnback were calculated. Since each turtle tested at each voltage was considered to be a separate experiment, most tests have nine replicates.

RESULTS

Juvenile Turtle Tests

General Response

The response of the juvenile turtles to the test parameters was relatively consistent. When placed in the test tank, a turtle would occasionally remain at the end of the tank for the entire 5 minute test period. Most, however, swam actively about the tank. A turtle entering a weak electrical field would normally swim through the field, reacting only by rapidly blinking its eyes (Figure 2_a). If the electrical field was strong, however, the turtle would halt its forward motion and use one or both front flippers to wipe its eyes in response to the irritation produced by the electric field (Figure 2_b). Typically, the turtle would quickly turn away from the electric field and return to the end of the test tank. Once at the end of the tank, the turtle would turn around and swim back into the electrical field. There was no indication that the turtles developed learned responses to the test situations. When no voltage was applied to

the electrodes as a turtle approached, the turtle swam between the electrodes with no hesitation.

Effect of Salinity on Response

The tests on juvenile turtles were conducted in water with a salinity of 9 ppt. Reducing the salinity to 9 ppt lowered the electrical conductivity and enabled the use of lower amperages to maintain the desired voltages between the electrodes. In a test to verify the assumption that decreasing the salinity to decrease power requirements would not influence test results, 30 volts AC was tested at a salinity of 27 ppt and resulted in a turnback rate of 46.3 percent at a mean distance of 19.7 cm (Table 4). This same voltage in two tests at a salinity of 9 ppt resulted in a mean turnback rate of 38.7 percent at a mean distance of 16.4 cm. These results are not significantly different.

AC Current

In tests using AC voltages, 20.8 percent of the juvenile turtles tested avoided a field produced by 20 volts applied to the electrodes. The percentage of turnbacks increased linearly as the voltage increased (Figure 3_a). At 50 volts, 90.8 percent of the attempts to swim the length of the tank resulted in avoidance. Some of the turtles exposed to 50 volts reacted very violently to the electrical field so no higher voltages were tested because of concern for the safety of the test animals. Based on the results of these tests, it appears that 100 percent turnback would probably have occurred at voltages of 55 to 60.

The electrical field intensity at the point where the juvenile turtles turned was measured for several AC voltages. When 40.7 percent turnback occurred, the field intensity at the mean turnback distance of 17.5 cm was 6 volts/m (with an applied voltage of 30). The field intensity was 10 volts/m (applied voltage of 50) when 90.8 percent turnback occurred at the mean turnback distance of 20.4 cm. Obviously, turnback of 100 percent of the juvenile turtles would require a field intensity in excess of 10 volts/m.

A single test was done to determine if AC inputs would be effective in an interrupted or pulsed fashion which would reduce power requirements. For this test, 40 volts was pulsed to the electrodes at 20 pps with an 8 ms pulse duration. There was no difference between the results of this test (69.2 percent turnback at a mean distance of 25.6 cm) and the average results from two tests with a continuous 40 volts applied to the electrodes (69.7 percent turnback at a mean distance of 21.2 cm). This test indicates that interrupted AC voltages could be used instead of continuous voltages.

<u>DC Current</u>

In tests with pulsed DC voltages, the rate of turnback increased with increasing voltage (Table 4, Figure 3_b). Considering only voltage, the percentage of turnbacks ranged from 46.9[a] to 73.5 percent when 50 volts were applied to the electrodes. These turnback rates increased to 78.9 to 95.2

[a] Test 7 had a turnback rate of 32.6 percent, but several factors including the lack of replicability with tests 15 and 17 make this test suspect. The voltage may have been lower than 50 volts.

percent when 85 volts were applied to the electrodes.

The primary cause of the variation in turnback rates at each voltage was the pulse rate. A pulse rate of 120 pps was more effective than 60 pps and 20 pps. No major differences in turnback rates at 60 pps and 20 pps were noted.

Sub-adult Turtle Tests

General Response

When placed in the test tank, the sub-adult turtles repeatedly swam up and down the length of the tank. As was seen with the juveniles, when the electric field was turned on, the sub-adult turtles would blink their eyes and wipe them with the front flippers. At higher voltages, the turtles often withdrew their heads prior to turning away from the field. Once out of the electric field, the turtles would swim to the end of the tank, turn and swim back toward the field. There was no indication that the sub-adult turtles developed any learned reaction to the electric field.

The six loggerhead and three green sub-adult turtles were tested individually at various AC and DC voltages. Based on the results of studies on juvenile turtles, AC inputs were examined thoroughly as were pulsed DC inputs of 60 pps with a 1 ms pulse width. Although this combination of DC characteristics was not the most effective in previous tests, it produced a response in the juveniles that was very similar to the most effective tested, but required much less power.

AC Current

The results of the tests conducted using AC current show an increase in the mean percentage of turnbacks from 13.3 to 89.0 percent when the input voltage was increased from 5.0 to 10.0 volts (Table 5, Figure 4). This marked change in response indicates a threshold level of sensitivity between these voltages. At applied voltages above 10.0, the turtles were turned back 100 percent of the time. The mean distance to turnback increased as a linear function of applied voltage and ranged from 1.8 cm at 5 volts to 41.0 cm at 20 volts. Green turtles may be more sensitive to electrical fields as indicated by their higher turnback rate at 5 volts.

Some studies have shown that a vertical field was not as effective as a horizontal field in blocking fish from moving through a channel (Meyer-Waarden, 1957). To determine if changing the orientation of the electrical field from horizontal to vertical would alter the responses of the turtles, a test with a vertical field was conducted. Twenty volts were applied to the electrodes located at the water surface and at the bottom of the tank. One hundred percent turnback was observed at a field intensity of 5.4 volts/m at a mean distance of 18.0 cm. These findings were consistant with the results obtained in the horizontal field tests when 100 percent turnback occurred when the field intensity was 5.3 volts/m at a mean distance of 41.0 cm.

DC Currents

The results of tests using pulsed DC were similar to those of the AC tests. At a pulse rate of 60 pps, the mean turnback rate increased from

14.3 percent at 10 volts to 96.7 percent at 25 volts (Table 5). The mean distance to turnback increased in a linear fashion from 0.0 to 25.0 cm over the range of voltages tested. A threshold of response similar to that seen in AC tests was observed. An increase in voltage from 10 to 15 increased the turnback rate from 14.3 to 58.9 percent. Several tests of sub-adults were conducted at 60 and 120 pps which verified the similarity of the responses (Table 4). At 15 volts the turnback rate was 58.9 percent and 60.0 percent at 60 and 120 pps respectively. At 20 volts, the turnback rates were 85.6 and 80.0 percent at 60 and 120 pps presectively.

DISCUSSION

Both AC and pulsed DC electrical fields effectively deterred the turtles tested. However, for each given peak voltage, AC fields were more effective than pulsed DC (Figures 3 and 4). Field intensities of approximately 5 volts/m AC and 10 volts/m DC were sufficient to turn back 100 percent of the turtles of the size that most commonly enter the St. Lucie Plant intake. This effectiveness of AC over DC has also been observed in studies of fish (Bary, 1956).

The voltages required to turnback the turtles were in inverse proportion to the size of the turtle. The field intensity at the average distance at which 100 percent of the sub-adults turned was 5 volts/m AC compared to 10 volts/m AC needed to turn 90 percent of the juveniles. Similar results were recorded for DC voltages. These results show that the larger sub-adult turtles were more sensitive to the electrical fields than

the juveniles. This observation is consistant with reports on the effects of electrical fields on various size fishes (Meyer-Waarden, 1957; Ellis, 1975) and is believed to reflect the larger total voltage interrupted by the animal. For fish, the electrical conduction along the body length is measured and the orientation of the fish in the field is often disregarded. For turtles, the critical distance may be the width of the field interrupted by the head of the animal. Supportive measurements would be needed to validate this possibility, but the blinking response indicates that the head region is highly sensitive. It is recognized that, although not measured, there was a head to tail electrical gradient. The possible influence of such a gradient is unknown.

These experimental studies were designed to test for electrical fields that would restrict the free movement of turtles in the test tank. While the sub-adults were disturbed sufficiently to keep them awake and moving without exciting them, their motivation to swim into the electrical field may or may not have been the same as a turtle seeking a place to hide. This factor can only be evaluated in a field test situation.

In a test conducted to observe the responses of highly motivated turtles, juvenile turtles were attracted toward the electric field by dragging food before them. Even with this motivation, the turtles were turned back 29.4 percent of the time at 20 applied volts AC, 64.7 percent at 30 volts AC and 94.1 percent at 40 volts AC (Table 6). These results are similar to those obtained when no external motivation was provided.

During the course of the study, we observed that some turtles, swimming rapidly due to fright or other motivation, were unable to stop in time to avoid the field and, if it was a strong field, lost coordination. In these instances, forward momentum carried the turtle through the field. Once past the field, the turtles quickly recovered coordinated movement.

In some cases, especially during tests at higher voltages, turtles penetrated deep into the electrical fields and lost motor coordination. In most instances, the response was a lack of coordinated swimming and the turtle escaped the field by disoriented movement of the flippers. In some instances, particularly with the sub-adult turtles, a narcosis resulted from exposure to the field and the turtle was unable to escape until the field was removed. With the elimination of the field, recovery was immediate and the turtle resumed swimming with no visible effects of stress.

The testing of electrical fields had no adverse effect on the sea turtles. Four of the sub-adult turtles exposed to the electrical fields used in these tests have been maintained in captivity since the tests. After three months, they are healthy and active and show no detrimental effects of the experimental procedures (Ross Witham and John Fletemeyer, personal communication).

An important difference between the responses of the sub-adult and juvenile turtles was in the shape of the response curve. The sub-adults had an extremely sharp threshold of response between the 13.3 percent turn-

back at 5 volts AC applied voltage and the 89.0 percent turnback at 10 volts AC applied voltage. By comparison, the juveniles did not show a pronounced threshold, but demonstrated that they were more likely to turn back when the voltage was higher.

Differences in the response of sub-adults and juveniles to pulsed DC fields were not as pronounced, although the larger turtles were much more sensitive to the electrical fields and to increases in the voltage. Again, indication of a threshold value of current was seen in the tests on the sub-adults which was lacking in the studies on the juveniles.

CONCLUSIONS

1. Marine turtles avoided both AC and pulsed DC electric fields of sufficient intensity.

2. Exposure to low voltage electric fields did not harm the turtles. Turtles did not exhibit learned behavior after repeated exposures to such fields.

3. For a given peak voltage, sine wave AC fields were more effective than pulsed DC in repelling turtles. While there was some variability in the response of turtles to different DC pulse rates, pulse widths and waveforms, no well-defined set of parameters appeared to be superior.

4. There was considerable variation in the responses exhibited by individual turtles to electrical fields. Size was important because the larger turtles are more sensitive. Species variations may exist as there was some indication that green turtles are more sensitive than loggerheads.

5. The field intensity experienced by the head of the turtle may be the most important electrical parameter determining behavior.

6. Under some conditions, turtles entered strong electrical fields and lost motor coordination. At the field intensities studied,

the turtles recovered immediately when released from the field with no apparent damage and, again, no apparent learning.

COMMENTS AND RECOMMENDATIONS

1. The successful use of electrical fields to turn away turtles has been demonstrated. This method should be more fully investigated for its applicability to the St. Lucie Plant intake structures.

2. Additional information on at least the following topics should be obtained before a definitive committment to install an electric barrier is made.

   a) Various configurations of electrodes could influence the effectiveness of the electrical barrier. For example, the placement of electrodes around an intake structure will influence the field shape. Additional information is needed to design a field with maximum effectiveness at the lowest power usage and least harm to turtles.

   b) The importance of various factors affecting turtle behavior should be investigated. The behavior of a turtle approaching the electric field may be different from our observations if the motivation is different. Also, temperature may significantly influence how a turtle responds to electrical fields.

   c) The practicality of this method should be investigated by evaluating the equipment and electrical costs required to produce the field types and intensities found to be effective in this study.

3. A field study to address the above concerns, while verifying the applicability of this method, is recommended. Such a study might utilize a model intake structure made in proportion to the offshore structure and located in the intake canal. The electrode configuration would be moveable to test various field shapes. The movement of the turtles entering the intake structure would be monitored and recorded remotely. The electrical field being tested would be alternately on and off for a 1 to 7 day period with off periods serving as controls. Testing would be conducted for one year to obtain data on the influence of seasonal changes.

   Testing would be most effectively conducted in the St. Lucie Plant intake canal for the following reasons:

   a) The turtles in the canal are the correct size and species for the test.

b) The salinity and temperature are identical to the conditions around the intake structures.

c) The enclosed population of turtles can be marked for observation and monitored to insure no detrimental effects to their health.

d) The intake canal is a high security area.

e) There is a nearby source of power.

LITERATURE CITED

ABI. 1980. Turtle entrainment deterrent study. A report to Florida Power & Light Company. Applied Biology, Inc. 15 pp.

Bary, B. 1956. The effect of electric fields on marine fishes. Scottish Home Department, Marine Research. No.1. 32 pp.

Ellis, J.E. 1975. Electrotaxic and narcotic responses of channel catfish to various electrical pulse rates and voltage amplitudes. Prog. Fish. Cult. 37:155-157.

Groody, T., A. Loukashkin and N. Grant. 1952. A preliminary report on the behavior of the Pacific Sardine (Sardinops caerulea) in an electric field. Proc. Calif. Acad. Sci. 27:311-323.

Klima, E.F. 1972. Voltage and pulse rates for inducing electrotaxis in twelve coastal pelagic and bottom fishes. J. Fish. Res. Bd. Canada. 29:1605-1614.

Maxfield, G.H., R.H. Lander and C.D. Volz. 1970. Laboratory tests of an electrical barrier for controlling predation by Northern Squawfish. U.S. Fish Wildl.Serv. Spec. Sci. Rep. Fish. No. 611. 8 pp.

McLain, A.L. and W.L. Nielsen. 1953. Directing the movement of fish with electricity. U.S. Fish. Wildl.Serv. Spec. Sci. Rep. Fish. No. 93. 24 pp.

Meyer-Waarden, P.F. 1957. Electrical fishing. FAO Fisheries Study No. 7. 78 pp.

Northrop, R.B. 1981. The use of underwater electric fields to control the movements of migratory fish. Report to Northeast Utilities Service Company. 36 pp.

O'Leary, J. 1981. Holyoke Dam fisheries studies - 1980. Report to Northeast Utilities Service Company. 30 pp.

Phillips, B.F. and A.B. Scolaro. 1980. An electrofishing apparatus for sampling sublittoral benthic marine habitats. J. Exp. Mar. Biol. Ecol. 47:69-75.

Seidel, W.R. and E.F. Klima. 1974. In situ experiments with coastal pelagic fishes to establish design criteria for electrical fish harvesting systems. Fish. Bull. 72:657-669.

Whitney, L.F. and R.L. Pierce. 1957. Factors controlling the input of electrical energy into a fish (Cyprinus carpio L.) in an electrical field. Limno. Oceanography. 2:55-61.

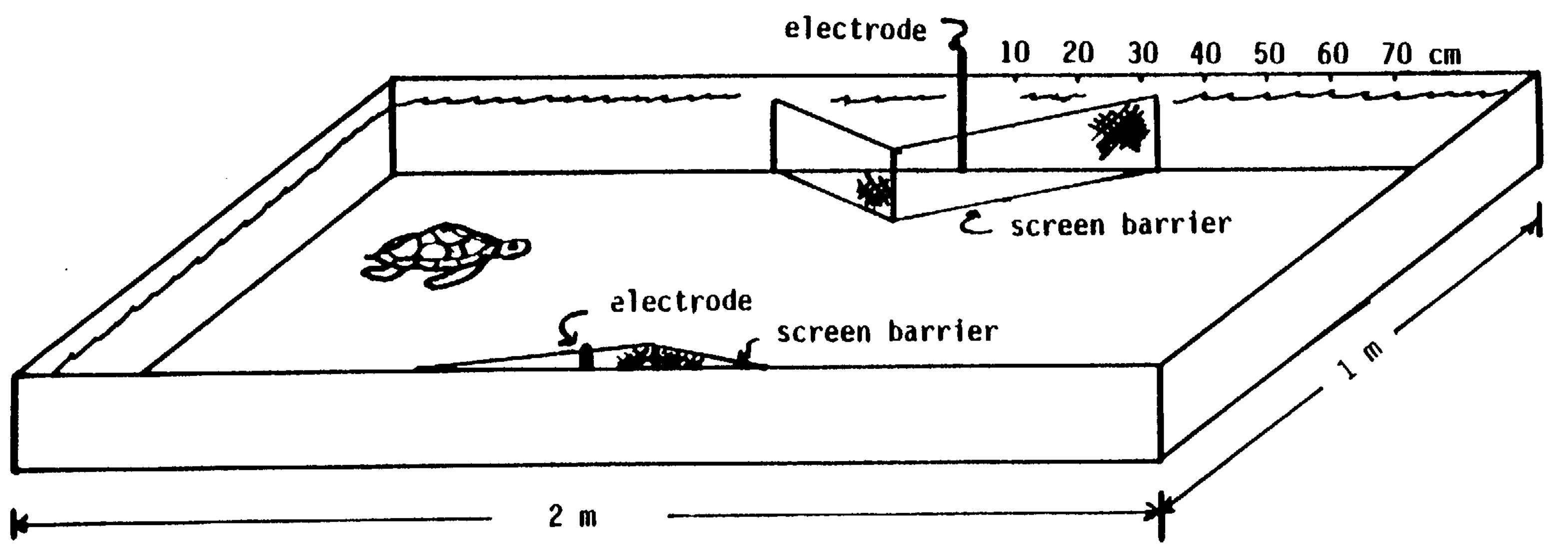


Figure 1. Diagrammatic view of test tank used in juvenile turtle experiments. (Not to scale)

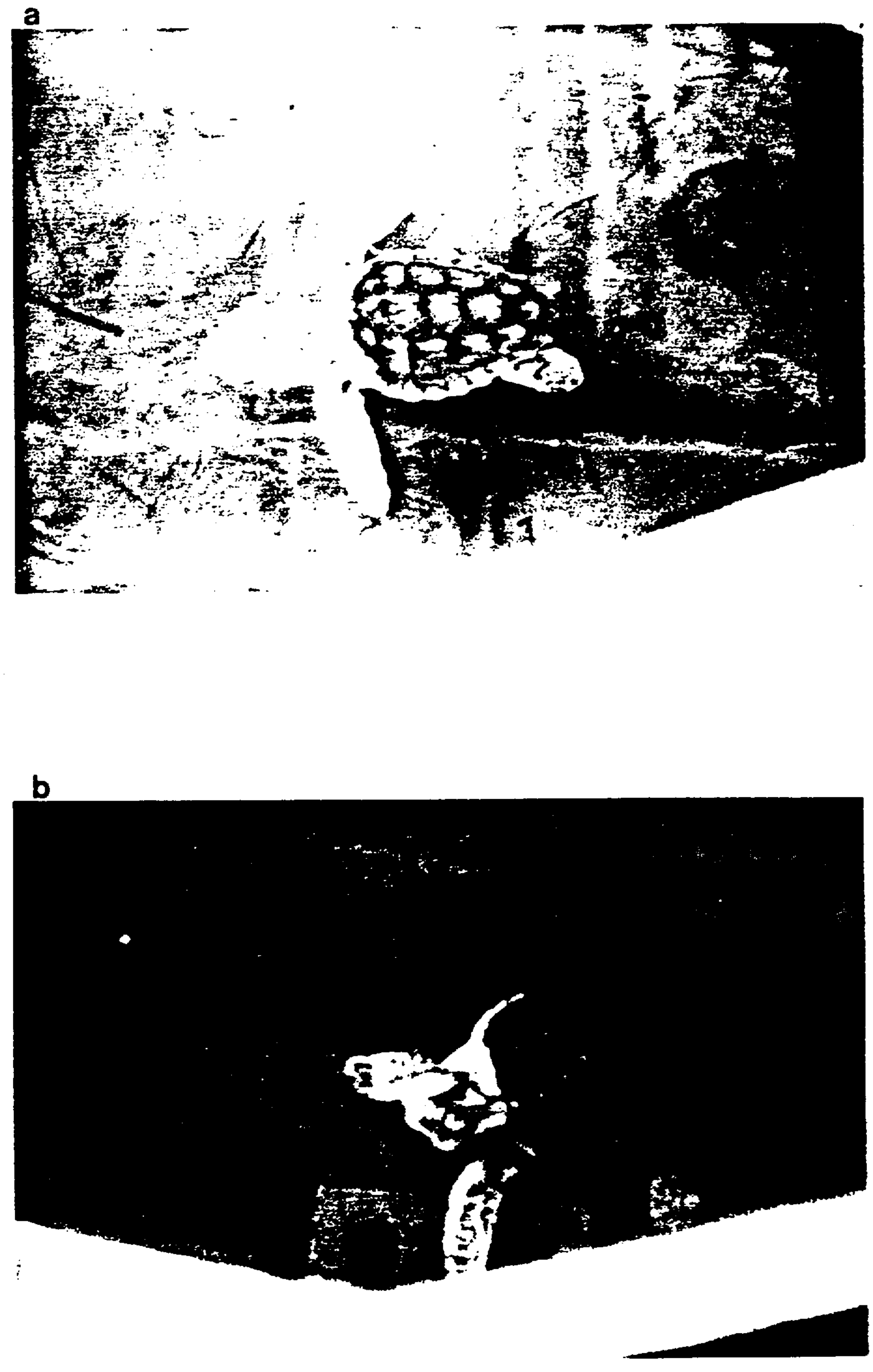


Figure 2. Photographs of juvenile turtles during testing. Photo a shows normal forward motion, photo b shows eye wiping response to electrical field.

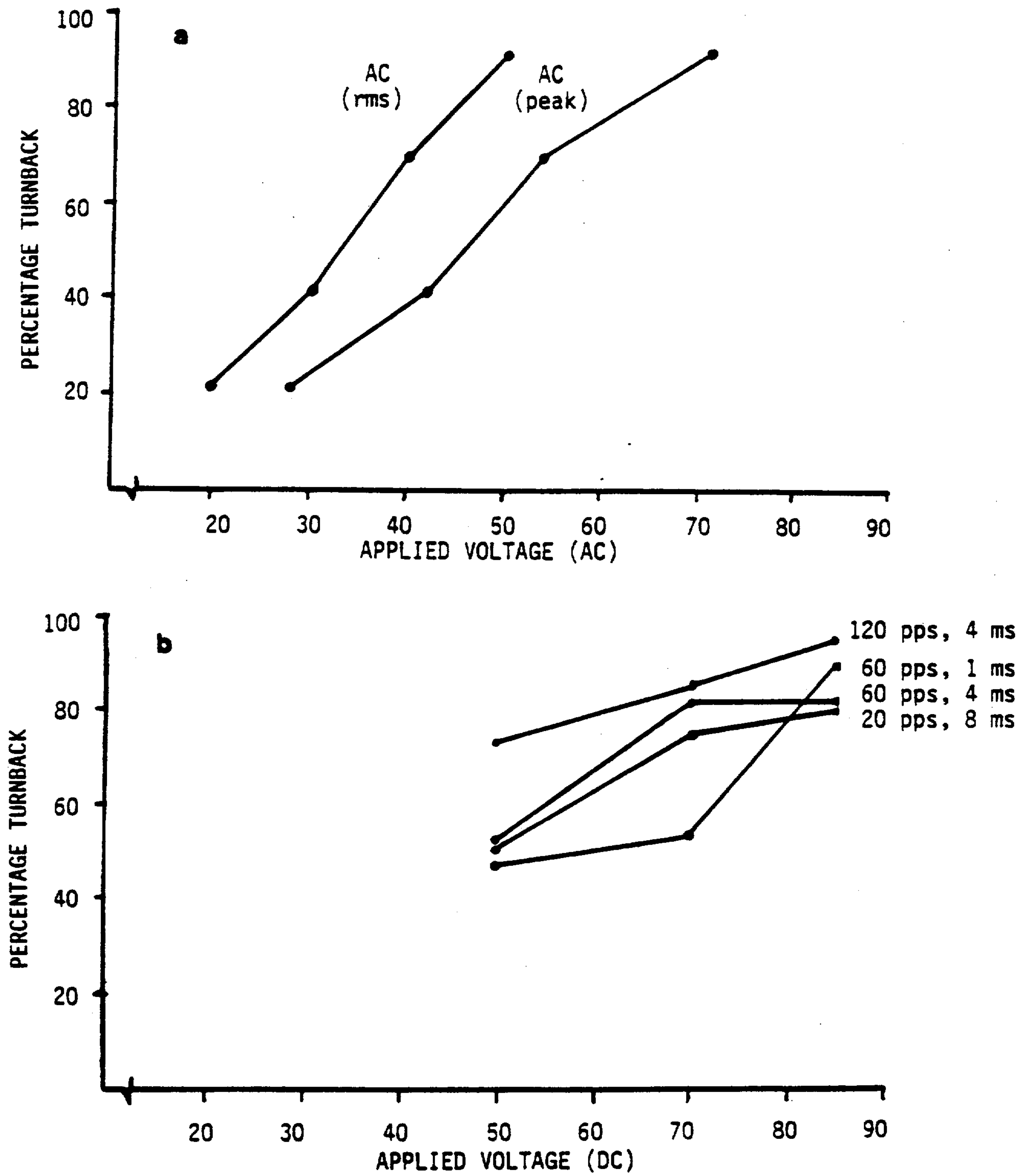


Figure 3. Percentage turnback of juvenile turtles exposed to a) AC and b) DC voltages.

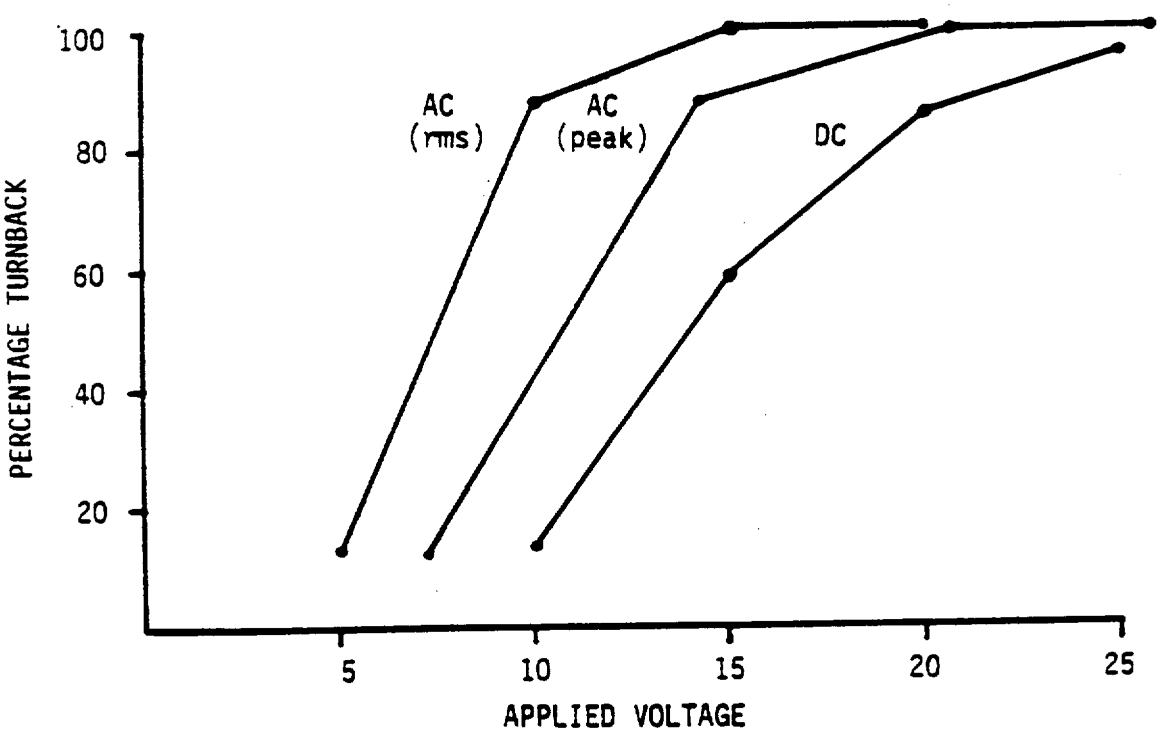


Figure 4. Percentage turnback of sub-adult turtles exposed to AC and DC voltages.

Table 1. Description of sea turtles used in low-intensity electrical fields experiments.

Turtle Designation	Species	Length (cm)	Weight (lbs)
Juveniles			
1	*Caretta caretta*	18	2.01
2	" "	17	1.7
3	" "	16	1.5
4	" "	17	1.7
5	" "	17	1.5
6	" "	17	1.5
7	" "	17	1.5
8	" "	15	1.3
9	" "	16	1.5
10	" "	17	1.5
11	" "	17	1.5
12	" "	16	1.3
13	" "	15	1.3
14	" "	16	1.2
15	" "	18	1.7
16	" "	17	1.6
17	" "	15	1.3
18	" "	16	1.5
19	" "	12	0.6
20	" "	14	0.9
21	" "	19	2.2

Table 1. (cont.) Description of sea turtles used in low-intensity electrical fields experiments.

Turtle Designation	Species	Length (cm)	Weight (lbs)
Sub-adults			
1s	*Caretta caretta*	57	80
2s	*Chelonia mydas*	70	140
3s	*Caretta caretta*	62	62
4s	" "	76	112
5s	*Chelonia mydas*	a	32
6s	" "	70	90
7s	*Caretta caretta*	58	60
8s	" "	63	65
9s	" "	67	72

a not recorded

Table 2. Combinations of electrical characteristics used in juvenile turtle tests.

Applied voltage	Pulse rate (pps)	Pulse width (ms)	Test no.	Other test characteristics
Alternating Current				
20	-	-	3	
30	-	-	5, 22	
30	-	-	27	27 ppt salinity
40	-	-	4, 23	
40	20	8	26	
50	-	-	6, 24	
Pulsed Direct Current				
50	20	8	18	capacitive discharge
50	60	1	10	
50	60	4	7, 15, 17	replicates
50	120	4	12	
70	20	8	19	capacitive discharge
70	20		25	dipolar pulse
70	60	1	11	
70	60	4	8	
70	120	4	13	
85	20	8	20	capacitive discharge
85	60	1	16	
85	60	4	9	
85	120	4	14	

Table 3. Combinations of electrical characteristics used in sub-adult turtle tests.

Applied voltage	Pulse rate (pps)	Pulse width (ms)
Alternating Current		
5	-	-
10	-	-
15	-	-
20	-	-
Pulsed Direct Current		
10	60	1
15	60	1
15	120	1
20	60	1
20	120	1
25	60	1

Table 4. Results and calculations of tests on juvenile turtles. Data for each test are totals or mean of results from ten turtles.

Test no.	Applied voltage	Pulse rate (pps)	Pulse width (ms)	No. of attempts	No. of turnbacks	% Turn-back	$\bar{x}$ Distance (cm)
Alternating Current							
3	20	-	-	77	16	20.8	not recorded
5	30	-	-	71	27	38.0	14.3
22	30	-	-	33	13	39.4	18.5
27[a]	30	-	-	41	19	46.3	19.7
4	40	-	-	45	31	68.9	21.6
23	40	-	-	51	36	70.6	20.8
26	40	20	8	13	9	69.2	25.6
6	50	-	-	45	41	91.1	25.5
24	50	-	-	31	28	90.3	15.2
Pulsed Direct Current							
18	50	20	8	26	13	50.0	15.4
19	70	20	8	31	23	74.2	20.7
25[b]	70	20	8	26	15	57.7	28.0
20	85	20	8	19	15	78.9	24.7

Table 4. (cont.) Results and calculations of tests on juvenile turtles. Data for each test are totals or mean of results from ten turtles.

Test no.	Applied voltage	Pulse rate (pps)	Pulse width (ms)	No. of attempts	No. of Turnbacks	% Turn-backs	$\bar{x}$ Distance (cm)
Pulsed Direct Current							
10	50	60	1	32	15	46.9	22.3
11	70	60	1	34	18	52.9	24.4
16	85	60	1	18	16	88.9	25.6
15	50	60	4	24	16	66.7	20.6
17	50	60	4	28	19	67.9	21.8
7	50	60	4	43	14	32.6	14.6
8	70	60	4	36	29	80.6	19.1
9	85	60	4	43	35	81.4	22.0
12	50	120	4	34	25	73.5	28.0
13	70	120	4	50	42	84.0	25.0
14	85	120	4	42	30	95.2	25.3

[a] high salinity
[b] dipolar

Table 5. Results and calculations of tests on sub-adult turtles. Data are for individual turtles and are presented as percentage turnback/mean distance to turnback (cm).

Turtle	Applied Voltage									
	AC				DC					
	60 Hz				60 pps				120 pps	
	5	10	15	20	10	15	20	25	15	20
1s	0/-	100/31	100/24	100/52		30/7	100/2	100/16		60/3
		80/29					90/9			
2s	60/2	100/9			60/0	100/17	50/8	90/34		
3s	0/-	70/13	100/25	100/47	10/0	70/8	100/24			100/20
4s	20/7	100/7	100/31	100/39	0/-	30/0	100/18		60/17	
5s	0/-	90/18	100/20	100/55		20/13	40/24	100/25		
6s	30/7	100/20	100/34		0/-	100/10				
7s	0/-	70/26	100/14	100/24	20/0	80/16	100/17			
8s	10/0	80/24	100/14	100/39	0/-	40/5	90/11			
9s	0/-	100/12	100/29	100/38	10/0	60/7	100/16			
9s			100/32	100/34						
$\bar{x}$ turnback / $\bar{x}$ distance	13.3/1.8	89.0/18.9	100.0/24.8	100.0/41.0	14.3/0.0	58.9/9.2	85.6/14.3	96.7/25.0	60.0/17.0	80.0/11.5

Table 6. Results and calculations of tests on juvenile turtles exposed to three voltage levels and motivated to enter the field by dragging food in front of them. Seventeen turtles were used in a single test at each voltage.

Test no.	Applied AC voltage	No. of attempts	No. of turnbacks	% Turn-back	$\bar{x}$ Distance (cm)
1A	20	17	5	29.4	16.4
1B	30	17	11	64.7	22.2
1C	40	17	16	94.1	31.3

Seismic Exploration
Air Guns as a Tool
for Sea Turtle Deterrence

by

James O'Hara
Environmental & Chemical Sciences, Inc.

and

J. Ross Wilcox
Florida Power & Light Company

INTRODUCTION

Sea turtles have been observed in the intake canal of the Florida Power & Light Company (FPL) St. Lucie Plant since the facility became operational in 1976. These turtles are entrained with cooling water from the Atlantic Ocean through two 3.7 m and one 4.9 m diameter intake pipes located 365 m offshore and fitted with velocity caps to reduce vertical currents. Intake water passes through buried pipes before emerging into the open 1500 meter-long intake canal. It is believed that the turtles voluntarily enter the intake structure, seeking a dark habitat in which to hide or sleep. The turtles are unharmed by passage through the intake pipes, but they must be regularly netted from the canal and returned to the ocean.

Marine turtles are protected by the Endangered Species Act of 1973, as amended, and FPL has been concerned with the need to discourage them from entering the intake pipes. Previous attempts to develop an effective turtle deterrent have been unsuccessful. A study of turtle behavior in response to lighting and bubble curtains in an enclosed pool indicated only a limited effectiveness depending on the amount of ambient light (ABI, 1980). O'Hara and Kania (1981) demonstrated that marine turtles could be turned back by both AC and pulsed DC electrical fields of low voltage. While this method was considered as a deterrent to turtle entry, FPL

considered the voltage and amperage required to produce an effective electrical barrier as a potential hazard to the public. Additionally, the installation and maintainence of the electrodes and hardware needed to operate the barrier reliably in a high energy marine environment make this method of deterrence impractical.

Based on observations of turtle behavior madd during the electrical field studies, the use of sound as a potential deterrent was considered. Ross Witham (personal communication) also suggested that sharp sound (e.g. pounding on the side of a tank) may alter turtle behavior.

The hearing ability of sea turtles has only been examined for the green sea turtle (Ridgeway et al., 1969). These workers recorded the electrical potential in the hearing chamber of green turtles exposed to different sound frequencies. They found the functional hearing range to be below 1000 Hertz (Hz) with the best sensitivity at 300 to 400 Hz. These values are consistent with data on other species of aquatic turtles (Wever, 1978) and results are probably applicable to the other species of sea turtles.

The only study to demonstrate an avoidance of sound by turtles was by Vogt (1980) who plunged an inverted cone attached to a handle deeply into the water to produce sounds. This device is

called a "carp horn" and, when used in fresh water, was effective in driving turtles into a collecting net.

In a series of preliminary experiments, we found that electronically produced sounds in the 100 to 1000 Hz range were not a viable deterrent to loggerhead turtle movement because we could not produce sound with enough energy (ECS, 1983). In order to obtain mechanically produced sounds in this frequency range and with sufficient decibels, we used seismic profiling air guns. This paper describes the effectiveness of air guns in modifying turtle behavior.

MATERIALS AND METHODS

Experiments on the response of turtles to sound were conducted in a semi-isolated canal within the FPL Turkey Point Plant cooling canal system. The test canal was approximately 300 m long, 45 m wide and up to 10 m in depth (Figure 1). The test canal is a dead end extension of the cooling canal grid, and when blocked with a barrier net at the open end, effectively contained the free-swimming turtles. The large size of the test canal was necessary because sound, particularly the low-frequency sounds that turtles hear best, travels far in water (Hunter, 1957). A large test environment also provided the turtles with opportunity of movement

approximating their normal behavior. The test protocol called for establishing a sound barrier across the canal which would effectively confine the turtles to one end of the canal.

Turtles were obtained from the National Marine Fisheries Service field collections at the Canaveral Ship Channel near Port Canaveral, Florida, and from the FPL St. Lucie Plant intake canal. Since the turtles that most frequently enter the St. Lucie intake canal weigh between 25 and 45 kg, only turtles of this size were used for experimentation. The turtles were transported by truck to the Turkey Point site, where they were released into a holding pond and allowed to swim freely.

For each experiment, a turtle was removed from the holding pond. A small hole was drilled in the posterior of the carapace and a self-coiling rope with a float was attached to the turtle before it was released into the test canal. At the end of the experimental period, the turtle was captured by means of the attached line and returned to the holding pond.

In the holding pond, the turtles were fed raw fish and fish scraps. Feeding was done every other day and the general health of each turtle was evaluated each time it was used for testing. In general, the turtles remained in good condition. Turtles that did

not appear to be adapting to captivity, lost weight or were fighting, were released. No feeding was done during an experiment.

A 48-hour test period was used to allow the turtle time to acclimate to the canal habitat and to have sufficient behavioral responses for a valid test. An electronic surveillance system was designed and installed to track the location of the turtles by recording the position of the float attached to the carapace. The surveillance system was automated to record the turtles' location in the canal during the entire 48-hr test period. The surveillance system consisted of a Panasonic Model WV1400 security monitoring camera with a telephoto lens that scanned the canal every seven minutes. The output from the camera was recorded on a Hitachi Model VT 6500A video tape recorder. To conserve video tape time, the recorder was programed to turn off between scanning intervals, which concentrated surveillance into a few hours of tape play. The system was designed by Alpha Controls, Inc. of Atlanta, Georgia.

In order to locate the turtle in the canal, the float attached to the turtle was visually compared with fixed markers, placed at 33 m intervals along the side of the canal. To monitor turtle movement at night, a battery-powered light was placed on the float and a blinking light was maintained at the barrier net as a point of reference. Both lights showed clearly on the video screen enabling determination of the turtle's location throughout the

night. Each morning, the video tape was reviewed and the location of the turtle for each surveillance interval was recorded on a data sheet.

Two types of seismic air guns (Bolt Technology, Norwalk, Conn.) were used during these tests. The first was a Model 542 air gun which had a 13 cm^3 capacity. The second type of air gun was a Model 600B air gun with a 165 cm^3 capacity.

The air for these tests was supplied by a 0.34 m^3/minute air compressor coupled to storage cylinders. The compressor maintained pressure of 280 Kg/cm^2 in the storage cylinders. This air supply was then regulated to the desired test pressures of 70, 140 and 245 Kg/cm^2. The pneumatic air guns were fired at programmed intervals by a Bolt Technology Model FC 100 firing circuit.

The first series of tests utilized three small (Model 542) air-guns spaced evenly across the canal (Figure 1) and fired at 245 Kg/cm^2. The second set of tests utilized two of the smaller air guns and the one 165 cm^2 air gun at either 70 or 140 Kg/cm^2. The firing mechanism was set at 15 or 7 second intervals (Table 1). The control for these experiments consisted of determining the position of the turtles during 48-hour tests when the air guns were shut off.

RESULTS AND DISCUSSION

During 324 hours of control periods, eight free-swimming turtles showed a preference to remain at the end of the canal that was blocked by netting from the cooling canal system (Figure 2). The turtles spent over 30 percent of their time in Zone 7. For the remainder of the time, the turtles were located throughout the canal system with no marked preference for any one location.

During a series of nine tests totaling 336 hours of observations when three small air guns were firing at 245 Kg/cm^2 (Table 1), the percentage of time that the turtles spent in Zone 1 was lower than in other areas (Figure 2). The percentage of time spent in the other zones was, in general, similar to the controls. In order to increase the the sound pressure in the canal, one of the small air guns was replaced with the 165 cm^3 air gun and all guns were operated at a pressure of 70 Kg/cm^2 (Table 1). During these tests, the turtles again avoided Zone 1, spending only 4.5 percent of their time near the sound source (Figure 2). One noticable difference was that they seemed to spend a greater amount of their time in Zone B, which was located between 33 and 66 m from the sound source. Although differences in behavior were noted during these tests described above, the percentage of time spent in each zone was not significantly different from the control.

When the pressure in the two small and one large air guns was increased to 140 Kg/cm^2 (Table 1), there was a pronounced change in the behavior of the turtles. Turtles swimming in the canal seldom entered Zone 1 before turning back to the more distant areas of the canal (Figure 3). Consequently Zones B, A, and 1 were occupied by turtles 1.7, 1.5 and 2.7 percentage of the time, respectively. These values were significantly different from the control (t-test; $p = 0.05$).

The most effective combination of air guns and pressures was found to be one 165 cm^3 and two 13 cm^3 air guns fired at 140 Kg/cm^2 at 15 second intervals. However, most of the energy released was from the larger air gun. The wave form produced by the 165 cm^3 air gun showed a rapid sound rise of approximately 120 decibels re one microbar at one meter with a rise time of approximately 1.0 to 1.5 millisecond (Figure 4). The sound pulse was closely followed by a strong near field pressure wave due to the displacement of water as the bubble of air expanded. At the source, the sound frequency had its strongest components at 25 Hz although frequencies in the 300 to 400 Hz range were very evident (Figure 5). Sound wave measurements and spectrum analysis were determined at the Bolt Technology facility in Norwalk, Connecticut, not at the experimental site.

The results of tests conducted at 140 Kg/cm^2 indicate that the exclusionary range of this large air gun is about 30 m. Some of the turtles that passed the sound barrier did so by going through that portion of the canal outside the 30 m range of this large air gun. Also, several observations on turtles that passed near the 165 cm^3 air gun indicated that they were moving along the bottom of the canal where the sound waves may be very different than those in the water column.

The significant reduction in the time the turtles spent in the Zones A, B and 1 of the experimental canal cannot be converted directly to turtle deterrence at the St. Lucie Plant. However, it should be noted that because these turtles were confined to the experimental canal, they had opportunity for acclimation to the sound and had opportunity for repeated attempts to bypass the sound barrier. We anticipate that free-swimming turtles would not remain near seismic air guns operated at 141 Kg/cm^2 or make repetitive attempts to swim past it.

Application of the seismic air gun as a turtle deterrent seems appropriate. One or more such air guns located near the St. Lucie Plant intake structures should be sufficient to keep turtles over 30 m from the air gun source. Since the water visibility is less than 30 m, particularly in the winter when most turtles enter the intake, the air guns should be able to minimize a turtle's visual

contact with the dark, cavelik·. ɔpening of the intake structures. Assuming that free-swimming turtles will leave the general area of the intake where they encounter this deterrent, the incidental catch of sea turtles at the St. Lucie Plant should be reduced.

The applicability of this tool, however, may vary. Although the air guns are mechanically and electrically simple, the guns and their support equipment require periodic maintenance and accessibility. Therefore, engineering costs, capital outlay and maintenance costs need to be evaluated for each site.

Acknowledgements

Our sincere thanks are gien to Paul Chelminski of Bolt Technology, Inc. for his help and advice on the methodology and equipment. We wish to thank Florida Power & Light Company for funding this project and we thank Earl Baker and his staff at the Florida Power & Light Turkey Point Plant for their help throughout this study. National Marine Fisheries Service and Applied Biology, Inc. provided experimental animals. This study was conducted under Permit No.'s TP-84 and PRT 2-3456.

LITERATURE CITED

ABI. 1980. Turtle entrainment deterrent study. A report to Florida Power & Light Company. Applied Biology, Inc. 15 pp.

ECS. 1983. Progress report for the turtle entrapment deterrent study. A report to Florida Power & Light Company. Environmental and Chemical Sciences, Inc. 14 pp.

Hunter, J.L. 1957. Acoustics. Prentiss Hall Inc. New York. 407 pp.

O'Hara, J., and H. Kania. 1981. Avoidance responses by sea turtles exposed to electrical fiends. Prepared for Florida Power & Light Company. Environmental & Chemical Sciences, Inc. 32 pp.

Ridgeway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, Chelonia mydas. Proc. Natl. Acad. Sci. 64:884-890.

Vogt, R.C. 1980. New methods for trapping aquatic turtles. Copeia. 1980:368-371.

Wever, E.G. 1978. The reptile ear. Princeton University Press, Princeton, New Jersey. 1024 pp.

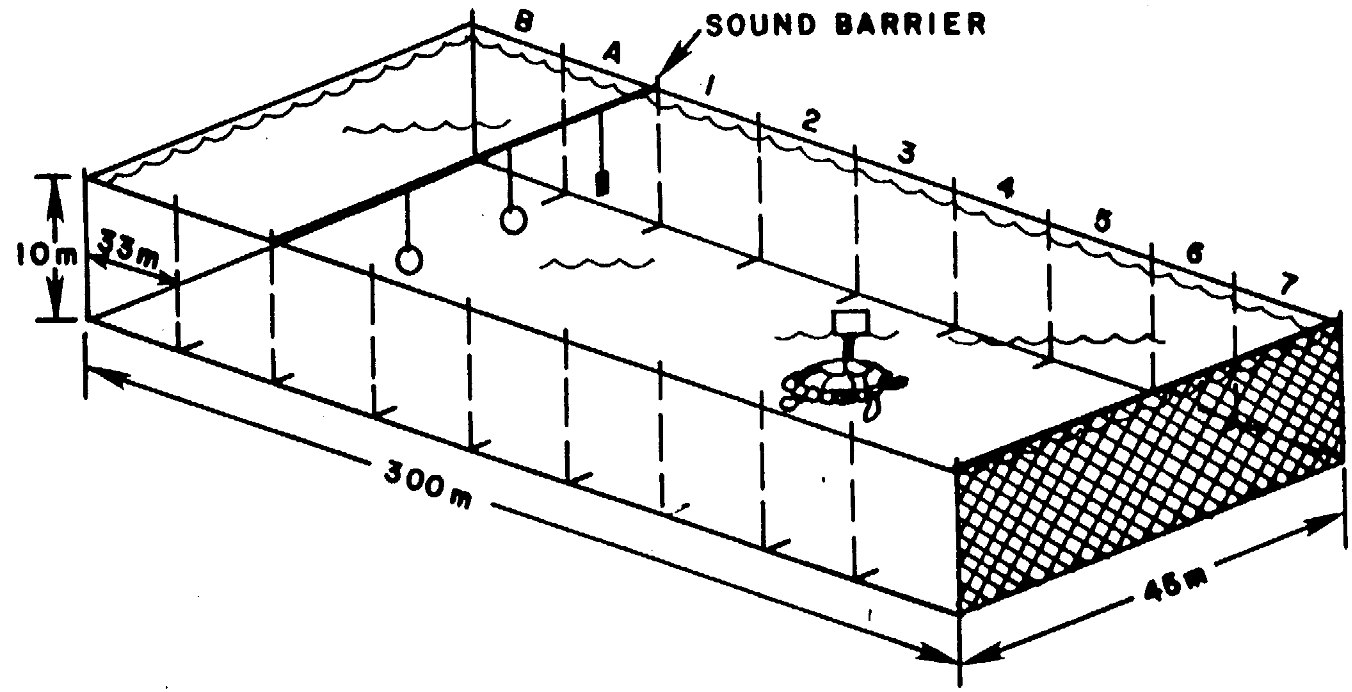


Figure 1. Diagram of the dead-end test canal with approximate demensions. A barrier net was placed at Zone 7 and the dead-end of the canal was at Zone B.

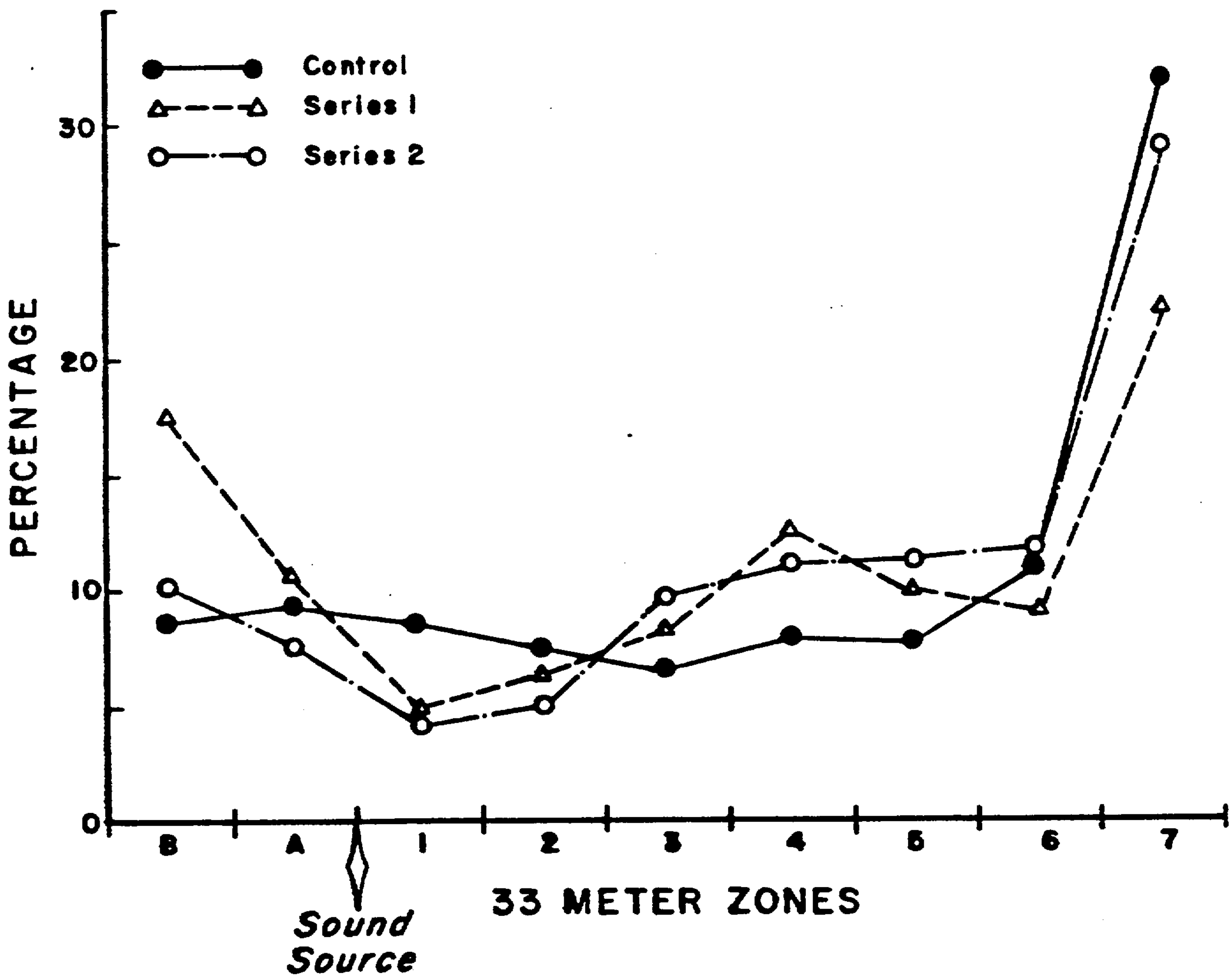


Figure 2. Percentage of total time spent by turtles in each zone during sound tests and control periods. For Series 1, two 13 cm^3 and one 165 cm^3 air guns at 70 Kg/cm^2 were used. For Series 2, three 13 cm^3 air guns were used at 245 Kg/cm^2. See Table 1 for firing frequency.

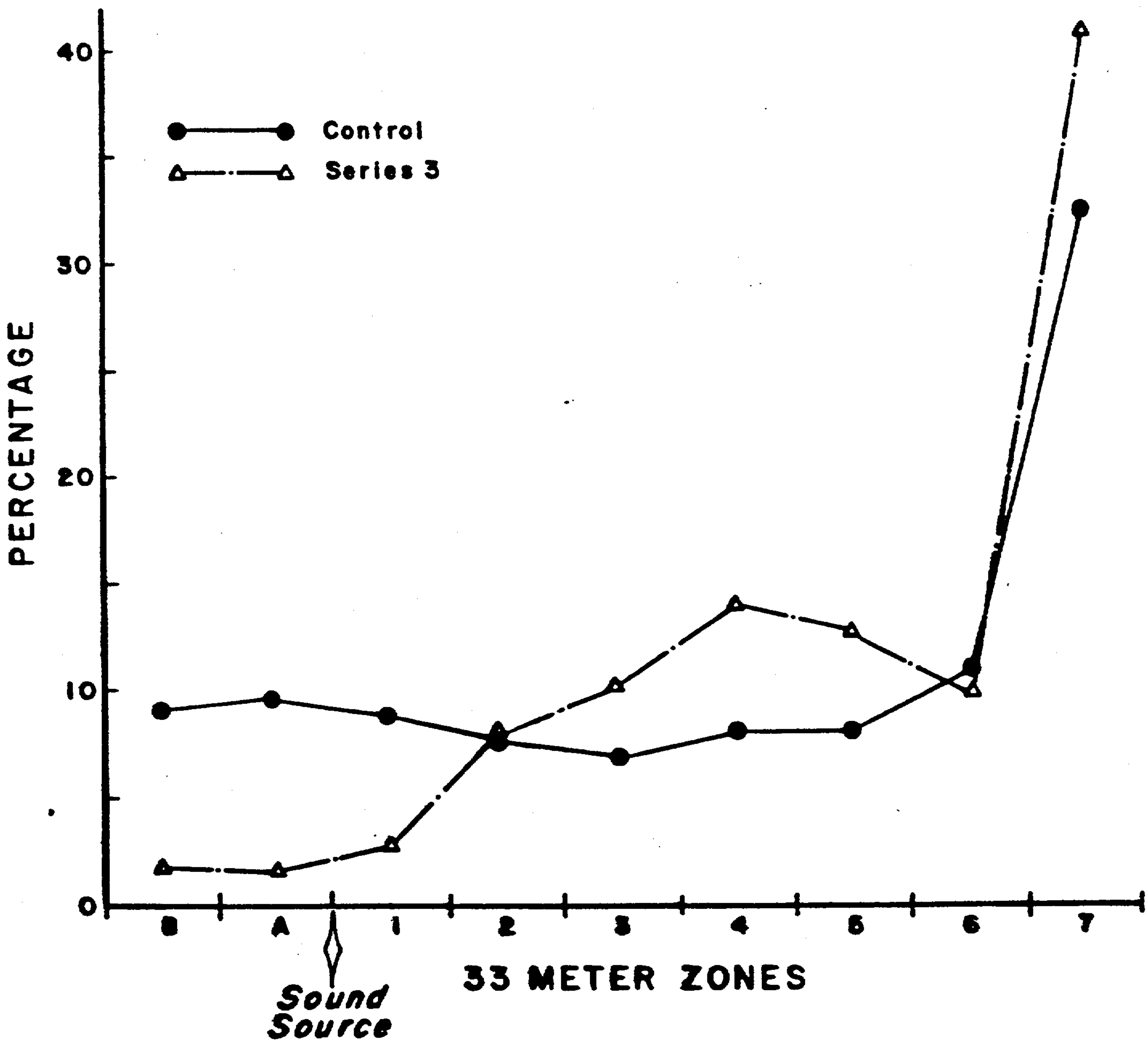


Figure 3. Percentage of total time spent by turtles in each zone during different sound tests and control periods. For Series 3, two 13 cm^3 and one 165 cm^3 air guns at 140 Kg/cm^2 were used. See Table 1 for firing frequency.

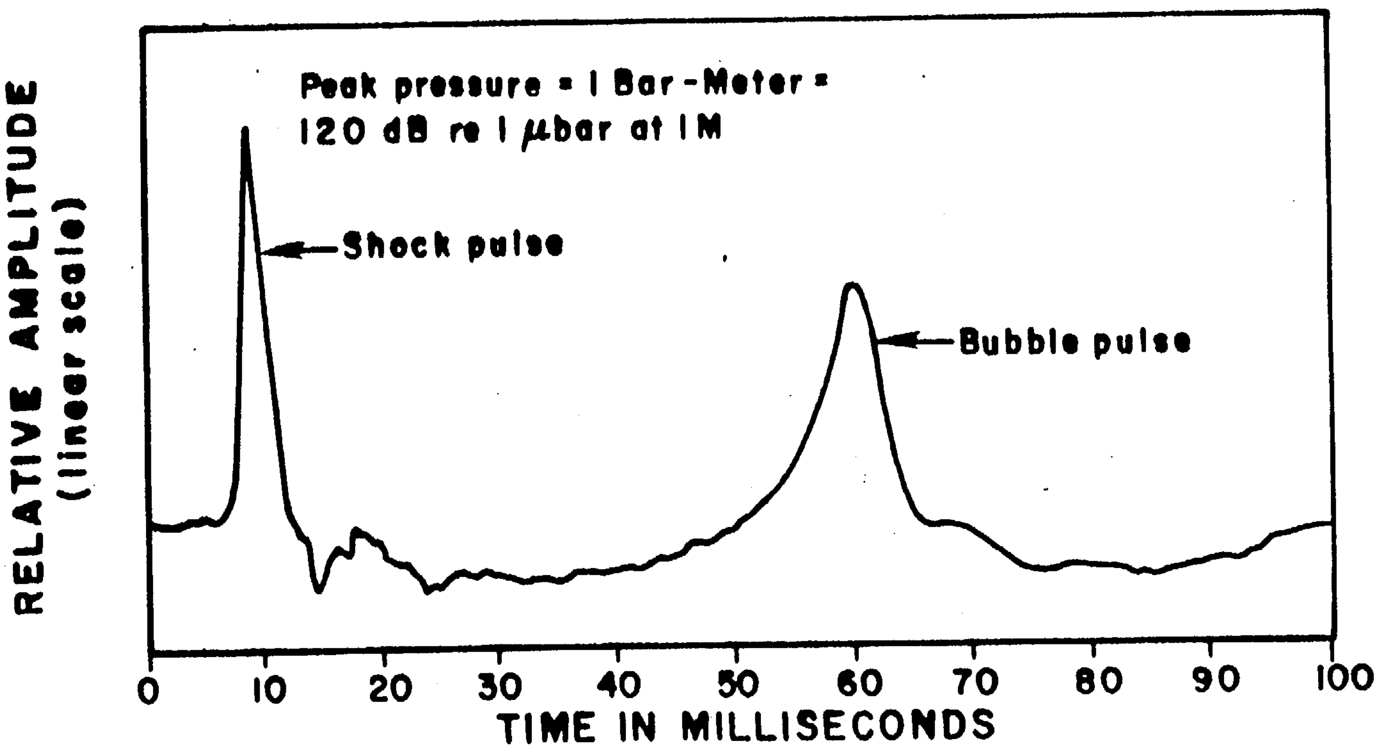


Figure 4. Nearfield wave form at 1.7 meters produced by Model 600 B air gun fired at 140 Kg/cm^2. Gun depth 2 meters.

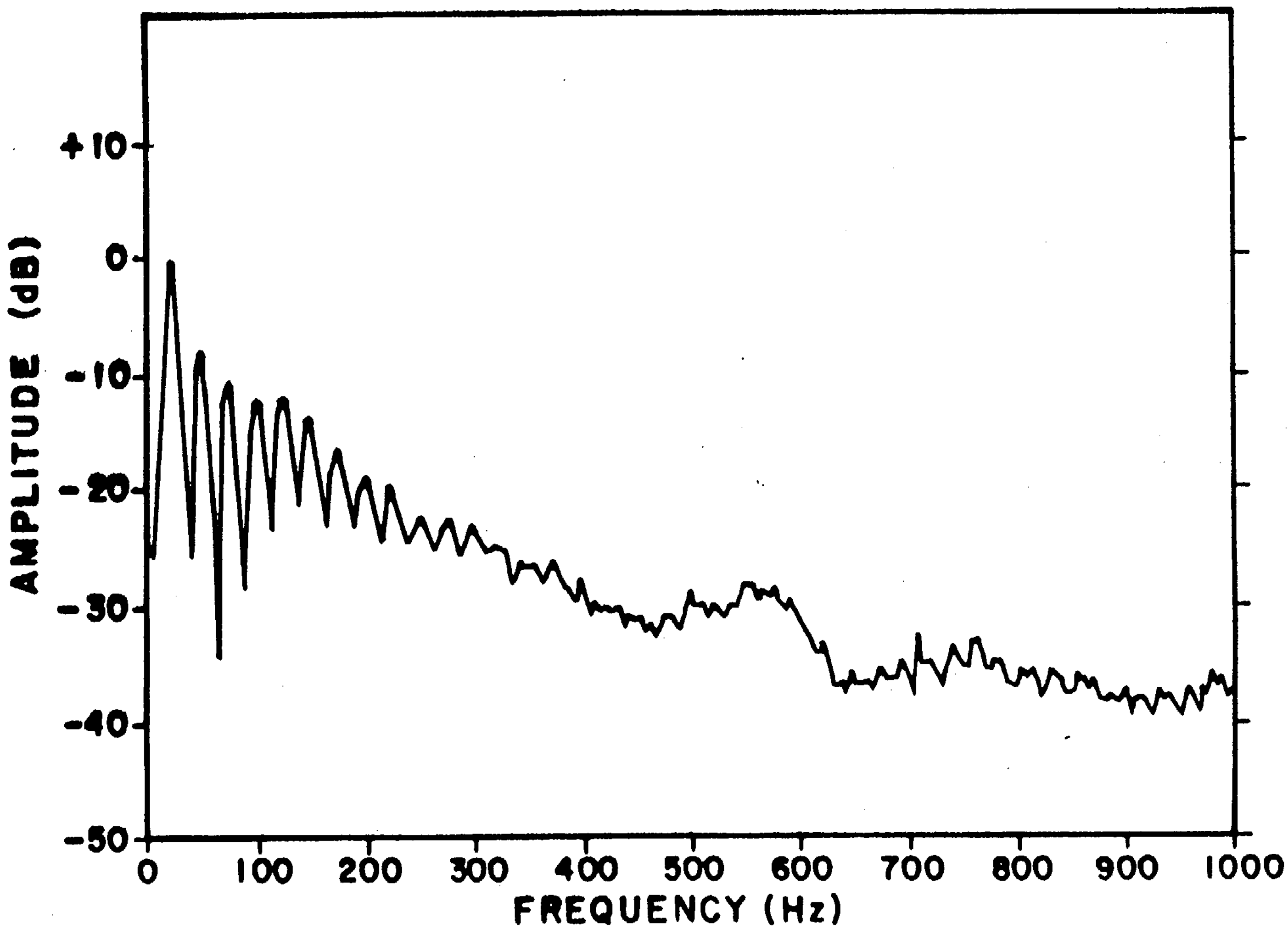


Figure 5. Sound frequency spectrum at 1.7 meter produced by 165 cm^3 Model 600 B air gun fired at 140 Kg/cm^2. Gun depth 2 meters. To show the relationship with other frequencies, the fundamental frequency (25 Hz) was arbitrarily set at 0 dB.

Table 1. Sound source and test conditions for turtle deterrent study.

No. and size of air guns: 1 cm^3	No. and size of air guns: 165 cm^3	Air pressure (Kg/cm^2)	Firing frequency (shots/min)	Number of Turtles	Hours of Testing	Number of Observations
0[a]	0	-	-	8	324	2776
3	0	245	4	9	336	2883
2	1	70	4	5	98	842
2	1	140	4	9	247	2119
2	1	140	8.6	9	275	2358

[a]Control

BEHAVIORAL RESPONSES OF LOGGERHEAD SEA TURTLES TO LIGHT

Submitted to: Dr. J. Ross Wilcox
Chief Ecologist
Florida Power and Light

Submitted by: Richard L. Raesly
Jay R. Stauffer, Jr.
Charles H. Hocutt
David R. Sager
Center for Environmental and Estuarine Studies
University of Maryland

9 January 1984

INTRODUCTION

Section 31b(b) of the Clean Water Act (PL 92-500) requires that electric utilities achieve the best available technology to reduce entrainment and impingement impacts by water intake systems of electric generating facilities. Numerous methods have been used to decrease impingement rates at water intake structures of steam electric generating facilities. The methods most commonly employed at present include cooling towers and diversion structures. However, the construction and maintenance of these devices are expensive. The use of behavioral barriers to reduce impingement of aquatic organisms at water intake structures represents an inexpensive alternative to costly underwater grates or diversion structures. Behavioral barriers are typically either visual or auditory.

Light may potentially be used as a barrier to any organism which relies on vision. The use of light as a behavioral barrier to fish has been reviewed by Nakrosius (1978) and Hocutt (1980). The Ontario Hydro Research Division (Toronto, Ontario, Canada) has investigated the effectiveness of various light regimes in repelling problem fish species from intake structures of their freshwater electric generating facilities. At Ontario Hydro, it was found that fish exhibited the greatest avoidance for strobe lights of all light sources tested (Patrick 1978, 1979a, 1979b, 1980a, 1980b, 1981a, 1981b, 1982). Strobe lights were found effective in "repelling" migrating American eels (*Anguilla rostrata* - Sheehan and Sim 1981) in field tests and also resulted in avoidance reactions from alewife (*Alosa pseudoharengus* - Patrick 1982) and gizzard shad (*Dorosoma cepedianum* - Patrick 1980b). Sager, Hocutt, and Stauffer (1983) found that certain estuarine fishes (white perch - *Morone americana*, spot - *Leiostomus xanthurus*, and menhaden - *Brevoortia tyrannus*) exhibited avoidance reactions

to strobe lights. Researchers at Ontario Hydro and the University of Maryland found that the use of strobe lights in conjunction with diversion devices increased the avoidance reactions of fishes. This increase in avoidance was found with strobe lights in combination with chain-net barriers (Patrick 1980c) and air bubble screens (Sager, Hocutt, and Stauffer 1983). Other investigators have found certain species of fish have preferred light intensities that may alter other behavioral actions (Reynolds et al. 1977, Kwain and McCauley 1978, Girsa 1969, Whitney 1969).

Reactions to light vary among species according to the morphology of the visual system, physiological conditioning (light or dark adapted, visual pigments, etc.), and behavioral responses to other simultaneous stimuli (Hoar and Randall 1971). The applicability of using light as a behavioral barrier depends on all these factors, as well as interactions among them.

Marine turtles are known to respond to a variety of visual stimuli. Light is important in both nesting biology and orientation. Positive phototaxis has been indicated in several studies involving both hatchling and mature turtles (Noble and Breslau 1938, Anderson 1958, Ortleb and Sexton 1964, Mrosovsky and Boycott 1966, Mrosovsky and Carr 1967, Ehrenfeld and Carr 1967, Ehrenfeld 1968, Fehring 1972).

However, it should not be assumed that positive phototaxis occurs under all conditions. For example, Anderson (1958) found that several species of freshwater aquatic turtles avoided bright light during the day, but were attracted to light in the evening. Color preferences may also change with changing conditions. Graf (1972) found some species prefer long wavelength light when stimuli were bright, but short wavelength light when stimuli were dim.

The physiology of marine turtle vision has been reviewed by Granda (1979). The maximal visual sensitivity of Chelonia mydas (the most intensively studied species) is at approximately 502 nm (Liebman and Granda 1971). This wavelength is close to the maximum transmission of seawater (Jerlov 1968). In dark adapted C. mydas the peak sensitivity shifts about 50 nm towards the shorter wavelengths (Granda and O'Shea 1972).

The importance of light and visual stimuli in the biology of sea turtles suggests the potential for using light as a behavioral barrier at intake structures. This study examines the responses of hatchling loggerhead sea turtles (Caretta caretta) to constant monochromatic light of different wavelengths and both hatchlings and subadults to white strobe light under several experimental conditions.

MATERIALS AND METHODS

Test Animals

Seven hatchling loggerhead turtles were used in preliminary tests of the effects of both white strobe light and constant monochromatic light of different wavelengths on behavior. Carapace lengths varied from 68 to 76 mm at the onset of testing. These individuals were experimental subjects from 12 November to 15 December 1982. Nine subadult loggerhead sea turtles weighing from 12.7 to 37.7 kg were used as experimental subjects from 6 April to 18 November 1983 for strobe light testing only.

All loggerhead turtle test specimens were collected from Florida by Florida Power and Light Company personnel and air freighted to University of Maryland personnel for this study. After the experiments were completed the turtles were returned to Florida Power and Light Company personnel via air freight.

Wavelength Preference Tests - Hatchlings

The test apparatus (Fig. 1) was a glass-bottomed trough with observation mirrors located below, similar to those used in various temperature preference studies (e.g., Meldrim and Gift 1971). Overhead baffle chambers were used to separate light reflected, by way of a system of mirrors, from projectors with monochromatic filters into discreet bands 38 cm in length. In this manner, an electromagnetic spectrum for 480 to 660 nm was divided into a series of 10 cells. Peak wavelength transmissions were 480, 500, 520, 540, 560, 580, 600, 620, 640, and 660 nm for cells 1 through 10, respectively.

Turtles were tested at light intensities of 0.2 and 0.3 μ Einsteins m^{-2} sec^{-1} using both light and dark acclimated individuals. Intensities were measured using a Li-Cor light meter with a quantum sensor. All

light measurements were taken beneath the glass bottom of the test trough. Therefore, the intensities were equal for all cells and light attenuation and absorption were taken into account for all wavelengths. The water in the test trough was filtered so little light scattering or turbidity differences were present along the test trough. Position of the turtle was recorded every 2 minutes during a 30 minute acclimation period. The projectors were then turned on producing the previously described spectrum. Position of the subject was again recorded at 2 min intervals for 30 min. Observations during the acclimation and test periods were used as expected and observed values, respectively, in a Chi-square test.

Only one turtle was introduced into the test tank for each test. However, all seven turtles were run for all experimental combinations.

Strobe Light Tests - Hatchlings

The experimental chamber (Fig. 2) was designed to produce a laminar flow through the test area. The strobe lights were contained in waterproof housing submerged to a depth of 5.1 cm. Observations were conducted using a remote-controlled camera positioned over the test area. The test area was 1.8 m in length and 1.2 m in width, with a barrier down the middle of the test area to within 25.4 cm of the upstream screen barrier. The strobe lights could be individually controlled and operated at various flash frequencies. The remote controlled camera and video cassette recorder enabled the recording of all tests for later analysis. Since the camera could not be used in total darkness, the dark acclimated turtles were actually tested under a red light system that enabled the use of the camera system. The red flourescent lights had a peak wavelength of 630 nm with 98% of light emitted between 600 and 750 nm, which is near the upper limit of sensitivity for most vertebrates. The turtles would

perceive much less light with this system than with the white lights used in the other tests.

Turtles were tested at flicker frequencies of 120 and 600 flashes/min. Tests for each strobe frequency were run at water velocities of 0.0 and 0.06 m sec^{-1}. Both light and dark acclimated specimens were tested under all experimental treatments. One turtle was used in each test run, but all seven individuals were tested under all experimental combinations.

Following a 20 min acclimation period, the position of the turtle was recorded at 2 min intervals for a period of 20 min. The strobe light in one channel was then activated and position of the subject was again recorded at 2 min intervals for 20 min. A Chi-square test of the turtle's distribution before (expected distribution) and during the strobe period (observed distribution) was used to determine the effects of the light.

Strobe Light Tests - Subadults

The test tank (Fig. 3) consisted of a 6.0 m diameter swimming pool with a plywood partition dividing the tank into four equal quadrants. Each partition arm extended 2 m out from the center of the tank, allowing an animal to circumnavigate the entire structure. Strobes were housed in plexiglass tubes and were positioned 22 cm below the surface of the water. The depth of the water column was approximately 1 m. A plywood sheet covered the top of the partitions making the four quadrants shaded, similarly to underwater caves or crevices. The strobe lights could be individually controlled to light up any combination of the quadrants. The strobe lights were arranged in individually controlled pairs in each plexiglass tube. This paired arrangement enabled the continuation of a test, if one strobe light failed, by initiating the back-up light. Tests were run with two of the quadrants lit by strobe lights. The quadrants

to be lit were altered between tests so that any preference for a certain area of the pool would be taken into account.

Turtles were fitted with a harness to which a helium balloon was attached. This balloon allowed the turtle's position to be perceived when the turtle was at the bottom of the test tank or moved under the covered areas. A camera focused on a convex mirror mounted above the test tank enabled the tracking of the turtle's movements throughout the test. The camera was equipped with a videocassette recorder and monitor so the entire test could be taped and reviewed later. The taping of the tests eliminated the need of an observer being present at all times, thus limiting the possible disturbance of the turtle's behavioral reactions.

The turtle was introduced into the test tank in quadrant 2 at 8:00 A.M., at which time the test began. Position of the animal was marked every 15 minutes throughout the experiment by the use of a videorecorder. The length of each test was 96 hours (4 days), each day consisting of a 12:12 light-dark photoperiod. As in the hatchlings strobe light tests, the camera could not function in total darkness. Therefore, the dark periods were actually lit by red flourescent lights, as explained previously. Day 1 was an acclimation period in which no strobe was lit. The distribution of observations during day 1 served as the expected value in a Chi-square test. After 24 hours the strobes in two adjacent quadrants were lit and remained on for 3 days. Positions of the turtle during days 2, 3, and 4 represent observed values for the Chi-square analysis.

Since it had been found that the avoidance reaction of fish to strobe lights varied with different flash frequencies (Patrick 1979a, 1982; Sager, Hocutt, and Stauffer 1983), subjects were tested at 4 regular strobe flicker frequency settings of 60, 120, 300, and 600 flashes min^{-1}.

Additionally, a capacitator was added to the strobe unit producing an irregular flash rate, which consisted of a burst of flashes at a rate of 300 min^{-1}, interrupted by pauses of 1-3 seconds. An air bubble curtain, positioned directly in front of the strobe to increase light scattering, was used in combination with several flicker frequencies. The air bubble curtain was tested because avoidance reactions of fish had been found to increase with a strobe light-air bubble curtain combination (Sager, Hocutt, and Stauffer 1983).

RESULTS AND DISCUSSION

Wavelength Preference Tests

Responses of both light and dark adapted hatchlings to monochromatic light are shown in Table 1. In general, more observations were recorded in the region of shorter wavelengths (Cell Nos. 1-5). Observations in the terminal cells of the trough (Nos. 1 and 10) were frequent because turtles spent a significant amount of time probing into the corners. Many turtles moved continuously throughout the duration of the experiment and showed no preference for any wavelength.

Several studies of green turtle (*Chelonia mydas*) hatchlings have shown preference for short wavelengths of light (Ehrenfeld and Carr 1967, Ehrenfeld 1968, Mrosovsky and Shettleworth 1968). These authors expressed their findings in terms of differential sensitivity rather than true "preference" behavior. Fehring (1972) has demonstrated that loggerhead hatchlings are able to discriminate hues, but he was unable to establish a connection between this ability and any specific behavioral trait.

Strobe Light Tests - Hatchlings

Chi-square values were significant ($P<0.05$) for 5 of 8 experimental treatments, indicating a preference for white strobe light (Table 2). No generalizations regarding the effects of flicker frequency or current can be made from these data.

Results should be interpreted cautiously due to small sample size. Two of the 5 significant X^2 values are caused by only one subject (Table 1A and 1E). This cannot be called "attraction", although the overall X^2 is significant. Larger sample sizes are needed to alleviate this problem.

This attraction to the strobe can be expected with hatchlings, because phototactic cues are used in sea-finding orientation after

emergence from the nest (Carr and Ogren 1960, Ehrenfeld 1968, Mrosovsky and Shettleworth 1968). At present, no studies have been conducted on the possibility of a developmental shift in orientation behavior.

Strobe Light Tests - Subadults

A total of 16 tests (64 test days) were run under experimental combinations shown in Table 3. Results of these tests appear in Table 4. Under all experimental combinations, subjects avoided the light in 10 tests, were attracted to the light in 2 tests, and showed no behavioral response in 4 tests.

There is apparently no difference in behavioral responses of naive and previously tested animals across all experimental treatments. The initial tests on each of the nine subjects resulted in 5 significant avoidance reactions, 1 significant attraction response, and no response in 3 individuals. Previously tested turtles showed avoidance in 5 tests, attraction in 1 test, and no response in 1 test (Table 5). However, behavioral responses to the strobes changed in 3 of the seven animals which were tested twice (see Table 4). This indicates a high degree of variability in behavior. Mrosovsky and Boycott (1966) have pointed out that many tests of visual discrimination are not extensive enough to reveal any preferences or biases. They cite several cases in which several trials were necessary before the turtles began to attend to visual stimuli. They also point out that several trials may be necessary to establish responses which are not affected by the apparatus.

When all tests are examined with regard to behavioral responses under light (white light) and dark (red light) conditions, it can be seen that strobes were more effective under light conditions (Table 6). This result is consistant with the findings of Anderson (1958) and others

who showed attraction to light under dim conditions and avoidance of light under bright conditions.

Strobe flicker frequencies of 300 min^{-1} at both regular and irregular rates were most effective in eliciting an avoidance reaction. Seventy-five percent of the tests run at these strobe rates resulted in significant avoidance responses. Presence or absence of an air bubble curtain had no effect on behavior (Table 7).

CONCLUSIONS

1. Hatchlings showed a slight preference for short wavelength light.
2. Hatchlings were attracted to strobe lights in 62.5% of all tests.
3. Subadults avoided strobe lights in 62.5% of all tests, indicating a behavioral switch in response to visual stimuli.
4. Strobes were more effective in eliciting avoidance responses under daylight conditions.
5. Strobe flicker frequencies of 300 regular flashes min^{-1} and 300 irregular flashes min^{-1} were most effective in causing an avoidance response in subadults. At this rate, 75% of the subjects avoided the light.
6. The use of an air bubble curtain to increase light scatter had no effect on turtle response to the light.
7. Behavior was highly variable, with change in the response of 43% of the subadult turtles which were tested twice.
8. Although the overall reaction of subadult turtles to strobe light was avoidance, all individuals approached the light at least several times, thus limiting the applicability of strobe lights in a behavioral diversion scheme for marine turtles.

LITERATURE CITED

Anderson, P. K. 1958. The photic responses and water-approach behavior of hatchling turtles. Copeia 1958:211-215.

Carr, A. F. and L. Ogren. 1960. The ecology and migrations of sea turtles. 4. The green turtle in the Caribbean Sea. Bulletin of the American Museum of Natural History 121:1-48.

Ehrenfeld, D. W. 1968. The role of vision in the sea-finding orientation of the green sea turtle (Chelonia mydas). 2. Orientation mechanism and range of spectral sensitivity. Animal Behaviour 16:281-287.

Ehrenfeld, D. W. and A. Carr. 1967. The role of vision in the sea-finding orientation of the green turtle (Chelonia mydas). Animal Behaviour 15:25-36.

Fehring, W. K. 1972. Hue discrimination in hatchling loggerhead turtles (Caretta caretta caretta). Animal Behaviour 20:632-636.

Girsa, I. 1969. Reaction to light in some freshwater fishes in the course of early development and in altered physiological states. Journal of Icthyology 9:126-135.

Graf, V. 1972. Behavioral visual functions for Chrysemys picta picta. Preferences and frequency responses. Brain Behavior and Evolution 5:155-175.

Granda, A. M. and P. J. O'Shea. 1972. Spectral sensitivity of the green turtle (Chelonia mydas mydas) determined by electrical responses to heterochromatic light. Brain Behavior and Evolution 5:143-154.

Hoar, W. S. and D. J. Randall, editors. 1971. Fish physiology, Volume 5: Sensory systems and electric organs. Academic Press, New York, USA.

Hocutt, C. 1980. Behavioral barriers and guidance systems. Pages 183-205 in Hocutt, C., J. Stauffer, Jr., J. Edinger, L. Hall, Jr., and R. Morgan II (Eds.). Power plants: Effects on fish and shellfish behavior. Academic Press, New York, USA.

Jerlov, N. G. 1968. Optical oceanography. Elsevier, Amsterdam.

Kwain, W. and R. McCauley. 1978. Effects of age and overhead illumination on temperatures preferred by under yearling rainbow trout, Salmo gairdneri, in a vertical temperature gradient. Journal of the Fisheries Research Board of Canada 35:1430-1433.

Liebman, P. A. and A. M. Granda. 1971. Microspectrophotometric measurements of visual pigments in two species of turtle, Pseudemys scripta and Chelonia mydas. Vis. Res. 11:105-114.

Meldrim, J. W. and J. W. Gift. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Ichthyological Association Bulletin No. 7:1-75.

Mrosovsky, N. and B. Boycott. 1966. Intra and interspecific differences in phototactic behavior of fresh water turtles. Behaviour 26:215-227.

Mrosovsky, N. and A. Carr. 1967. Preference for light of short wavelengths in hatchling green sea turtles, Chelonia mydas, tested on their natural nesting beaches. Behaviour 28:217-231.

Mrosovsky, N. and S. Shettleworth. 1968. The wavelength preference and brightness cues in the water finding behavior of sea turtles. Behaviour 32:211-257.

Nakrosius, R. 1978. Literature review: Responses of fish to light. Ontario Hydro Research Division Report No. 78-408-K.

Noble, G. K. and A. M. Breslau. 1938. The senses involved in the migration of young fresh water turtles after hatching. Journal of Comparative Psychology 25:175-193.

Ortleb, E. P. and O. J. Sexton. 1964. Orientation of the painted turtle, Chrysemys picta. American Midland Naturalist.

Patrick, P. H. 1978. Responses of fish to light. Ontario Hydro Research Division Report. No. 78-516-K.

______. 1979a. Responses of gizzard shad to strobe lights. Ontario Hydro Research Division Report. No. 79-104-K.

______. 1979b. Responses of gizzard shad to strobe light - Phases II and III. Ontario Hydro Research Division Report. No. 79-370-K.

______. 1980a. Responses of American eels to strobe light. Ontario Hydro Research Division Report. No. 80-86-K.

______. 1980b. Responses of gizzard shad to white strobe light at various current velocities. Ontario Hydro Research Division Report. No. 80-238-K.

______. 1980c. Effectiveness of a chain-net strobe light shad exclusion scheme. Ontario Hydro Research Division Report. No. 80-156-K.

______. 1981a. Responses of fish to light. Proceedings of the Advanced Intake Technology Workshop. San Diego, USA.

______. 1981b. Responses of alewife to mercury vapour light. Ontario Hydro Research Division Report No. 80-413-K.

______. 1982. Responses of alewife to flashing light. Ontario Hydro Research Division Report No. 82-305-K.

Reynolds, W., D. Thomson, and M. Casterlin. 1977. Responses of young California grunion, Leuresthes tenuis, to gradients of temperature and light. Copeia 1:144-149.

Sager, D. R., C. H. Hocutt, and J. R. Stauffer, Jr. 1983. Avoidance behavior of estuarine fishes to strobe lights as a possible impingement mitigation factor. 113th Annual Meeting of American Fisheries Society. Milwaukee, Wisconsin.

Sheehan, R. and B. Sim. 1981. American eel response to white strobe light. Ontario Hydro Research Division Report. No. 81-61-K

Whitney, R. 1969. Schooling of fishes relative to available light. Transactions of the American Fisheries Society 3:497-504.

Table 1. Responses of loggerhead sea turtles to various wavelengths of monochromatic light under all experimental treatments.

Conditions
Light intensity: 0.2 μ E m^{-2} sec^{-1}
Acclimation: light

Cell #	λ	Test # 1	2	3	4	5	6	7	
1	480 nm	0	0	2	8	0	10	2	Σ = 22
2	500 nm	3	0	1	1	0	3	2	Σ = 10
3	520 nm	2	0	0	0	0	2	4	Σ = 8
4	540 nm	1	0	0	1	0	0	5	Σ = 7
5	560 nm	3	0	0	0	15	0	1	Σ = 19
6	580 nm	1	0	1	0	0	0	1	Σ = 3
7	600 nm	0	0	2	0	0	0	0	Σ = 2
8	620 nm	0	0	2	0	0	0	0	Σ = 2
9	640 nm	1	1	1	0	0	0	0	Σ = 3
10	660 nm	4	14	6	5	0	0	0	Σ = 29

Conditions
Light intensity: 0.3 μ E m^{-2} sec^{-1}
Acclimation: light

Cell #	λ	Test # 1	2	3	4	5	6	7	
1	480 nm	3	11	0	15	14	0	2	Σ = 45
2	500 nm	2	0	0	0	1	0	2	Σ = 5
3	520 nm	2	1	6	0	0	0	1	Σ = 10
4	540 nm	3	0	7	0	0	0	2	Σ = 12
5	560 nm	0	0	2	0	0	0	1	Σ = 3
6	580 nm	1	0	0	0	0	15	2	Σ = 18
7	600 nm	0	0	0	0	0	0	2	Σ = 2
8	620 nm	0	0	0	0	0	0	1	Σ = 1
9	640 nm	3	1	0	0	0	0	2	Σ = 6
10	660 nm	1	2	0	0	0	0	0	Σ = 3

Table 1. (Continued)

Conditions
Light intensity: 0.2 μ E m^{-2} sec^{-1}
Acclimation: light

Cell #	λ	Test # 1	2	3	4	5	6	7	
1	480 nm	2	0	4	2	4	1	-	Σ = 13
2	500 nm	0	0	1	0	2	4	-	Σ = 7
3	520 nm	1	3	0	1	0	5	-	Σ = 10
4	540 nm	0	0	3	0	2	1	-	Σ = 6
5	560 nm	2	2	0	2	1	1	-	Σ = 8
6	580 nm	2	1	1	2	2	1	-	Σ = 9
7	600 nm	0	1	1	1	3	2	-	Σ = 8
8	620 nm	2	1	1	1	1	0	-	Σ = 6
9	640 nm	2	2	1	2	0	0	-	Σ = 7
10	660 nm	3	5	3	4	0	0	-	Σ = 15

Conditions
Light intensity: 0.3 μ E m^{-2} sec^{-1}
Acclimation: light

Cell #	λ	Test # 1	2	3	4	5	6	7	
1	480 nm	0	1	0	1	3	5	6	Σ = 16
2	500 nm	1	0	1	0	4	1	2	Σ = 9
3	520 nm	4	1	5	0	3	4	2	Σ = 19
4	540 nm	8	0	0	0	1	0	2	Σ = 11
5	560 nm	2	1	2	1	1	1	1	Σ = 9
6	580 nm	0	2	4	0	1	1	0	Σ = 8
7	600 nm	0	0	1	0	2	1	1	Σ = 5
8	620 nm	0	2	2	0	0	1	0	Σ = 5
9	640 nm	0	1	0	2	0	0	1	Σ = 4
10	660 nm	0	7	0	11	0	1	0	Σ = 19

Table 2. Responses of hatchling loggerhead sea turtles to strobe lights under all experimental treatments. χ^2 values are calculated using the formula $\frac{((0+1 - (e+1))^2}{(e+1)}$, thus eliminating zero values in the denominator. x = channel lit with strobe; y = channel prior to strobe. Values marked * are significant at the 0.05 level.

A. Conditions:

Flow rate: 0.0m sec^{-1}
Strobe frequency: 120/min
Acclimation: light

	Test # 1	2	3	4	5	6	7	
x	3	5	6	7	10	5	10	x = 46
y	3	5	1	7	10	6	10	y = 42
χ^2	0.0	0.0	12.5	0.0	0.0	0.1	0.0	$\Sigma\chi^2$ = 12

B. Conditions:

Flow rate: 0.06m sec^{-1}
Strobe frequency: 120/min
Acclimation: light

	Test # 1	2	3	4	5	6	7	
x	9	0	4	0	0	2	9	x = 24
y	4	0	1	0	0	6	4	y = 15
χ^2	5.0	0.0	4.5	0.0	0.0	2.3	5.0	$\Sigma\chi^2$ = 16

C. Conditions:

Flow rate: 0.0m sec^{-1}
Strobe frequency: 600/min
Acclimation: light

	Test # 1	2	3	4	5	6	7	
x	0	7	0	0	8	0	9	x = 24
y	0	5	0	1	5	0	9	y = 20
χ^2	0.0	0.7	0.0	0.5	1.5	0.0	0.0	$\Sigma\chi^2$ = 2

Table 2. (Continued)

D. Conditions:

Flow rate: 0.06m sec^{-1}
Strobe frequency: 600/min
Acclimation: light

	Test #							
	1	2	3	4	5	6	7	
x	10	10	0	6	0	4	0	x = 30
y	10	5	0	2	0	3	0	y = 20
χ^2	0.0	4.2	0.0	5.3	0.0	0.2	0.0	$\Sigma\chi^2$ = 9.

E. Conditions:

Flow rate: 0.0m sec^{-1}
Strobe frequency: 120/min
Acclimation: dark

	Test #							
	1	2	3	4	5	6	7	
x	7	8	0	0	6	9	10	x = 40
y	9	0	0	3	10	9	10	y = 41
χ^2	0.4	64.0	0.0	2.2	1.5	0.0	0.0	$\Sigma\chi^2$ = 6

F. Conditions:

Flow rate: 0.06m sec^{-1}
Strobe frequency: 120/min
Acclimation: dark

	Test #							
	1	2	3	4	5	6	7	
x	10	0	10	10	10	0	3	x = 4
y	2	1	0	6	10	5	0	y = 2
χ^2	21.3	0.5	100.0	2.3	0.0	4.2	9.0	$\Sigma\chi^2$ = 1

Table 2. (Continued)

G. Conditions:

Flow rate: 0.0m sec^{-1}
Strobe frequency: 600/min
Acclimation: dark

	Test #							
	1	2	3	4	5	6	7	
x	8	5	2	10	10	8		x = 43
y	7	5	4	4	10	7		y = 37
χ^2	0.1	0.0	0.8	7.2	0.0	0.1		$\Sigma\chi^2$ = 8

H. Conditions:

Flow rate: 0.06m sec^{-1}
Strobe frequency: 600/min
Acclimation: dark

	Test #							
	1	2	3	4	5	6	7	
x	10	10	10	10	9	0		x = 49
y	7	4	3	2	6	1		y = 23
χ^2	1.1	7.2	12.2	21.3	1.3	0.5		$\Sigma\chi^2$ = 43

Table 3. Summary of experimental conditions used during strobe light testing for subadults. Numbers indicate the number of tests performed under each set of experimental conditions.

Strobe flicker rate	No air bubble curtain	Air bubble curtain
60/min	1	
120/min	2	
300/min	2	2
600/min	3	2
300 irregular/min		4

Test 4. Results of strobe light tests on subadults. Values marked * are significant at the 0.05 level.

TEST #1

Flicker frequency: 60/min
Turtle identification #: AAH-389
Total occurrences in lit side for white light acclimation: 22
Total occurrences in lit side for red light acclimation: 28
Total occurrences in lit side for white light by test day: 17, 30, 21
Total occurrences in lit side for red light by test day: 29, 15, 8

Chi-square values

White light Chi-square values by test day are: 1.14(-), 2.91(+), 0.05(-)
Red light Chi-square values by test day are: 0.04(+), 6.04(-), 14.29(-)
Sum of white light Chi-square values is: 1.72(+)
Sum of red light Chi-square values is: 20.29(-)*
Total Chi-square value is: 18.57(-)*

Notes:

TEST #2

Flicker frequency: 120/min
Turtle identification #: AAH-402, AAH-403
Total occurrences in lit side for white light acclimation: 26
Total occurrences in lit side for red light acclimation: 22
Total occurrences in lit side for white light by test day: 11, 6, 13
Total occurrences in lit side for red light by test day: 36, 37, 41

Chi-square values

White light Chi-square values by test day are: 8.65(-), 15.38(-), 6.50(-)
Red light Chi-square values by test day are: 8.91(+), 10.23(+), 16.41(+)
Sum of white light Chi-square values is: 30.54(-)*
Sum of red light Chi-square values is: 35.55(+)*
Total Chi-square value is: 5.01(+)

Notes:

Table 4. (Continued)

TEST #3

Flicker frequency: 300/min
Turtle identification #: AAH-409, AAH-410
Total occurrences in lit side for white light acclimation: 25
Total occurrences in lit side for red light acclimation: 29
Total occurrences in lit side for white light by test day: 20, 14, 14
Total occurrences in lit side for red light by test day: 29, 19, 32

<u>Chi-square values</u>

White light Chi-square values by test day are: 1.00(-), 4.84(-), 4.84(-)
Red light Chi-square values by test day are: 0, 3.45(-), 0.31(+)
Sum of white light Chi-square values is: 10.68(-)*
Sum of red light Chi-square values is: 3.14(-)
Total Chi-square value is: 13.82(-)*

Notes:

TEST #4

Flicker frequency: 600/min
Turtle identification #: AAH-389
Total occurrences in lit side for white light acclimation: 23
Total occurrences in lit side for red light acclimation: 21
Total occurrences in lit side for white light by test day: 19, 14, 17
Total occurrences in lit side for red light by test day: 33, 29, 21

<u>Chi-square values</u>

White light Chi-square values by test day are: 0.70(-), 3.52(-), 1.57(-)
Red light Chi-square values by test day are: 6.86(+), 3.05(+), 0
Sum of white light Chi-square values is: 5.78(-)
Sum of red light Chi-square values is: 9.91(+)*
Total Chi-square value is: 4.13(+)

Notes: Turtle was previously tested and showed avoidance at 60 flashes/min.

Table 4. (Continued)

TEST #5

Flicker frequency: 600/min
Turtle identification #: AAH-428, AAH-429
Total occurrences in lit side for white light acclimation: 27
Total occurrences in lit side for red light acclimation: 29
Total occurrences in lit side for white light by test day: 25, 8, 3
Total occurrences in lit side for red light by test day: 16, 9, 5

Chi-square values

White light Chi-square values by test day are: 0.15(-), 13.37(-), 21.33(-)
Red light Chi-square values by test day are: 5.83(-), 13.79(-), 19.86(-)
Sum of white light Chi-square values is: 34.85(-)*
Sum of red light Chi-square values is: 39.48(-)*
Total Chi-square value is: 74.33(-)*

Notes:

TEST #6

Flicker frequency: 600/min
Turtle identification #: AAH-341, AAH-342
Total occurrences in lit side for white light acclimation: 24
Total occurrences in lit side for red light acclimation: 25
Total occurrences in lit side for white light by test day: 24, 19, 27
Total occurrences in lit side for red light by test day: 29, 47, 24

Chi-square values

White light Chi-square values by test day are: 0, 1.04(-), 0.37(+)
Red light Chi-square values by test day are: 0.64(+), 19.36(+), 0.04(-)
Sum of white light Chi-square values is: 0.67(-)
Sum of red light Chi-square values is: 19.96(+)*
Total Chi-square value is: 19.29(+)*

Notes:

Table 4. (Continued)

TEST #7

Flicker frequency: 120/min
Turtle identification #: AAH-428, AAH-429
Total occurrences in lit side for white light acclimation: 26
Total occurrences in lit side for red light acclimation: 29
Total occurrences in lit side for white light by test day: 19, 26, 21
Total occurrences in lit side for red light by test day: 18, 19, 14

Chi-square values

White light Chi-square values by test day are: 1.88(-), 0, 0.96(-)
Red light Chi-square values by test day are: 4.17(-), 3.45(-), 7.76(-)
Sum of white light Chi-square values is: 2.85(-)
Sum of red light Chi-square values is: 15.38(-)*
Total Chi-square value is: 18.23(-)*

Notes: Turtle was previously tested and showed avoidance at 600 flashes min^{-1}.

TEST #8

Flicker frequency: 300/min
Turtle identification #: AAH-341, AAH-342
Total occurrences in lit side for white light acclimation: 26
Total occurrences in lit side for red light acclimation: 26
Total occurrences in lit side for white light by test day: 19, 6, 29
Total occurrences in lit side for red light by test day: 23, 22, 3

Chi-square values

White light Chi-square values by test day are: 1.88(-), 15.38(-), 0.35(+)
Red light Chi-square values by test day are: 0.35(-), 0.62(-), 20.35(-)
Sum of white light Chi-square values is: 16.91(-)*
Sum of red light Chi-square values is: 21.32(-)*
Total Chi-square value is: 38.23(-)*

Notes: Turtle was previously tested and showed attraction at 600 flashes min^{-1}.

Table 4. (Continued)

TEST #9

Flicker frequency: 600/min
Turtle identification #: AAH-897, AAH-898
Total occurrences in lit side for white light acclimation: 21
Total occurrences in lit side for red light acclimation: 29
Total occurrences in lit side for white light by test day: 6, 16, 14
Total occurrences in lit side for red light by test day: 29, 25, 18

Chi-square values

White light Chi-square values by test day are: 10.71(-), 1.19(-), 2.33(-)
Red light Chi-square values by test day are: 0, 0.55(-), 4.17(-)
Sum of white light Chi-square values is: 14.24(-)*
Sum of red light Chi-square values is: 4.72(-)
Total Chi-square value is: 18.96(-)*

Notes: A bubble curtain was used in conjunction with the strobe.

TEST #10

Flicker frequency: 600/min
Turtle identification #: AAH-893, AAH-894
Total occurrences in lit side for white light acclimation: 25
Total occurrences in lit side for red light acclimation: 25
Total occurrences in lit side for white light by test day: 20, 19, 21
Total occurrences in lit side for red light by test day: 25, 28, 32

Chi-square values

White light Chi-square values by test day are: 1.0(-), 1.44(-), 0.64(-)
Red light Chi-square values by test day are: 0, 0.36(+), 1.96(+)
Sum of white light Chi-square values is: 3.08(-)
Sum of red light Chi-square values is: 2.32(+)
Total Chi-square value is: 0.76(-)

Notes: A bubble curtain was used in conjunction with the strobe.

Table 4. (Continued)

TEST #11

Flicker frequency: 300/min
Turtle identification #: AAH-885, AAH-886
Total occurrences in lit side for white light acclimation: 33
Total occurrences in lit side for red light acclimation: 24
Total occurrences in lit side for white light by test day: 30, 25, 30
Total occurrences in lit side for red light by test day: 20, 15, 27

Chi-square values

White light Chi-square values by test day are: 0.27(-), 1.94(-), 0.27(-)
Red light Chi-square values by test day are: 0.67(-), 3.38(-), 0.38(+)
Sum of white light Chi-square values is: 2.48(-)
Sum of red light Chi-square values is: 3.67(-)
Total Chi-square value is: 6.15(-)*

Notes: A bubble curtain was used in conjunction with the strobe.

TEST #12

Flicker frequency: 300/min
Turtle identification #: AAH-895, AAH-896
Total occurrences in lit side for white light acclimation: 27
Total occurrences in lit side for red light acclimation: 28
Total occurrences in lit side for white light by test day: 13, 26, 30
Total occurrences in lit side for red light by test day: 18, 17, 21

Chi-square values

White light Chi-square values by test day are: 7.26(-), 0.04(-), 0.33(+)
Red light Chi-square values by test day are: 3.57(-), 4.32(-), 1.75(-)
Sum of white light Chi-square values is: 6.97(-)*
Sum of red light Chi-square values is: 9.64(-)*
Total Chi-square value is: 16.61(-)*

Notes: A bubble curtain was used in conjunction with the strobe.

Table 4. (Continued)

TEST #13

Flicker frequency: 300/min Irregular
Turtle identification #: AAH-885, AAH-886
Total occurrences in lit side for white light acclimation: 24
Total occurrences in lit side for red light acclimation: 29
Total occurrences in lit side for white light by test day: 23, 25, 10
Total occurrences in lit side for red light by test day: 17, 25, 37

Chi-square values

White light Chi-square values by test day are: 0.04(-), 0.04(+), 8.17(-)
Red light Chi-square values by test day are: 4.97(-), 0.55(-), 2.21(+)
Sum of white light Chi-square values is: 8.17(-)*
Sum of red light Chi-square values is: 3.31(-)
Total Chi-square value is: 11.48(-)*

Notes: A bubble curtain used in conjunction with an irregular strobe. This turtle was tested previously and showed avoidance at 300 flashes min^{-1}. Due to equipment failure, some observations were missed during the red light period of test day 1. To correct for these missing observations, the percentage of recorded observations were used to calculate an overall value for this period. These values are underscored.

TEST #14

Flicker frequency: 300/min Irregular
Turtle identification #: AAH-893, AAH-894
Total occurrences in lit side for white light acclimation: 21
Total occurrences in lit side for red light acclimation: 21
Total occurrences in lit side for white light by test day: 41, 13, 43
Total occurrences in lit side for red light by test day: 35, 36, 38

Chi-square values

White light Chi-square values by test day are: 19.05(+), 3.05(-), 23.05(+)
Red light Chi-square values by test day are: 9.33(+), 10.71(+), 13.76(+)
Sum of white light Chi-square values is: 39.05(+)
Sum of red light Chi-square values is: 33.80(+)
Total Chi-square value is: 72.85(+)

Notes: A bubble curtain was used in conjunction with an irregular strobe. This turtle was tested previously at 600 flashes min^{-1} and showed no reaction to the strobe.

Table 4. Continued.

TEST #15

Flicker frequency: 300/min Irregular
Turtle identification #: AAH-897, AAH-898
Total occurrences in lit side for white light acclimation: 29
Total occurrences in lit side for red light acclimation: 26
Total occurrences in lit side for white light by test day: 30, 8, 24
Total occurrences in lit side for red light by test day: 21, 12, 33

Chi-square values

White light Chi-square values by test day are: 0.03(+), 15.21(-), 0.86(-)
Red light Chi-square values by test day are: 0.96(-), 7.54(-), 1.88(+)
Sum of white light Chi-square values is: 16.04(-)
Sum of red light Chi-square values is: 6.62(-)
Total Chi-square value is: 22.66(-)

Notes: A bubble curtain was used in conjunction with an oscillating strobe. This turtle was tested previously at 600 flashes/min and avoided the light.

TEST #16

Flicker frequency: 300/min Irregular
Turtle identification #: AAH-895, AAH-896
Total occurrences in lit side for white light acclimation: 30
Total occurrences in lit side for red light acclimation: 24
Total occurrences in lit side for white light by test day: 14, 9, 10
Total occurrences in lit side for red light by test day: 39, 36, 37

Chi-square values

White light Chi-square values by test day are: 8.53(-), 14.70(-), 13.33(-)
Red light Chi-square values by test day are: 9.37(+), 6.00(+), 7.04(+)
Sum of white light Chi-square values is: 36.56(-)*
Sum of red light Chi-square values is: 22.41(+)*
Total Chi-square value is: 14.15(-)*

Notes: A bubble curtain was in conjunction with an oscillating strobe. The turtle was tested previously at a regular stobe frequency of 300 flashes and showed avoidance. Due to equipment failure, some observations were missed during the redlight period test day 1. To correct for these missing observations, the percentage of recorded observations were used to calculate an overall value for this period. These values are underscored.

Table 5. Responses of naive and previously tested subadult loggerheads to strobe lights under all experimental treatments.

	Naive Individuals	Previously Tested Individuals
Avoidance	5	5
Attraction	1	1
No response	3	1

Table 6. Responses of subadult loggerhead sea turtles to strobe light under white light and red light conditions.

	White Light	Red Light
Avoidance	7	9
Attraction	5	1
No response	4	6

le 7. Effects of strobe flicker frequency and the presence or absence of an air bubble curtain on behavioral responses of subadult loggerhead sea turtles to strobe light.

	60 min^{-1}		120 min^{-1}		300 min^{-1}		600 min^{-1}		300 min^{-1} irregular	
	No Curtain	Curtain	No Curtain	Curtain	No Curtain	Curtain	No Curtain	Curtain	No Curtain	Curtai
idance	1		1		2	1	1	1		3
raction							1			1
Response			1			1	1	1		

Fig. 1. Light preference trough. All organisms were introduced into cell #1 (480nm).

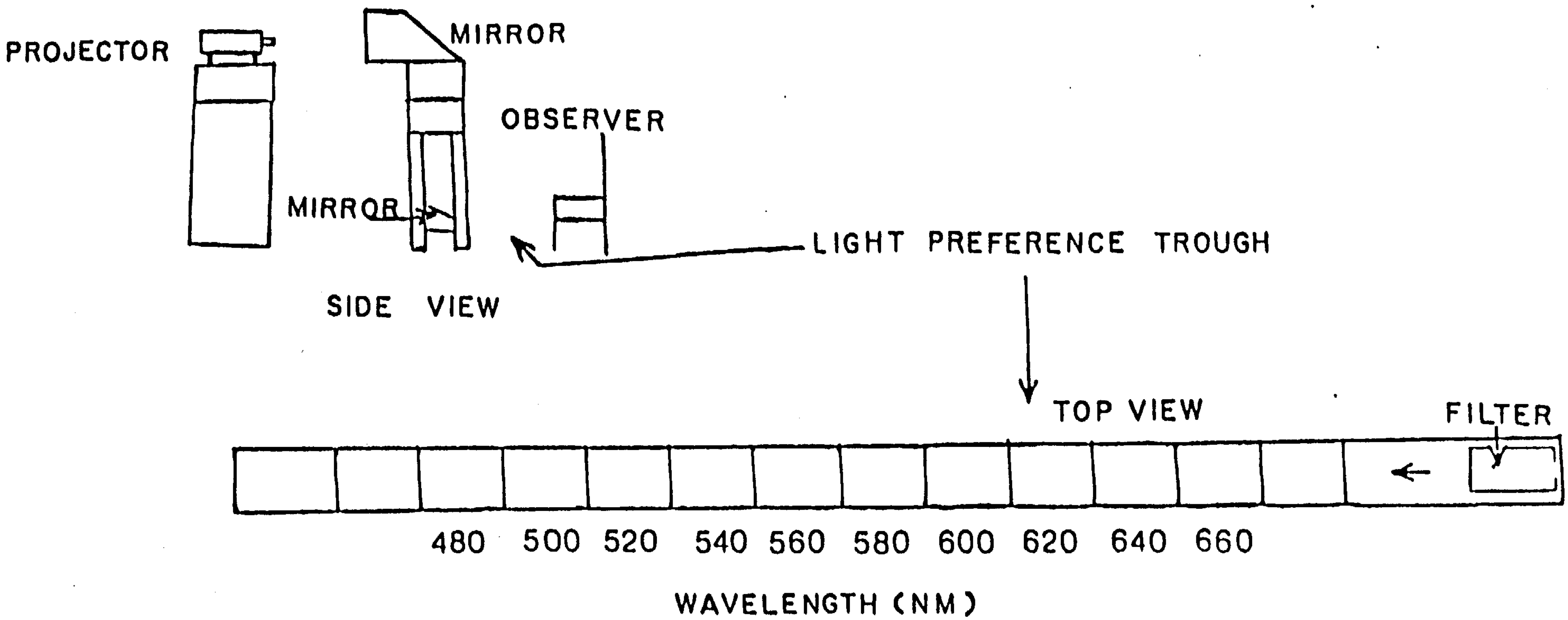


Fig. 2. Strobe light avoidance trough. Arrows indicate direction of flow.

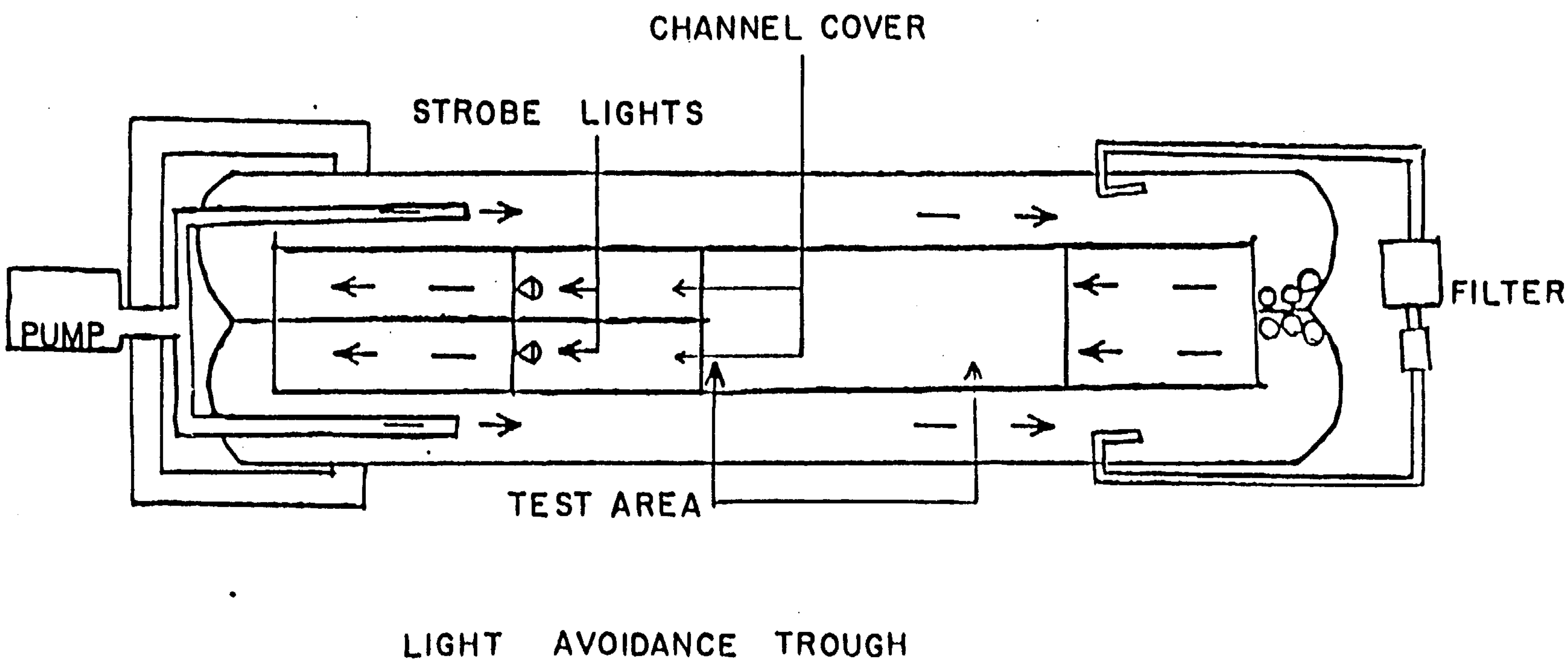
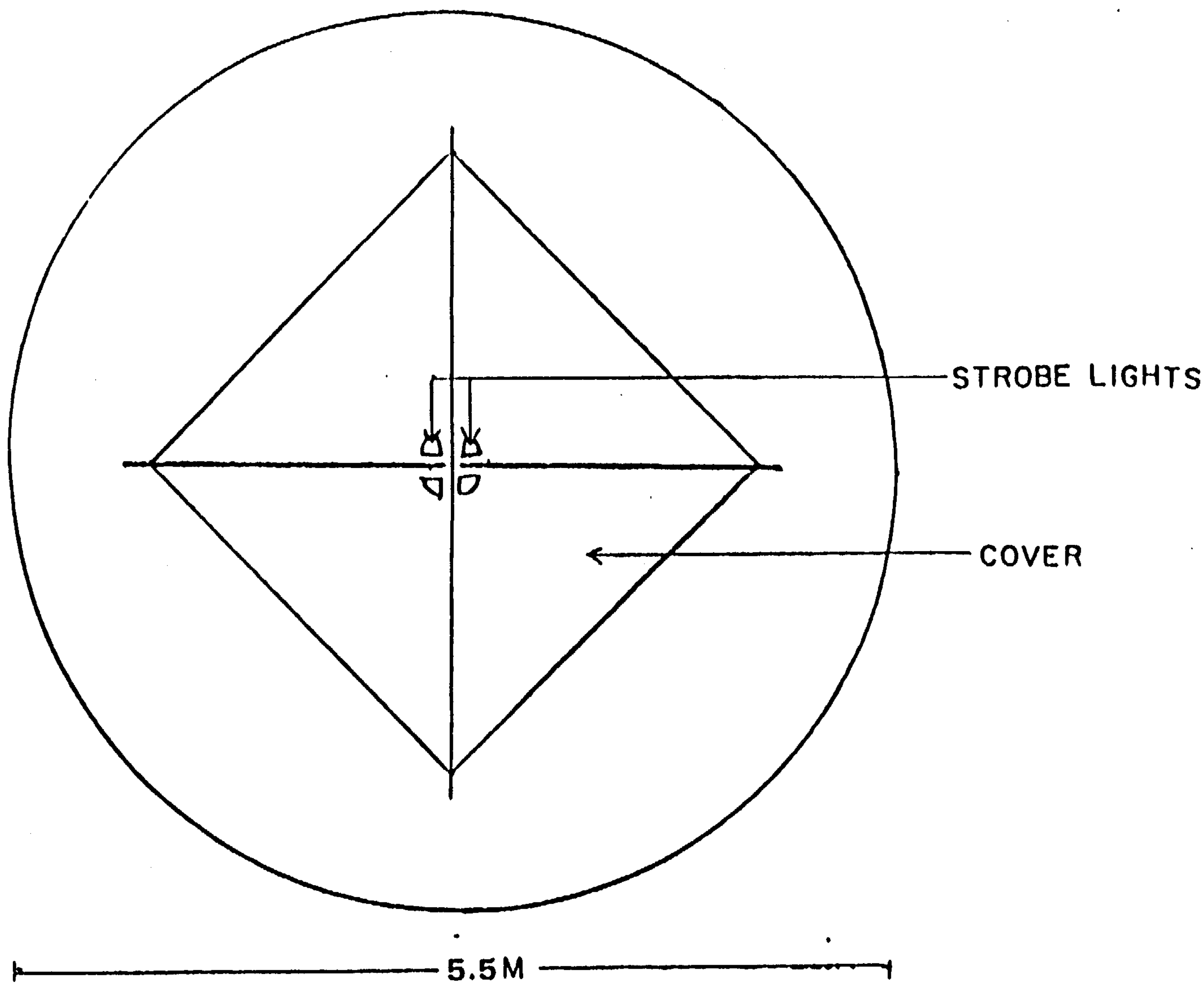


Fig. 3. Test tank for subadults.



3/19/84

P. O. BOX 14000, JUNO BEACH, FL 33408

FPL

FLORIDA POWER & LIGHT COMPANY

March 7, 1984
L-84-61

Office of Nuclear Reactor Regulation
Attention: Mr. Darrell G. Eisenhut, Director
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Eisenhut:

Re: St. Lucie Unit No. 2
Docket No. 50-389
Environmental Protection Plan

In accordance with Section 4.2.2 of the St. Lucie Unit 2 Enviromental Protection Plan (Appendix B to Facility Operating License No. NPF-16), a study to evaluate and/or mitigate turtle entrapment at the intake structure has been implemented, and a draft report of the results is expected to be completed in early March 1984.

Florida Power & Light Company will be prepared to discuss the report with the following agencies during the Week of April 8, 1984:

U. S. Nuclear Regulatory Commission
U. S. Environmental Protection Agency
National Marine Fisheries Service
U. S. Fish and Wildlife Service
Florida Department of National Resources
Florida Game and Fresh Water Fish Commission

Attached is a list of names and addresses for key individuals in each agency.

We are recommending that the presentation be held at the St. Lucie Plant Site. We will be contacting members of your staff and each of the key individuals on the attached list to coordinate the meeting.

Very truly yours,

J. W. Williams, Jr.
Vice President
Nuclear Energy

JWW/RJS/cab

Attachment

AGENCIES CONTACTS FOR PSL TURTLE ENTRAPMENT PRESENTATION

1. National Marine Fisheries Service

   Mr. Andreas Mager
   Endangered Species Specialist
   National Marine Fisheries Service
   9450 Koger Blvd.
   St. Petersburg, FL 33702

   Mr. Frederick Berry
   Fisheries Biologist
   Southeast Fisheries Center
   National Marine Fisheries Service
   75 Virginia Beach Drive
   Miami, FL 33149

2. U.S. Fish and Wildlife Service

   Mr. David Smith
   Endangered Species Coordinator
   U.S. Fish and Wildlife Service
   P.O. Box 2676
   Vero Beach, FL 32960

3. Environmental Protection Agency

   Dr. Ronald Raschke
   Ecology Branch
   U.S. Environmental Protection Agency
   College Station Road
   Athens, GA 30601

4. Department of Natural Resources

   Mr. J. Alan Huff
   Senior Biologist
   Bureau of Marine Science and Technology
   Department of Natural Resources
   100 Eighth Avenue, S.E.
   St. Petersburg, FL 33701

   Mr. Ross Witham
   Department of Natural Resources
   P.O. Box 941
   Jensen Beach, FL 33457

5. Game and Fresh Water Fish Commission

   Mr. Don Wood
   Endangered Species Coordinator
   Florida Game and Fresh Water Fish Commission
   620 S. Meridian Street
   Tallahassee, FL 32301

FLORIDA POWER & LIGHT COMPANY

INTER-OFFICE CORRESPONDENCE

LOCATION JEA

TO File

DATE April 13, 1984

FROM J. R. Wilcox

COPIES TO W. J. Barrow, Jr.
C. D. Henderson
M. M. Kleinhenz

SUBJECT: **MEETING ON SECTION 4.2.2 OF PSL-EPP**

On April 11, 1984, FPL hosted a meeting at the Emergency Operations Facility to brief federal and state agencies on our efforts to satisfy Section 4.2.2 of the PSL-EPP. A list of attendees is attached.

The presentations were as follows:

Introduction - FPL
J. R. Wilcox

Lights and Bubble Curtains - Applied Biology, Inc.
J. R. Wilcox

Strobe Lights and Bubble Curtains -
University of Maryland
C. H. Hocutt

Electric Fields and Pneumatic Guns -
Environmental and Chemical Sciences
J. O'Hara

Physical Barriers - FPL
W. Brannen

Discussion and Recommendation - FPL
J. R. Wilcox

A draft copy of the report was distributed to each participant and they were asked for their comments. We agreed that a draft copy also needs to be distributed to EPA, USFWS, and Florida Audubon Society for their review. Upon receipt of any comments, a final report will be prepared and formally submitted to the NRC (through the Nuclear Licensing Department).

The initial verbal comments from the agencies were all supportive of FPL's recommendation to continue netting turtles from the intake canal in lieu of behavioral or physical barriers for exclusion.

JRW

J. R. Wilcox

JRW:mw

Attachment

April 11, 1984

ATTENDEES

J. Ross Wilcox	FPL
Andreas Mager, Jr.	National Marine Fisheries Service
Charles W. Billups	NRC - (301)492-8118
Ross Witham	FDNR - (305)334-1667
Charles Hocutt	University of Maryland - (301)228-8200
David J. Herrema	Applied Biology, Inc. - (404)296-3900
R. Erik Martin	Applied Biology, Inc. - (305)334-3729
Ronald J. Stevens	FPL - Nuclear Licensing - (305)863-3620
William F. Brannen	FPL - Power Plant Engineering - (305)863-3241
James O'Hara	Environmental & Chemical Sciences - (803)652-2206
L. D. Slepow	FPL - (305)863-3028
H. D. Mantz	FPL - (305)863-3057
S. G. Brain	FPL - (305)863-3322

P O BOX 14000, JUNO BEACH, FL 33408
FPL
FLORIDA POWER & LIGHT COMPANY

April 18, 1984

Mr. David Smith
Endangered Species Coordinator
U.S. Fish and Wildlife Service
P.O. Box 2676
Vero Beach, FL 32960

Dear Dave:

As per a request of Dr. Charles Billups for the Nuclear Regulatory Commission, this document is being provided to you for your review and comment. Dr. Billups will be contacting you by telephone for any comments or suggestions regarding Florida Power & Light Company satisfying Section 4.2.2 of the St. Lucie Plant Environmental Protection Plan.

If you have any technical questions or need clarification, please feel free to contact me at 305/863-3623.

Sincerely,

Ross

J. Ross Wilcox, Ph.D.
Chief Ecologist

JRW:mw

Enclosure

cc: Dr. Charles Billups

P. O. BOX 14000, JUNO BEACH, FL 3340(

FLORIDA POWER & LIGHT COMPANY

April 18, 1984

Dr. Peter Pritchard
Florida Audubon Society
1101 Audubon Way
Maitland, FL 32751

Dear Peter:

As per a request of Dr. Charles Billups for the Nuclear Regulatory Commission, this document is being provided to you for your review and comment. Dr. Billups will be contacting you by telephone for any comments or suggestions regarding Florida Power & Light Company satisfying Section 4.2.2 of the St. Lucie Plant Environmental Protection Plan.

If you have any technical questions or need clarification, please feel free to contact me at 305/863-3623.

Sincerely,

Ross

J. Ross Wilcox, Ph.D.
Chief Ecologist

JRW:mw

Enclosure

cc: Dr. Charles Billups

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Region
9450 Koger Boulevard
St. Petersburg, FL 33702

April 12, 1984 F/SER23:AM:cf

TO: FILES

FROM: F/SER23 - Andreas Mager, Jr. AM

SUBJECT: Meeting with Florida Power and Light Company on the Environmental Protection Plan for the St. Lucie Nuclear Power Plant

The subject meeting convened at 9:30 a.m. on March 11, 1984, in Ft. Pierce, Florida (a list of attendees is attached). The purpose of the meeting was to review the results of various methods to prevent turtle entrapment at the St. Lucie Nuclear Power Plant (SLNPP).

Background

The SLNPP became operational in 1976, employing an ocean intake and discharge for cooling water. The intake consists of two 12-ft. diameter pipes. A third 16-ft. diameter pipe was placed in 1983. Soon after the plant became operational, it was learned that turtles were being trapped by the SLNPP intakes. Most turtles were loggerheads, but greens and leatherbacks also were taken. So far, only one Kemp's ridley and one hawksbill have been trapped.

The Section 7 consultation initiated in 1982 with the Nuclear Regulatory Commission as the lead federal agency provided for certain programs by FP&L to prevent turtles from entering the SLNPP intakes. Studies were outlined in the April 1983, Environmental Protection Plan, Appendix B (Section 4.22). On completion of the program, FP&L was to submit a final report to NRC, EPA, NMFS, and FWS for evaluation. The subject meeting was held to brief the involved agencies on the results of FP&L's studies in preparation for submittal of the final report.

Discussion

FP&L has studied a number of methods aimed at preventing turtles from entering the intake pipes as follows:

1. Lights and bubble curtains - This technique involved the use of lights including (strobes) and bubbles in connection with the lights in an attempt to scare turtles away from the intake pipes. It was learned that this technique, while very effective on fish, did not work well for turtles;

2. Electrical fields - AC and DC electrical fields of varying intensites were studied as deterrents. Marine turtles avoided both AC and DC electrical fields of sufficient intensity. However, to place an array on the intake structures would require 400-600 A and would be extremely difficult to maintain in a high energy

environment. In addition to high electrical energy requirements, significant safety problems exist since an unguarded electrial source would be in an area used by commercial and recreational fishermen. This technique was, therefore, not feasible at SLNPP;

3. Pneumatic air guns - Air guns used for seismic exploration were tested as deterrents based on the idea of using sound and vibrations to scare turtles. This technique worked very well, but also proved infeasible for use at the SLNPP. Expenses involved with obtaining a large compressor, laying lines through a surf zone, installing air guns, and maintenance and operation were prohibitive. To study this technique alone would have cost between $720,000 for a six month study and $1,053,000 for a year-long study. Also, the air guns are not reliable enough to allow continued operation for long time periods; and

4. Physical barriers - Engineering studies were conducted of various physical barriers around the velocity caps to prevent turtles from entering the intakes. Problems encountered were high corrosion rates, high fouling probabilities (trash and biological), and very high maintenance and installation costs - both units of the SLNPP would have to be shut down to install barriers costing in the millions of dollars. Also, there appears to be a significant safety problem with the barriers. Should fouling occur, there would be a reduction in water needed to cool the nuclear units. FP&L, therefore, believes that physical barriers are also not feasible.

Since no effective and/or feasible methods were found to deter turtles from entering the intake pipes, FP&L proposes to continue their existing program of capturing and releasing turtles from the intake canal of the SLNPP. This recommendation will be part of the final report that NMFS will receive for review and comment.

Recommendations

Since initiation of FP&L's capture and release program for turtles trapped in the intake canal, significant improvements have been made in the capture techniques. Turtle deaths due to trapping have been greatly reduced and improvements continue to be made.

Additionally, discussions with the SEFC reveal that the plant site provides unique research opportunities and information generated on turtles at SLNPP has greatly enhanced our knowledge of sea turtle biology. In this regard, Ross Witham (FLDNR) proposed that FP&L consider construction of a research facility at the project site.

FP&L, in connection with the SLNPP, has also initiated a number of educational programs and materials that enhance public awareness of sea turtle conservation. These educational programs have considerably aided sea turtle conservation.

In view of the above, I recommend that FP&L be allowed to continue with their current capture and release program as well as other sea turtle conser-

vation programs. FP&L has adequately demonstrated that technology does not currently exist to deter turtles from entering the SLNPP intakes in a cost-effective manner.

Attachment

cc:
F/SEC, Fred Berry
F/M412
F/SER2
Ross Witham, FLDNR

Memo to: Ross Wilcox
From: Peter C. H. Pritchard

November 2 1984

Comments on report entitled SEA TURTLE INTAKE ENTRAPMENT STUDIES

After reviewing the accounts of the type and condition of turtles caught in the canal system at the St. Lucie Plant, the procedures for releasing them to the ocean, and the results of the various experiments to deter turtles from entering the system, I share the conclusion that continued removal of entrapped turtles is an adequate response to the entrapment problem, and that if this is conducted conscientiously there should be no jeopardy to the populations of sea turtles on the Atlantic coast of Florida.

Beyond this, it might be added that it would be difficult for an experimenter to devise a more effective "random sampler" of the sea turtle populations in waters of the Central Atlantic coast of Florida, and the accidental entrapment holds the potential for generating much data of extraordinary interest on the relative numbers of each species in the area, the sex ratio, and the proportion of juvenile to mature turtles in the population. Virtually all other techniques of population sampling have obvious or subtle bias, resulting in selection for either certain species or certain life stages. Such techniques that have been used include pelagic surveys from aircraft (which select for larger individuals of species that spend relatively large amounts of time on the surface); nesting beach surveys, which obviously select for adult females only, and which fail to include adequate representation of species that may live or feed in Florida waters but which usually nest elsewhere; or trawler surveys, which may be somewhat more random that the previous two methods, but which preferentially catch the slower swimmers (i.e. Caretta), rarely catching fast turtles such as Chelonia or Dermochelys.

Review of the data in Appendix A already reveals some interesting findings. Thus, although visible populations of leatherback turtles (Dermochelys) are usually composed almost entirely of adults, immatures being regarded as rarely encountered, the specimens listed of this species include probably 50% immatures (if we regard those of carapace length of less than 125 cm as immature). Specimens of the green turtle (Chelonia mydas) include a large number of specimens in the 20-30 cm range of carapace lengths. The age of such turtles remains unknown -- recent observations suggest extremely slow growth rates for Chelonia in the 40-70 cm size range, when they have an herbivorous diet, but since turtles can be grown to this size within a year of hatching under captive conditions, they may represent yearlings. The complete absence of adult females in the sample, but the presence of three adult males, is of considerabl[e] interest, though interpretation of this finding would be largely speculative. The data on the immature turtles are sufficient to subject to statistical analysis to determine at what overall size sexual dimorphism, e.g. in tail length, and possibly also in relative shell dimensions, first becomes apparent.

The Caretta data, including a huge series of individuals, is particularly valuable. Again, the data could be subjected ~~to analysis~~ to statistical analysis to determine when and how sexual dimorphism first becomes apparent, though unfortunately these tables do not include tail length. Extant equations on allometric growth and appearance of sexual dimorphism in Caretta are generally unsatisfactory or based upon too few specimen[s] and the FPL data hold much potential for improvement of this situation.

The figures clearly show the absence of "small" loggerheads in Florida waters, and lend support to the theory that specimens between hatchling size and a carapace length of about 45 cm are particating in a circuit of the North Atlantic "gyre"; specimens in the missing size range are regularly caught in waters of the north-eastern Atlantic, including Spain, the Canary Islands, the Azores, and Madeira.

The largest specimens of Caretta recorded at St. Lucie appear to reach or exceed the maximum known size for the species. Such "giants" include NNC-415 (108cm male), HI-2151 (129 cm), and an untagged dead specimen with a 125 cm carapace. When such huge animals are found dead, they should be preserved if this is possible; if freshly dead they could be frozen and ultimately freeze-dried or otherwise prepared for exhibit; if rotten, they could be prepared as skeletons. At the minimum, accurate measurements should be taken of all loggerheads found that are over about 112 cm in straight line carapace length. I would also appreciate being advised by telephone when such animals are encountered.

As I discussed in my book Turtles of Venezuela, considerable interest attaches to formulae for relating head width of loggerheads to overall body size, and to also to quantify the reported greater relative head width of adult males. Some exceedingly flawed formulae have been perpetrated in print, and it would be valuable to have the data to set the record straight, especially for males, which of course are not encountered (except as occasional beach strandings) by turtle tagging crews. Routine measurement of maximum head width (across the "cheeks") of adult loggerheads of both sexes in addition to dimensions of carapace, plastron, and tail length, would allow these analyses to be undertaken, and it is highly desirable that this be undertaken. For animals being handled anyway, it would entail negligible extra work.