DELAWARE ESTUARY

MONITORING REPORT

Covering Monitoring Developments and

Data Collected or Reported during 1999 - 2003

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DELAWARE ESTUARY PROGRAM

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LIST OF ABBREVIATIONS AND ACRONYMS

ASMFC	Atlantic States Marine Fisheries Commission
AVS	Acid Volatile Sulfides
BCI	benthic condition index
CCMP	Comprehensive Conservation and Management Plan for the Delaware Estuary
C&D	Canal Chesapeake and Delaware Canal
CPUE	Catch per unit effort
CSOs	Combined Sewer Overflows
DELEP	Delaware Estuary Program
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorous
DO	dissolved oxygen
DNREC	Delaware Department of Resources and Environmental Control
DRBC	Delaware River Basin Commission
EEZ	Economic Exclusion Zone
EPA	U.S. Environmental Protection Agency
ERL	effects range low
ERM	effects range median
FDA	U.S. Food and Drug Administration
FMP	Fisheries Management Plan
gC/m^2yr	grams of carbon per square meter per year
GIS	geographic information system
HABs	harmful algal blooms
HMW	high molecular weight
km^2	square kilometer
LA	Load allocation (non-point source)
lbs	Pounds
m	Meter
MAIA	Mid Atlantic Integrated Assessment
m^2	square meter
mg/L	milligram per liter
mi	Mile
Mm	million metric
NCA	EPA's National Coastal Assessment Program
ng/g	nanograms per gram
NHEERL	National Health and Environmental Effects Research Laboratory
NJDEP	New Jersey Department of Environmental Protection
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
ISSC	Interstate Shellfish Sanitation Conference ISSC
PADEP	Pennsylvania Department of Environmental Protection
PAHs	polycyclic aromatic hydrocarbons
PBB	polybrominated biphenyls

PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyl congeners
POTW	publicly owned treatment works
ppm	parts per million
REMAP	Regional EMAP
RM	River Mile (Measured from the seaward extent towards upstream)
SAV	submerged aquatic vegetation
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SSB	spawning stock biomass
WWTPs	Wastewater treatment plants
t	metric tons
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
ug/l	microgram per liter
USACOE	U.S. Army Corps of Engineers
USFWS	USFWS U.S. Fish and Wildlife Service
USGS U.S.	Geological Survey
VOC	volatile organic compounds
WLA	Waste Load Allocation
VPA	virtual population analysis
YOY	young of the year

EXECUTIVE SUMMARY

The Delaware Estuary Monitoring Report summarizes data and monitoring program developments for the 1999-2003 calendar years. This report was prepared by the Delaware River Basin Commission (DRBC) Monitoring Coordinator under the direction of the DRBC Monitoring Advisory Committee. It fulfills a program element of the Comprehensive Conservation and Management Plan (CCMP) for the Delaware Estuary.

The Delaware Estuary is an interstate watershed that occupies over 6,700 square miles in three states: Delaware, New Jersey, and Pennsylvania. It extends 134 miles from the mouth of the Delaware Bay between Cape May, New Jersey, and Cape Henlopen, Delaware upstream through Wilmington, Camden, and Philadelphia to the falls of the Delaware River at Trenton, New Jersey. Its tributary watersheds drain urban, suburban, and rural communities. Many industrial areas affect in different ways the water quality and habitat in the Delaware Estuary.

The Delaware Estuary is a major transportation corridor and home of the world's largest freshwater port, the Philadelphia port complex, and the second largest oil port in the United States. The Delaware Bay also handles about 85% of the East Coast's oil imports and serves six major refineries. In 2002, ports along the Delaware River and its tributaries handled about 118 million tons of imports and 75.4 million tons of exports.

The hydrodynamics of the Estuary are influenced primarily by the inflow of freshwater, the pulsing circulation of oceanic currents, and the wind. Approximately 60% of the freshwater inflow arrives in the Estuary from the mainstem of the Delaware River at Trenton and another 10% flows in from the Schuylkill River. The remaining freshwater flowing to the Estuary comes from other Estuary tributaries and overland. Since riverine water flow is of major importance to the Estuary, the current report includes sections dealing with hydrological conditions and water use analysis. Much of the water withdrawn in the Estuary is used for cooling purposes in power generation.

There are three major ecological zones in the Estuary, distinguished by differences in salinity, turbidity, and biological productivity. The upper zone is characterized by freshwater under tidal influence and extends from Trenton downstream to Marcus Hook. The transition zone lies between Marcus Hook and Artificial Island; it has a wide range of salinity (from 0-15 parts per thousand) and is characterized by high turbidity and low primary biological productivity. The lower zone is open bay, extending to the Atlantic Ocean, and has higher salinity, large areas that are fairly shallow, and the highest levels of primary biological productivity.

Geophysical studies of estuary sediments by the University of Delaware show that much of the sediment influx is initially deposited in channel and shoal environments of the estuarine mainstem, where it undergoes numerous re-suspension-deposition cycles before becoming permanently sequestered in fringing salt marshes of Delaware and New Jersey. Based upon those studies most of the estuary consists of reworked sediments with distinct areas of deposition and non-deposition. There does appear to be a transition from a dominantly

coarse-grained (sand and gravel) in the upper estuary from Philadelphia north to fine-grain (clayey silt to silty clay) bottom type centered near the Delaware/Pennsylvania border. This suggests that much of the estuary is erosional in nature. Sediment characteristics and spatial distribution suggest a very dynamic system, whereby physical processes mix and remix sediments. Areas identified as depositional were in close proximity to non-depositional areas.

Commensurate with sediment mapping, core samples were taken from the open estuary and marsh areas to determine sedimentation rates. Sedimentation rates computed from the CS-137 profiles indicate accumulation rates of 0.3 to 1.5 cm/year. The results of this study were used to inform the hydrodynamic and sedimentation modeling efforts for use in the development of a TMDL for PCBs in the Delaware Estuary.

Dissolved oxygen data show dramatic improvements over the period at the Philadelphia area sampling stations, RM84 through RM111. The mean value at almost every sampling station remained above the average value of 4.5 mg/l at Philadelphia area stations. No significant sag occurred from the summer of 1998 through 2003. Dissolved oxygen levels during the monitoring period reversed a three-to-four-year decline that had slightly eroded prior gains. During the summer months, the seasonal decline in dissolved oxygen was minor, where two decades earlier it had been dramatic. Improvements in dissolved oxygen levels in the Camden-Philadelphia area have been substantial since the late 1970's.

Bacteria and nutrients showed generally positive trends being below criteria. Main channel bacteria counts remained within federal and DRBC standards for the length of the estuary for the fifteenth consecutive year. The 1998-2003 main channel (boat run) data for bacteria showed mean annual (March through November) levels below the federal primary contact recreation standards. In contrast with bacteria trends in the main channel, shoreline and tributary data for the years 1998-2003 show persistent exceedence of the federal criteria in the tributaries over the reporting period in the tidal portions of the Delaware River where recreational contact may be more frequent.

Nutrient loadings to the estuary in 1998-2003 continued to be elevated, but with a continued absence of eutrophic effects. Chlorophyll levels and nutrients in this report were consistent with NJDEP monitoring results for this time period. However, it is important to note that measurements taken at the channel are not necessarily representative of the entire estuary. Differences exist between the levels of parameters such as dissolved oxygen and nutrients between the channel locations where DRBC monitors and other portions of the bay. For example, based on NJDEP monitoring data, chlorophyll *a* levels at the channel average around 6 μg/L whereas non-channel stations average around 9 μg/L. Also, nitrate levels tend to be higher at channel stations than at non-channel stations. Overall variability of the data at the channel tends to be much less that at more inshore locations. This is especially true in the lower portion of the bay.

In Delaware Bay, areas considered safe for shellfishing decreased slightly. At the end of 2003, the State of New Jersey classified 235 acres within the Maurice River Cove from Approved to Seasonally Approved. There are a few areas in the bay where water quality

restrictions limit shellfish harvesting. Prohibited areas cover approximately 15.6 percent of the bay, or slightly fewer than 70,000 acres. They primarily occur north of the Smyrna River on the Delaware side and north of Artificial Island on the New Jersey side. Approved areas cover 377,579 acres.

There continues to be widespread fish advisories in the Delaware Estuary, predominantly from PCB contamination. The best available information currently indicates that point sources are the second-largest PCB loading source to the estuary. However, there are many significant sources not regulated by the NPDES program. It is evident that point source controls alone would not result in sufficient reductions to eliminate fish consumption advisories based on PCB contamination. Implementation of a broad-based effort to achieve PCB reductions from point and non-point sources will be necessary.

For the first time the Monitoring Matrix presented in Appendix 12.1 includes information on volunteer monitoring programs within the Delaware River Basin in addition to information regarding Federal and state agency monitoring programs.

Delaware oyster abundance ranged from 350 oysters per bushel to slightly less than 100, and recently these resources have shown a substantial drop to the low end of the range. Historically, in the Delaware Estuary, oysters were removed from the seed beds and planted on leased grounds farther down bay. The four year period of very low spat abundance from 2000 to 2003 has caused a significant loss of oyster resources in the higher salinity parts of the seed beds. If this trend continues it will yield a continued reduction in oyster abundance throughout the Delaware Estuary.

Regarding the horseshoe crab, researchers conclude that spawning activity in the Delaware Bay over the past 5 years has been either stable or declining at a rate of less than 8% per year. Spawning activity appears to be more stable in New Jersey than in Delaware. The restrictive measures introduced in the Delaware Bay region on harvesting, the implementation of the Carl N. Shuster Jr. Horseshoe Crab Reserve (CNSJrHSCR), and the utilization of bait bags seem to be benefiting the horseshoe crab population. However, the increase is not substantial enough to warrant any less restrictive measures in the management of the species.

The population of striped bass in the Delaware River has experienced a remarkable recovery within the last decade, largely attributable to improved water quality and strict fishery management measures. Over the past 5 years the striped bass harvest has stayed at approximately 2,500,000 to 3,500,000 fish. Recent estimates indicate the juvenile striped bass index for 2003 will be a record high value.

Based upon hydroacoustic methods, an estimated 300,000 American shad returned to the Delaware River to spawn in 2003 indicating a decline of approximately 40 percent from the 2002 population. The fluctuation in population over the report period likely reflects natural variation.

Over the report period the abundance level of weakfish has ranged from approximately 220 weakfish per nautical mile in 2001 to 100 in 2002 (the last year reported). Some of the fluctuation in abundance may be due to changes in fishing pressure.

1.0 HYDROLOGICAL CONDITIONS 1999-2003

1.1 Delaware River Basin Hydrology

The 1999 to 2003 period demonstrated that hydrology is a study of extremes. It included one of the most prolonged and intense drought periods since the record drought of the 1960's, and ended with 2003 producing the highest average annual flow on record for the Delaware River at Trenton, NJ.

Figure 1.1.1 presents the total monthly precipitation for January 1999 through December 2003. The totals are the average for the Delaware Basin above Trenton, NJ, reported by the National Weather Service's Mid-Atlantic River Forecast Center. Also shown is the normal monthly precipitation for each month for the period 1971-2000. With the exception of Hurricane Floyd in September 1999, the period from January 1999 to July 2002 was very dry. Precipitation deficiencies occurred in 24 of the 43 months and deficits exceeded one inch in 13 of the months. The period beginning in June of 2003 was extremely wet and produced record seasonal and annual average flows at Trenton, NJ

Figure 1.1.2 presents the accumulated precipitation deficit for the period June 1998 through December 2003, averaged above Trenton, NJ. The 1998 period is included because the lack of precipitation beginning in July of 1998 contributed to the extremely dry conditions, particularly in the Lower Delaware Basin, during the summer of 1999. The average deficit built to as high as 16 inches (approximately one third of the total annual precipitation) by March of 2002 and persisted until the heavy rains during the second half of 2003.

Figures 1.1.3 and 1.1.4 present the 7-day mean and 7-day median flows for the period 1971 through 2000 for the Delaware River at Trenton, NJ. These plots indicate total runoff, including ground water discharge or base flow, and provide a representative indicator for total estuary inflow. The plot of median 7-day flows shows that the most significant extended periods of below normal inflow to the estuary occurred from March to September of 1999 and from September 2001 to April of 2002. The extremely high flows beginning June 2003 are also illustrated on the plot.

Figure 1.1.5 presents the U.S. Geological Survey's Streamflow Conditions Index for the States of New Jersey, Delaware, and Pennsylvania since July 2, 1999. This index represents the daily average index value (a value based on the percent of time the observed flow rate is equaled or exceeded) for all gauging stations in the respective state. The Pennsylvania plot is less representative of Delaware Basin conditions due to the large geographic area of the state located outside of the basin. The New Jersey and Delaware plots are considered most representative of streamflow conditions in the Lower Delaware Basin, and clearly show two distinct periods of deficient streamflow – the summer of 1999 and the period from the early fall of 2001 to late

2002, with the dry period most prolonged in Delaware. The New Jersey and Delaware plots reflect local streamflow effects, and therefore show some differences in timing of the dry periods from the plots for the Delaware River at Trenton.

1.2 Estuary Salt Line Movement

Chloride concentrations in the Delaware River play an important role in the Delaware River Basin Commission's (DRBC) water quality and drought policies. Chloride concentrations have been monitored since the 1960s and in recent years, have been monitored daily using data collected from several automatic monitoring stations along the Delaware River. The DRBC monitors the location of the 7-day average 250 parts per million chloride concentration or "salt line." The location of the salt line is important because DRBC's drought plan focuses on controlling the upstream migration of salty water from the Delaware Bay during low-flow conditions in the basin's rivers and streams. As brackish water moves upstream, it may lead to higher water treatment costs for water suppliers and may also lead to higher corrosion control costs for industries along the river.

1.2.1 Sources of Chloride Data

The DRBC uses daily mean specific conductance data as well as direct chloride measurements from several different sources to determine the location of the salt line. The United States Geological Survey (USGS) is a major provider of daily specific conductance data. Specific conductance data are collected from the Delaware River by four water quality monitors located at Reedy Island, Delaware, Chester, Pennsylvania, Fort Mifflin, Pennsylvania, and the Ben Franklin Bridge, Pennsylvania. After the data are collected, daily mean specific conductance in micromhos units are converted to chloride measurements in parts per million (ppm).

Another source of chloride data used by the DRBC is the Kimberly-Clark Corporation (KCC). Technicians measure chloride concentrations in the Delaware River near the KCC facility in Chester, Pennsylvania (RM 83). Samples are collected at each high and low tide for a total of four samples a day. The daily minimum, maximum, and average chloride measurements are reported to DRBC via e-mail at least twice a week.

1.2.2 Determination of the Salt Line Location

For most of the year, the location of the salt line is determined using the data supplied by the Kimberly-Clark Corporation and the USGS Reedy Island water quality monitor. The location of the salt line is estimated by interpolating between the seven day average chloride concentrations at each station. During dry periods, when low stream flow causes chloride concentrations to increase and the salt line to migrate further upstream, other stations are used for the interpolation process. For example, once the salt line moves above RM 83, data from the USGS water quality

monitors at Chester (RM 83) and Ft. Mifflin (RM 92) are used to determine the salt line's location. If the salt line migrates to above the Ft. Mifflin monitoring station, data from the USGS monitor at the Ben Franklin Bridge (RM 100) are used along with the data from the Ft. Mifflin monitor to determine the salt line's location.

1.2.3 Salt line Movement: 1999-2003

Chloride concentrations in the Delaware River vary widely during the course of a year. During wetter times of the year, such as late winter and early spring, the salt line is normally located further downstream in the river. This is due to the higher streamflows in the river that dilute the chloride concentrations. During drier periods of the year, such as the summer and early fall when water use demands and evaporation rates are higher and freshwater inflow into the river is reduced, chloride concentrations will increase and the salt line migrates further upstream.

Dry periods can be a concern with regard to salinity intrusion into drinking water supplies. During such times, saline water threatens to intrude on Philadelphia's drinking water intake at the Delaware River at Torresdale. During periods of low streamflow, releases may be directed by the DRBC from Blue Marsh and Beltzville reservoirs in the lower basin. These releases augment streamflow along the Delaware River, providing additional freshwater to dilute chlorides and maintain the salt line below the mouth of the Schuylkill River (RM 92).

The five years between 1999 and 2003 contained a mix of wet periods (2000 and 2003) and dry periods (1999 and 2001-02). During this time, the salt line ranged from below RM 54 (the furthest downstream location the DRBC measures) to as high as RM 89. During the wettest years, the 250-ppm chloride concentration stayed at or below the normal mid-month locations for most of the year. For example, during 2003, annual rainfall surpluses of more than 20 inches in some parts of the Delaware Basin kept streamflows above normal for much of the year. As a result, chlorides in the river were kept so diluted that the salt line location was consistently below the normal location (sometimes by as much as 30 miles) from June through December.

Drought plagued the basin twice in the years between 1999 and 2003. The first time was during the summer of 1999 and the second time was for a longer stretch from summer 2001 through autumn 2002. During both of these droughts, the effects of below normal precipitation and the resulting low surface runoff and base flow was mirrored in the salt line's movements. In August 1999, the salt line crept to RM 89, which is near the location of the Philadelphia International Airport. Fortunately, Hurricane Floyd blew through the basin less than one month later raising streamflows to levels that swiftly pushed the salt line back to below the normal level for that time of year. During the second drought of the five year period, the salt line reached RM 89 by late September 2001. Relief arrived shortly after in the form of heavy rainfall that pushed the salt line back toward the Delaware Bay.

Figure 1.2-1 shows the Location of the 7-Day Average of the 250-ppm Isochlor for a graphical representation of the salt line movement over the period 1999-2003. **Figure 1.2-2** presents a map depicting the locations of the water quality monitoring stations used to

monitor the salt line and shows the furthest upstream Location of the 7-Day Average of the 250-ppm Isochlor over the report period.

1.3 Water Use in the Estuary

Withdrawals and consumptive uses have been analyzed for the Estuary as a whole and also on a sub-basin basis. **Figure 1.3-1** presents the change in population between 1990 and 2000.

In 1996, water withdrawals in the Estuary watershed accounted for approximately 83% of total withdrawals in the Delaware River Basin. Water use by sector is shown for both total withdrawals and consumptive use in **Figures 1.3-2 a-f** and **Figures 1.3-3 a-f** respectively. Although data are presented for 1996, this broad assessment of water use is the most recent available and assumed valid for the monitoring period 1999 through 2003. While it is useful to consider relative water withdrawals, it is often more informative to examine consumptive uses.

The significance of consumptive use is that it measures how much of the withdrawal volume is not directly returned to the hydrologic system for downstream users, or to meet instream flow needs.

<u>Schuylkill Valley</u>:
Public water supply and thermopower generation each account for around 40% of withdrawals and consumptive use. Mining and industrial withdrawals each make up half of the remainder. Consumptive use is also largely attributed to public water supply and power generation in this sub-basin, which combined account for 75% of total consumptive losses.

<u>Upper Estuary:</u>
Withdrawals in the Upper Estuary are dominated by the power sector, accounting for 75% of the total. However, power facilities in this region are not highly consumptive in nature and therefore that sector represents only 15% of total consumptive use, similar to the industrial sector. Public water supply accounts for over 50% of the consumptive use in 1996.

<u>Lower Estuary:</u>
Withdrawals in the Lower Estuary are dominated by the power sector, accounting for over 85% of the total. There are very few public water supply withdrawals in this sub-basin; none on the mainstem of the river. Power generating facilities located in this sub-basin are more consumptive and account for more than 65% of total consumptive use. Industry, agriculture and public water supply each account for approximately a third of the remainder.

<u>Delaware Bay:</u>
The Delaware Bay is the only Estuary sub-basin that does not have power generation facilities. Here, the dominant uses are for public water supply, mining, and agriculture – the latter accounting for over 50% of consumptive use in the sub-basin.

Estuary:

In summary, much of the water withdrawn in the Estuary is used for power generation. The Estuary is home to the majority of power generating facilities in the Delaware River Basin which all withdraw large quantities of surface water. Over 92% of withdrawals by thermo-electric power generating facilities (those that have some consumptive use component) are located in the Estuary, mainly in the Lower and Upper Estuary sub-basins. However, in terms of consumptive use, the power sector (at 34% of total consumptive use) is only slightly larger than public water supply (32%). Industrial, agricultural, and mining operations, in that order, account for the majority of the remainder. The relative proportions of water withdrawn and consumed in the Estuary closely reflect those of the Delaware River Basin as a whole.

2.0 DATA COLLECTION AND INTER-AGENCY COORDINATION

2.1 DRBC Boat Run Program Developments

The DRBC's boat run program, begun in the late 1960s, collects water quality data from the center channel of the main stem Delaware River and Delaware Bay. Twenty-two stations were sampled twelve times per year from March - October during the report period. These stations extended from RM 127.5, a short distance south of Trenton, New Jersey, to South Brown Shoal in Delaware Bay at RM 6.5, near the bay mouth. The stations are plotted on an estuary map in **Figure 2.1-1** and listed by RM and geographic coordinates. T**able 2.1-1** identifies the parameters for which data are collected at each station. Data categories include routine pollutants: bacteria and radioactivity; heavy metals; algae and organic carbon; and oxygen demand. Additional surveys for other pollutants are performed on an as - needed basis.

2.2 National Coastal Assessment Program

The National Coastal Assessment (NCA) program developed by USEPA was developed to establish a baseline of environmental conditions for the estuaries of the coastal states as part of a national survey of estuarine condition, and trace changes in that condition through time. The intent is to create a base of data/information that supports assessments at national, regional, and state levels.

The goal of the program is to assess the ecological condition of estuarine resources at multiple scales for the entire country to determine reference conditions for ecological responses/stressors and to build the infrastructure in EPA Regions and in states in order to ensure continued monitoring and assessment.

The program utilizes a probabilistic monitoring design to evaluate reference conditions for estuaries in the United States. This probabilistic design was developed by USEPA using ecological response indicators, along with diagnostic indicators. The strata were developed using biogeographical provinces. For the northeastern US, these are the Acadian & Virginian provinces (the sub-strata in Delaware Bay includes the coastal states). Proportional sampling includes all types of estuaries which are classified by size.

The NCA program has set up cooperative agreements with the states. The state matches program contributions with in-kind services. The strategy is to partner with state resource agencies for design of the monitoring program, collection and processing of samples. This will help to develop state and regional infrastructure and develop state and regional capacity. The NCA Target Species include the following; Channel Catfish, White Catfish, Scup, Summer Flounder, Weakfish, White Perch, Winter Flounder, and Blue Claw Crab. The current sampling stations from which data are collected under this program over the period 2000-2003 are presented in **Figure 2.2-1.** Organisms were collected from trawls within the Delaware Bay and tidal tributaries. A complete list of the fishes collected in 2000-2002 is presented in **Table 2.2-2**. A list of the 564 benthic infauna species collected from sediment samples during the 2000 season is provided in **Appendix 12-2.**

Only the 2000 data were available at the time of this report. A summary report of the findings of the NCA program for the Northeast is presented in EPA (2004). That report presented only the data for the 2000 sampling year for one sampling event at 35 stations in the Delaware Estuary regarding water quality, coastal wetlands, sediment condition, benthic condition and fish contaminants collected under the program.

2.2.1 Fish Tissue Analyses collected for the DRBC during the USEPA National Coastal Assessment Program

Beginning in the 1980's, a number of studies of contaminant levels in resident and anadromous fish species, invertebrates such as the blue crab, and shellfish have been conducted by federal, state and interstate organizations (see, e.g., DRBC, 1988; Greene and Miller, 1994; Hauge *et al.*, 1990; U.S. F&WS, 1991 and 1992). These studies were expanded in scope and frequency after 1989 when the states bordering the Delaware River began to issue advisories banning or limiting the consumption of certain species. With funding from DELEP, the DRBC and DNREC prepared a report that summarized the data on contaminants in biota and described the current approaches used by the states in developing their fish consumption advisories. **(http://www.state.nj.us/drbc/fishtiss.htm).** A list of the organisms collected and analyzed under this DRBC activity during 2000-2002 is presented in **Table 2.2-3**

The DRBC worked with the NCA chemistry laboratory, Arthur D. Little, (ADL) to “merge” its program requirements for additional analytes and the analysis of edible tissue into the existing analytical framework. With moderate matching funds, DRBC arranged for ADL to analyze fish fillet and Blue Crab samples collected in Delaware Bay for additional PCB congeners using DRBC protocols, beyond the NOAA 18 standard congeners analyzed in the NCA Program. In cooperation with the USEPA Program management, DRBC selected fish samples to be filleted**.** The fillets and offal were analyzed separately for NCA parameters as well as the additional congeners needed by DRBC for fillet samples. ADL reported results for the fillet samples to DRBC, which will be using these data to determine congeners of concern in the Delaware Bay System and for trend analysis. The laboratory summed fillet and offal data by weight percent to provide NCA with whole body results consistent with the national program requirements. During 2000, 45 additional samples of Blue Claw Crab, White perch, Channel Catfish and Weakfish representing 321 organisms were collected and analyzed for use by DRBC. A list of the samples analyzed are presented in **Table 2.2-3**. By working with the USEPA, The National Laboratory Contractor, and the NCA Program, the DRBC was able to expand the analysis of fish samples beyond that mandated by NCA to meet its program needs. During the 2000-2003 period, a number of fish species were collected in this program. The numerical abundance of the major species collected is presented in **Figure 2.2-2.** This figure shows that the collection was dominated by spot, striped bass, and weakfish.

2.3 Data Analysis of the MAIA Program

Data collected during the Mid Atlantic Integrated Assessment Program (MAIA) in 1997 continue to be evaluated by the NOAA members of the Coastal Monitoring Bio-Affects

Division (CMBAD). Aquatic sediment samples of macroinvertebrates collected during the 1997 survey were sorted and identified. Evaluations of this data by NOAA have identified over 18,000 organisms representing 233 taxa collected during the effort in the Delaware Estuary. Based upon the presence of unique taxa, nodal analysis performed by Dr. Ian Hartwell of NOAA (personal communication) suggests that seven habitat types exist within the estuary based upon the salinity regime and sediment grain size. **Figure 2.3-1** presents these habitat types. **Figure 2.3-2** presents a nodal analysis of the species identified. Based upon this nodal analysis, **Figure 2.3-3 and 2.3-4** presents seven species associations which are grouped based upon the physical associations in the Delaware Estuary (Personal communication Dr. Ian Hartwell). These include the following categories:

- Freshwater mud
- Freshwater sand/mix
- Freshwater/saltwater transition zone
- Upper Estuary depositional estuary
- Deep Estuary
- Ocean Tributary
- Atypical area identified as site 64 (this category was not grouped within any other cluster)

2.4 Sedimentology and Geophysical Studies of the Estuary

The Delaware Estuary experiences a number of environmental and engineering problems related to sedimentation, most conspicuously, chronic infilling of navigable channels and burial of particle-borne contaminants. In this regard, the Delaware is akin to many urbanized estuaries worldwide. The industrialized corridor between Philadelphia and Wilmington happens to be situated in the estuarine turbidity maximum (ETM) zone, an innate feature in river estuaries created by a combination of sediment dynamics and flow patterns. Accordingly, natural processes contribute to the ubiquitous shoaling and contaminant dispersal problems in the upper estuary (Delaware River Basin Commission, 1998A). Despite a substantial outlay to mitigate these problems, a fundamental understanding of mechanisms that govern sediment movement and storage has been elusive. An average 1.4 million metric tons of suspended sediment is delivered annually to the Delaware Estuary from mainstem and tributary river sources (Mansue and Commings, 1974). About 56% of this load is supplied by the Delaware River upriver of Trenton, 20% from the Schuylkill River, 9% from the Christina River, with the remainder derived from numerous Piedmont and Coastal Plain tributaries. During a typical year, as much as 50% of the annual load is supplied during the months of March and April, when rainstorms and snowmelt elevate streamflow. Much of the sediment influx is initially deposited in channel and shoal environments of the estuarine mainstem, where it undergoes enumerable re-suspension-deposition cycles before becoming permanently sequestered in fringing salt marshes of the Delaware and New Jersey shoreline. Most of the sediment in suspension resides in the ETM zone, typically centered between Philadelphia and Artificial Island. Research elsewhere has shown that ETM suspended sediments are sourced from tidal resuspension, whereas the locus and maintenance of the ETM may be caused by processes including flocculation, gravitational circulation, tidal pumping, and stratification, either collectively or mutually

exclusive of one another (Jay and Musiak, 1994; Sanford et al., 2001).

A sedimentological and geophysical survey of the upper Delaware Estuary was conducted during 2001–2002 by the University of Delaware (UDel) in cooperation with the Delaware River Basin Commission (DRBC). The estuary between Burlington, New Jersey south to the Smyrna River, Delaware was identified for study. The study objectives were to:

- Perform a systematic, high-resolution characterization of the bottom based on sonar mapping data, sediment sampling and analysis, and a regular classification scheme.
- Quantify sedimentation rates at selected sites within the estuary and fringing tidal marshes using core samples.

The study provided a map of bottom sediment types in the tidal river and estuary and an estimate of sedimentation rates at selected sites in the estuary and tidal marshes. Furthermore, it provides a conceptual framework of the sedimentological regime in the upper estuary. Sediment characteristics and spatial distribution suggest a very dynamic system whereby physical processes mix and remix sediments. Areas identified as depositional were in close proximity to non-depositional areas. **Results of this study were used to inform the hydrodynamic and sedimentation modeling efforts for use in the development of a Total Daily Maximum Load (TMDL) for PCBs in the Delaware Estuary**.

<u>Sediment Survey</u>
Acoustic mapping techniques were used to construct images of the estuary bottom. Sidescan, chirp sonar, and single beam echosounding were used to assess the lateral distribution of morphology, thickness, and continuity of sedimentary strata and bedrock and bottom depths, respectively. Approximately 250 sediment samples were collected to ground truth the sonar data and to provide grain size and porosity measurements. Approximately 350 miles of sonar data were collected and a continuous record was obtained in the study area for water depths exceeding five meters. Geographic position was determined using a Differential Global Positioning System which interfaced with the three sonars. Positional data were considered accurate to within +- 5 meters. Essentially, four distinct types of sediment were identified in the study area:

- Reworked bottom (consisting of fine, mixed and coarse grained sediment)
- Coarse grained bedload bottom
- Non-depositional or erosional bottom
- Fine-grained deposition

The most commonly observed bottom sediment type was reworked sediments, encompassing approximately 75% of all sediment types in the study area. A spatial distribution of the sediment types is presented in **Figure 2.4-1**. Additional features, such as bedload forms, core profiles and depositional profiles, are presented in **Figure 2.4-2.** Bedload features identified in the upper estuary further enhance the interpretation that the Delaware Estuary is a very dynamic system. However, another significant finding is that fine-grained depositional areas also occur in the estuary, primarily in the Marcus Hook through the New Castle area. This finding is consistent with dredging records for the same reaches which indicated that less

than 60% of all the sediment dredged in the shipping channel of the Delaware River is dredged from Marcus Hook through the New Castle reach.

Sedimentation Rates

Undisturbed sediment cores for chronological studies were collected using a hydraulically damped corer and push cores. An estimation of the sedimentation rates in the tidal portion of the river below Philadelphia is presented in **Figure 2.4-2**. Sediment accumulation rates were estimated from down core profiles of the artificial radionuclide Cs-137 (t1/2=30 years), a product of nuclear fission. Cesium-137 fallout was first detected in the environment around 1954, and peaked in 1963–1964, and thereafter dropped to insignificant levels by 1980. Therefore, the concentration and distribution of Cs-137 in the sediment column may be used to estimate net accumulation rate averages over the past several decade. Additionally, sedimentation rates were also calculated from another radioactive isotope BE-7 (t1/2=53 days), thus providing depositional information on a seasonal time frame. Results of the sedimentation study indicates that the Cs-137 profile was absent in the open estuary. This suggests that the rates of fine-sediment accumulation in the open estuary are too low, or the bottom too disturbed, for the Cs-137 method to provide reliable chronologies. This result is consistent with sonar observations of a physically reworked bottom. However, samples collected in the marsh areas yield usable Cs-137 concentrations and in particular the core collected at Woodbury displayed the ideal profile, presented in **Figure 2.4-3. Sedimentation rates computed from the CS-137 profiles indicate accumulation rates of 0.3 to 1.5 cm/year.** The PCB concentration in the core collected at Woodbury showed levels of PCBs at the highest concentrations at depths of 40-50 centimeters. Dating of those levels suggest that they were deposited over the period 1963-1974.

Analysis of Be-7 radioisotopes in cores collected in depositional areas suggests a seasonal depositional history in the estuary. Essentially, Be-7 can be detected for a period of approximately five months. Therefore, when detectable concentrations of Be-7 are observed, this indicates that the depositional flux exceeds the rate of loss through decay or physical redistribution. Depositional rates in some cores were on the order of centimeters per month.

The overall framework of sediments in the tidal Delaware estuary range from mud to gravel and are extremely spatially variable. While most of the estuary consists of reworked sediments from natural processes, there are distinct areas of deposition and non-deposition. There does, however, appear to be a transition from a dominantly coarse-grained (sand and gravel) in the upper estuary from Philadelphia north to fine-grain (clayey silt to salty clay) bottom type falls centered on the Delaware-Pennsylvania border. Furthermore, it appears that sedimentation rates in the tidal marshes are more continuous than within the adjacent open estuary.

3.0 WATER QUALITY

The estuary is classified not only as a drowned river valley, but also as a partially mixed and moderately stratified estuary. The salinity of surface waters increases from near zero at Chester, Pennsylvania, to about 30 parts per thousand at the mouth of the estuary. Normally, the estuary is well mixed by strong tidal currents. Suspended sediments in the Delaware Estuary range in size from sand grains to clay particles to colloidal materials. They are predominantly derived from shore and land erosion, and are carried into the estuary by rivers.

3.1 Dissolved Oxygen

The DRBC boat run sampling data indicate that mean seasonal (March-November) dissolved oxygen levels in the main channel were at or near the DRBC water quality criteria for the entire length of the estuary. DRBC criteria are as follows: a 24-hour average of 5.0 mg/l for Zone 2 and 3.5 mg/l for Zones 3, 4 and 5; a minimum of 5.0 mg/l at all times in Zone 6 unless diminished by natural conditions; and a seasonal average (April 1 through June 15 and September 16 through December 3) of not less than 6.5 mg/l for Zones 2, 3, 4, and 5. Notably, mean levels over the report period for the entire boat run stations improved over levels of years prior to 1998. See **Figure 3.1-1** for the location of DRBC zone boundaries.

Plots of average dissolved oxygen concentrations in summertime over the period 1967-2003 periods for each of the boat run stations are provided in **Figures 3.1-2**. The data show dramatic improvements over the period at the Philadelphia area sampling stations, RM 84 through RM111 since 1980.

Notwithstanding the improvement in annual mean dissolved oxygen levels over the length of the estuary by 2003, the mean value at almost every sampling station remained appreciably above average values of 4.5 mg/l at or above at Philadelphia area stations.

Consistent improvement in dissolved oxygen levels during summertime (June through September) conditions of highest average temperature and low freshwater flow were reported recently in other publications (Santoro and Sharp, 1999 and Collier *et al.,* 1999). These reports show steady improvement in summertime levels for the years 1971, 1977, 1987, 1994, and 1998 through 2003. As **Figure 3.1-2** illustrates, during the summer months of 1967 and 1980 serious oxygen sag extended twenty miles, from approximately RM 75 to RM 95. **In contrast, no significant sag occurred during the summers of 1998 through 2003.**

Some monitoring stations in the Delaware Bay, sampled by the states of Delaware and New Jersey, are routinely used along with DRBC Boat Run data for assessment purposes. These data have shown some excursions of dissolved oxygen below DRBC criteria for Zone 6. On the Delaware side of the Bay, three stations (out of six that provide dissolved oxygen data) each exhibited greater than 10% of samples with dissolved oxygen levels less than 5.0 mg/l between 2000 and 2002. The stations which are located in near-shore areas at the mouths of tributaries may reflect water quality impacts from those tributaries. However, this warrants further investigation. On the New Jersey side of the Bay, also between 2000 and 2002, 13 locations (out of 41 that provided dissolved oxygen data) exhibited greater than ten percent

of samples with oxygen levels less than 5.0 mg/l.

3.2 Bacteria

Previous data reported by Santoro (2000) for the period prior to 1999 showed a decline in bacteria levels in the main channel of the Delaware River between Trenton and Wilmington. Recent data support this trend. Shoreline and tributary data supplied by DRBC, DNREC, the New Jersey Department of Environmental Protection (NJDEP) and the Pennsylvania Department of Environmental Protection (PADEP) for the years 1998-2003 are compiled and plotted together with the main channel boat run data (see **Figure 3.2-1**). The plot illustrates that although **water in the main channel does not exceed the federal primary contact recreation standards for bacteria, frequent exceedence of the standards persists in tributaries and in shallow areas near the shore, where recreational contact is more frequent.**

The 1998-2003 main channel (boat run) data for bacteria showed mean annual (March through November) levels below the federal primary contact recreation standards. That is, mean main channel data were within the maximum geometric average of 200 colonies per 100 milliliters (200 colonies/100 ml) for fecal coliform, and 35 colonies/100 ml for enterococcus in marine waters and 33 colonies/100 ml for freshwaters. Main channel samples thus met the identical or more lenient DRBC standards, which vary by river zone: for fecal coliform, 200 colonies/100 ml in Zones 2 and 6, and below RM 81.8 in Zone 4; 770 colonies/100 ml in Zone 3 and above RM 81.8 in Zone 4; and for enterococcus, 33 colonies per 100 ml in Zone 2 and below RM 81.8 in Zone 4; 88 colonies/100 ml in Zone 3 and above RM 81.8 in Zone 4; and 35 colonies/100 ml in Zones 5 and 6. **In contrast with bacteria trends in the main channel, shoreline and tributary data for the years 1998-2003 show persistent exceedence of the federal criteria in the tributaries over the reporting period** (see **Figure 3.2-1**).

3.3 Shellfish Closure Areas

The states of Delaware and New Jersey have aggressively regulated the harvest of shellfish in the estuary for many years, in order to protect consumers from diseases caused by water-borne pathogens. Both states participate in the Interstate Shellfish Sanitation Conference (ISSC), a cooperative alliance between the states, the United States Food and Drug Administration, and the shellfish industry, under which shellfish harvesting is prohibited in all areas not expressly approved by the states for harvest. In addition to ensuring clean shellfish growing waters, the ISSC provides for safe handling, processing, packaging, and distribution of the shellfish harvest.

Coastal states classify shellfish growing waters according to ISSC guidelines, based on water quality and shoreline surveys of pollution sources. Areas are classified as *approved for harvest* or assigned one of several *harvest-limited* categories.

The harvest-limited categories for Delaware Bay include:

- Prohibited
- Seasonally Restricted
- Special Restricted

In approved areas, shellfish harvesting is unconditionally permitted year-round. Prohibited areas consist of areas that have been placed off-limits to shellfish harvesting due to a combination of sanitary survey data that indicate actual or potential pollution problems, and/or due to bacteria monitoring. States may use either the total or fecal coliform standard. Delaware uses the ISSC- approved total coliform standards, which are a geometric mean of 70 cells/100 ml for the most recent 30 samples collected per station; and no more than 10 % may exceed 330 MPN cells /100 ml. using a 3-tube dilution test. New Jersey also uses the ISSC approved total coliform standard as well as the ISSC-approved fecal coliform standards which are a geometric mean of 14 cells/100 ml for the most recent 30 samples collected per station; and no more than 10 % of the samples collected may exceed 49 MPN cell/100 ml using a 3 tube decimal dilution test. Delaware uses only the approved and prohibited designations.

New Jersey limits shellfish harvesting in seasonally restricted areas to the months of November through April or January through April. Shellfish harvested in New Jersey waters from either seasonally restricted or defined areas must be relayed to clean waters or to depuration facilities for a designated period of time to reduce their levels of bacteria and viruses before they are processed for human consumption.

Although the large majority of acres are classified based on water quality, prohibited areas include some acreage not tested because it is not fished, and seasonal restricted and special restricted areas include some acreage that is harvest-limited because of competing uses, such as recreation. However, these exceptions to water-quality-based classification are deemed small enough in the Delaware Estuary, that changes in approved and prohibited acreage over time remain a good indicator of water quality trends.

A map of shellfish classification areas in Delaware Bay south of the Pennsylvania-Delaware border is found in **Figure 3.3-1**. **There are few areas in the bay where water quality restrictions limit shellfish harvesting. Prohibited areas cover approximately 15.6 percent of the bay, or slightly fewer than 70,000 acres.** They primarily occur north of the Smyrna River on the Delaware side and north of Artificial Island on the New Jersey side. **Approved areas cover 377,579 acres.**

Figure 3.3-2 shows a graph of approved and prohibited acreage for the years 1990 to 2003. The 377,579 acres of the bay unconditionally approved for harvest in 1998 represented an increase of 2.4 percent, or 8,828 acres, over the corresponding area in 1990.

In Delaware Bay a slight decrease in the areas classified as approved for shellfishing occurred. At the end of 2003 the State of New Jersey modified 235 acres within the Maurice

River Cove from Approved to Seasonally Approved. This delineates those waters as approved for harvest of shellfish for part of the year and as Special Restricted for the remainder of the year. The approved period is from November 1 through the following April 30 of each year.

3.4 Nutrients

The Delaware Bay receives heavy inputs of nutrients primarily from atmospheric, urban and industrial sources. **The mainstem waters flowing between Burlington, New Jersey, and Wilmington, Delaware, have the highest concentrations of nitrogen of any major estuary in the United States. Approximately 50% of the inorganic nitrogen that enters the Delaware Estuary comes from atmospheric input, and it has been estimated that 80% of the phosphate entering the estuary results from human activity**. The Delaware Estuary has been historically very turbid (i.e., light limited). However, historically the Delaware River and Bay have not experienced the typical signs of eutrophication i.e.; fish kills, algal blooms, water discoloration or other effect. The turbidity maximum varies depending upon river inflow but typically occurs near Reedy Island, Delaware. The flushing time (the time a water molecule takes to move out of the system) in the system is typically 90 – 120 days. From the 1960's to the late 1980's large increases in dissolved oxygen and a large reduction in phosphorus had occurred. Over that period there has been little or no change in suspended solids and total nitrogen levels. Currently, the minimum oxygen levels are well above 4.5 mg/l. The DRBC boat run program measures nutrient concentrations and algal biomass, which are useful to determine the river's trophic status. Nutrients, especially phosphorous in fresh waters, are a link to increased algal biomass, although physical constraints, such as light, temperature, and current, can determine the potential for nutrient utilization by algae and aquatic plants. Chlorophyll-a, a green pigment used by algae and green plants during photosynthesis to convert light, carbon dioxide, and water to sugar, is commonly used as an index of algal biomass. Phaeophytin is a degradation product of chlorophyll-a. Thus, the relative distribution of chlorophyll-a and phaeophytin may be used to assess the growth of a phytoplankton community.

Santoro (2000) documented a dramatic increase in nutrient loading to the Delaware Estuary since the early 1900's, associated with dramatic population growth during the first half of the century. That report also noted that high nutrient concentrations have not had significant eutrophic effects in the estuary. As a benchmark for nutrient levels in the Delaware Estuary, it is helpful to look at corresponding levels in the Chesapeake Bay, where eutrophication has been a major concern triggering regulatory action. C.F. Cerco and T. Cole, who developed a three-dimensional eutrophication model for the Chesapeake, observed chlorophyll-a values between 10 and 25 mg/l nitrate, nitrite values between 0.0 and 0.75 mg/l and total phosphorous values between 3.5 to 16 mg/l (Cerco & Cole, 1993). In the Delaware Estuary, the mean chlorophyll-a value is similar, as are mean nitrite values. Mean nitrate values, with exceptions at the top and bottom of the estuary, are somewhat higher than in the Chesapeake Bay; and total phosphorous values are considerably lower, ranging from 0.00 to 0.97 mg/l. Again, no eutrophic effects are noted anywhere in the Delaware Estuary.

3.4.1 Range of Nutrient and Pigment Values

Nitrogen (NO3): The highest mean values in the lower Delaware River for nitrate-nitrogen are located around the New Castle and Cherry Island stations, with the lowest values located at either ends of the area, at the Mahon River and Fieldsboro stations. Average values are less than 0.2 mg/l. Minimum values are at 0.001 mg/l. Maximum levels are highest down in the bay at 1.9 mg/l **(see Figure 3.4-1)**.

Nitrite (NO2): The maximum value is 3.2 mg/l. at the Paulsboro, NJ station. Average values range between 0.1 and 2.0 mg/l **(See Figure 3.4-2)** and are highest between New Castle, DE and the Navy Yard.

Ammonia Nitrogen NH3+NH4-N: A maximum value of 0.3 mg/l was found at the Burlington Bristol Bridge Station **(See Figure 3.4-3)**. The mean values are between 0.05 and 0.15 mg/l. The larger mean values seem occur around the upper portion of the estuary north of the Burlington Bristol Bridge.

Total Phosphorous: Average levels of total P in the estuary are all less than 0.2 mg/l **(Figure 3-4.4)**. Maximum values range between 0.5 and 1.62 mg/l.

Orthophosphate: Average values of orthophosphate fall between 0.02 and 0.1 mg/l. Maximum values occurred in the upper portions of the bay (0.15 and 0.48 mg/l) **(see Figure 3.4-5).**

Chlorophyll a and Phaeophytin: The levels for these two photosynthetic pigments are presented in **Figures 3.4-6 and 3.4-7.** Chlorophyll levels and nutrients reported here were consistent with NJDEP monitoring results for this time period and the locations monitored by DRBC. However, it is important to note that measurements taken at the channel are not necessarily representative of the entire estuary. Differences exist between the levels of parameters such as dissolved oxygen and nutrients between the channel locations where DRBC monitors and other portions of the bay. For example, based on NJDEP monitoring data, chlorophyll *a* levels at the channel average around 6 μg/L whereas non-channel stations average around 9 μg/L. Also, nitrate levels tend to be higher at channel stations than at non-channel stations. Overall variability of the data at the channel tends to be much less that at more inshore locations. This is especially true in the lower portion of the bay (personal communication - Robert Connell, NJDEP).

3.4.2 Depth Related Effects on Nutrient Levels

Depth related data for nutrients during the report period was collected in 1997 during the MAIA program and in 2000 through 2003 during the NCA Program. These data were collected once at each of the 92 stations in the Delaware Estuary in 1997 and at 35 stations at each of the other years. The programs sampled bottom, mid and surface levels for different nutrient parameters. The results of this data set suggest that the Delaware River is a well mixed body of water, with the surface and bottom nutrient levels generally similar. **Figures 3.4-8 A-C** depict NCA data for the fall 2000 period, other years show a similar pattern.

4.0 TOXICS

4.1 PCBS

In 1996, the *Comprehensive Conservation and Management Plan for the Delaware River Estuary* (CCMP) identified PCBs as a pollutant of concern. Pennsylvania, New Jersey, and Delaware have all issued broad fish consumption advisories based upon PCB contamination in fish tissue to a lesser degree, contamination by chlordane and the chlorinated pesticides DDT and its metabolites DDE and DDD (DRBC 1998A).

Polychlorinated biphenyls (PCBs) are present in the environment in various media including air, water, and sediment. While the manufacture of PCBs was essentially banned in the late 1970's, they continue to be dispersed in the environment by human activity. They enter the atmosphere as a gas, spill into soils and waterways, and lodge in sediments. PCBs can also be generated as a byproduct by some industrial processes. The states of Delaware, New Jersey, and Pennsylvania have listed the Delaware Estuary as impaired due to elevated levels of PCBs in the tissue of fish caught in this portion of the Delaware River. This required the development of TMDLs for an 85-mile reach of the estuary (Santoro et al, 2004). A TMDL is the maxiumum amount of the pollutant that the estuary, lake, or river can receive and still attain the water quality standards.

On behalf of the states of Delaware, New Jersey and Pennsylvania, and in cooperation with the DRBC, the USEPA Regions II and III established TMDLs for PCBs in the Delaware River Estuary in 2003. EPA establishes these TMDLs in order to achieve and maintain the applicable water quality criteria for PCBs designed to protect human health from the carcinogenic effects of eating contaminated fish now found in the Delaware Estuary. In accordance with Section 303(d) of the Clean Water Act (CWA) and its implementing regulations, these TMDLs provide allocations to point sources (WLA) discharging PCBs as well as allocations to nonpoint sources (LA) of PCBs, and an explicit margin of safety (MOS) to account for uncertainties. The TMDL report and its appendices set forth the basis for these TMDLs and allocations and discusses follow up strategies that will be necessary to achieve substantial reductions of PCBs. EPA will continue to work with the Commission and the States to develop enhanced Stage 2 PCB TMDLs based on information to be collected and analyzed over the next several years. While EPA acknowledges that implementation of the TMDLs will be difficult and may take decades to fully achieve, the establishment of these TMDLs sets forth a framework and specific goals to protect human health from the effects of PCB pollution and restore the Delaware River to safe levels.

In addition to the human health risks associated with consumption of PCB-contaminated fish, PCBs pose an ecological risk to aquatic biota, particularly sediment-dwelling organisms. A study performed for the Delaware Estuary Program (Costa and Sauer, 1994) found that PCBs are far more widespread in sediments than was previously believed. PCB levels in sediments exceeded the no-observable-effects level (NOEL) at 14 of 16 stations sampled, with the highest concentrations detected between Chester, PA and Trenton, NJ. Importantly, these 16 stations were located in non-channel shoal areas, which comprise a far greater total

area than the channel and are recognized as an important ecological habitat (DRBC 1998A). The high PCB levels found in non-channel areas, the extent of these areas, and the food web interactions known to exist in them serve to reaffirm the significance of the estuary PCB problem. More recent sampling performed by the USACOE in connection with the proposed "main channel deepening" project also revealed the presence of PCBs in main channel sediment samples, although at significantly lower levels than in adjacent shoal samples (Burton, 1997). The lack of comprehensive and reliable information concerning the sources of PCBs in the estuary and their transport pathways has hampered mitigation of the estuary PCB problem. A 1998 study by the DRBC began to address this critical gap in information (DRBC 1998A). **Figure 4.1-1** depicts the current PCB monitoring programs and locations in the Delaware Estuary that were initiated by DRBC during the report period.

4.1-1 Air Monitoring for PCBs in the Delaware Estuary

A study to quantify the concentration of polychlorinated biphenyls (PCBs) in the air and the flux of PCBs between the Estuary waters and the air were conducted during 2001-2003 by Rutgers University and the DRBC.

The study objectives included establishing and operating three atmospheric monitoring sites for PCBs at Lums Pond Delaware; Northeast Airport, Pennsylvania; and Swarthmore, Pennsylvania. These sites were used to quantify gaseous and particulate PCBs in the Delaware Estuary, and to identify and quantify regional and background sources.

The air monitoring stations were monitored in accordance with the protocols established for the New Jersey Atmospheric Deposition Network. The three stations identified above complement the existing three stations located in the New Jersey portion of the Delaware estuary and are identified in **Figure 4.1-1 and 4.1-2**. Station selection was based on identifying the regional signals of PCB pollution by locating monitoring sites in urban and suburban areas in the upwind and downwind direction of the prevailing weather patterns. Data from all stations have provided long-term spatial and temporal information on the concentration and seasonal variability of PCBs in the Delaware estuary. Approximately 200 samples have been collected and analyzed for particulate and dissolved PCBs during the study period and the results have been used to inform the DRBC's PCB modeling efforts.

Air-water exchange measurements have been conducted over a one year period during the study period at five different locations. Net fluxes varied by location but generally the net flux was from the water to the air. Results of the water air flux study of PCBs have provided vital information for the modeling of PCBs in the Delaware Estuary.

<u>Air Deposition Survey</u>
Concentrations of PCBs in the air were measured in the particulate and dissolved phases using a high volume air sampler. Quartz fiber filters were used to capture particulate matter and polyurethane foam plugs were used to capture the dissolved phases. Analysis was conducted using a gas chromatography equipped with a nickel electron capture detector. The resulting detection limits were on the order of < 1 pg/l. Typically, less than 10% of the total

atmospheric PCB concentrations are found in the particulate phase. Furthermore, gas phase concentration can vary by up to two orders of magnitude from site to site, with the highest concentrations occurring in the urbanized area of NE Airport and Swarthmore, Pennsylvania. The highest PCB concentrations ever reported have been observed at the Camden location. A graphical representation of gaseous PCB concentrations at the three monitoring stations is provided in **Figure 4.1-3**.

Air-Water Flux Survey
Five surveys were conducted in the Delaware Estuary in order to quantify the air-water exchange fluxes of PCBs. These surveys occurred during all four seasons at five locations within the estuary. These surveys were conduced concurrently with the air deposition study. Air samples were collected at the same location as water samples and analyzed in the same manner. The concentrations measured over the water are in good agreement with those measured on land for those dates where sampling coincided. The typical net flux for all four sampling locations for all five cruises is from the water to the air.

The results of the study show that PCB concentrations vary by orders of magnitude between urbanized and rural areas, suggesting existing sources of PCBs are volatilizing to the atmosphere. Concentrations recorded in some urbanized areas also suggest that the PCBs in the air may ultimately be a source of loadings to the estuary for those locations.

4.1-2 Stream flow monitoring for PCBs

An analysis of stream flow for the Delaware River at Trenton, and the Schuylkill River at Philadelphia was conducted by DRBC in support of the PCB TMDL development for the Delaware Estuary. The study objective was to identify a twelve month period that represented the long-term flow conditions at the Delaware River at Trenton and the Schuylkill River at Philadelphia.

The DRBC constructed hydrodynamic and water quality models to determine the transport and fate of PCBs in the Estuary. A decadal scale modeling simulation was required as a part of the model calibration and TMDL development. It was determined to use a one year period to represent hydrologic conditions and cycle the one year period to conduct long-term simulations. The Delaware River at Trenton and the Schuylkill River at Philadelphia together represent over 70 percent of stream inflows into the Delaware Estuary. Therefore, in order to accurately represent the transport of PCBs in the estuary, it was necessary to select flow regimes that represented long-term flow conditions. Representativeness was determined by comparing flow statistics from the calibration period to long-term flow statistics. Stream flow information from the USGS gage at Trenton, (USGS gage 01463500) for the period of record 1912-present and for the USGS gage at Philadelphia (USGS gage 01474500) for the period of record 1934-present was used in this analysis. The following approach was utilized in selection of a 12 month period to be used in modeling runs:

1. Data for the period of record for each gage was ranked and percentile graphs were constructed.

2. Twelve month rolling bin increments for the calibration period beginning in September 2001 were ranked and graphically compared to the historical data.

Graphical representations are provided in **Figures 4.1-4 and 4.1-5** for the Schuylkill and Delaware Rivers respectively. Both graphs represent the flows in cubic feet per second vs. the percentile for that flow for the long-term and twelve month periods. The February 2002 to January 2003 period of record from the nineteen month calibration was selected as the best match to the long-term flow data for the Delaware River at Trenton and the Schuylkill River at Philadelphia. This period was then used in decadal scale model runs.

4.1.3 Ambient Water Body PCBs

The PCB modeling effort supports the establishment of four pollution budgets known as TMDLs, one for each management zone that set the maximum amount of a specific pollutant in this case PCBs that can be introduced into the river. The EPA has classified PCB as a probable human carcinogen. Although their production was banned in the United States in the late 1970s, substantial amounts of the toxic substance remain in the environment. PCBs are still found in thousands of industrial and commercial applications, including electrical transformers, and in paint, plastic, and rubber products. They accumulate in river sediment and soil, and in the fatty tissue of fish. Human exposure results from eating those fish.

The PCB TMDL addresses all potential sources of PCBs, including storm water runoff point sources, tributaries, and runoff from Superfund sites, which are the major contributor of PCBs into the river. EPA, the three states, and other stakeholders are in the process of developing pollution reduction strategies to address these major sources.

The point sources include 142 permitted discharges from municipal waste water and industrial facilities along the river that were identified in Stage 1. These sources will be required to identify how and where the PCBs were located before they are discharged to the Delaware River.

To support development of the Delaware Estuary PCB Homolog Water Quality Model, accurate measurements of PCB concentrations in the Estuary were required. Ambient water samples were collected from the mainstem Delaware Estuary for the analysis of PCB concentrations at low, high and intermediate flows in the portions of the Delaware Estuary listed for TMDL development. Fifteen main stem channel sites in the tidal river were sampled for a total of seven sampling events, and four surveys in Delaware Bay.

PCB (total) data are presented in Figure 4.1-6. This figure indicates that in general higher concentrations of PCB are observed in low flow conditions. As the river flow increases the concentration of PCB decreases. In the lower flow sampling events, the concentration of PCB shows a pattern of elevated PCB between river miles 80 and 107 indicating PCB loadings in the urbanized areas of the river. A similar pattern of PCB distribution is not observed in the higher flow sampling events. In the higher flow sampling events, PCB concentrations are lower and more evenly distributed over the sample area probably from dilution of PCB during high flow conditions.

4.1.4 Fish Tissue Levels

The states of Delaware, New Jersey, and Pennsylvania have identified the Delaware Estuary as impaired on their respective lists pursuant to Section 303(d) of the CWA. The States identified the impairments based on their findings of elevated levels of polychlorinated biphenyls (PCBs) in the tissue of fish caught in this portion of the Delaware River. The listing was based upon the failure to attain one of the estuary's primary designated uses – fishable waters and the inherent protection of human health from consumption of unsafe fish. When water quality standards, including a numeric criterion and a designated use, are not attained despite the technology-based control of industrial and municipal wastewater (point sources), the Clean Water Act requires that the impaired water be identified on the state's Section 303 list of impaired waters and that a total maximum daily load (TMDL) is developed.

Figure 4.1-7 presents analytical results for the white perch and channel catfish samples collected in the Delaware River. For each sampling location, the total concentration based on the sum of 99 PCB congeners normalized to lipid percent in the tissue sample is shown. These fish exhibited concentrations between 270 and 910 ug/g lipd weights by lipid percent with the highest concentrations observed in fish collected near the C&D Canal and Crosswicks Creek. A PCB concentration of 3.33 ug/g lipd (the equivalent for fish tissue of the established water quality standard) is projected to result in one additional cancer case per million people exposed through consumption of one-half pound of fish every 35 days.

Metals
Figure 4.1-8 shows the metals concentrations in tissues of white perch and channel catfish **(Figure 4.1-9)** collected in several locations in the Estuary. Elevated levels in white perch exist for arsenic (6.5-10 ppm wet wt) and to a lesser extent copper (1-2ppm wet wt.). A similar pattern exists for channel catfish which contained arsenic levels of 4-5.5 ppm wet wt. and copper levels from 0.25-1.3 ppm wet wt as well as levels of nickel (0.1-1.4 ppm wet wt.).

4.2 Sediment Toxicity

As part of the 2000 National Coastal Assessment, amphipods (*Ampelisca abdita)* were exposed to sediment samples from the Delaware Estuary for 10 days under static conditions. The survival of the amphipods in estuarine sediment samples was compared to survival in control sediments. If the sample mean survival was less than 20% of the control survival, the sediment was reported as toxic (NCA, 2000). Based on the National Coastal Assessment Report, two out of twenty-six sites are shown in **Figure 4.2-1** as toxic. One toxic site is in the Maurice River and the other site is in the Delaware Bay north of the Broadkill River. The National Coastal Report also lists the Maurice River site as having high sediment contamination and a poor benthic index providing a strong weight of evidence for sediment toxicity. The Delaware Bay toxic site is reported to have a poor benthic index based on the contaminants measured, but is not reported to have high sediment contamination. It should be noted that sediment toxicity data are absent for the 2000 National Coastal Assessment locations in Zones 2 and 3 where sediment toxicity has previously been measured (AD Little DELEP Report #94-08 and Santoro, 2000).

5.0 LIVING RESOURCES

More than 200 species of migrant and resident finfish species have been identified in the Delaware Estuary. Some of the prevalent species include sharks, skates, sturgeon, American eel, blueback herring, Atlantic menhaden, alewife, American shad, striped bass, bluefish, weakfish, and flounder. Currently, some 31 finfish species are caught commercially in the Delaware Estuary, but the commercial fishing industry is much smaller than the recreational fishing industry.

The Delaware Estuary is internationally recognized for its importance as a stopover for migrating birds. The living resources monitored in the Delaware River and Delaware Bay include horseshoe crab, blue crab, and six species of finfish – American shad, weakfish, striped bass, Atlantic sturgeon, shortnose sturgeon, and American eel. The Estuary is the home of the world's largest population of horseshoe crabs. The blood of the horseshoe crab is used to help detect minute amounts of bacterial toxins associated with bacterial diseases, fever, shock, and death of humans. The annual late-spring mating and nesting of the horseshoe crab is an inspiring spectacle for avid bird watchers who travel to the bay shore to gaze at hundreds of thousands of red knots, ruddy turnstones, sanderlings, semipalmated sandpipers, and other migratory birds feasting on horseshoe crab eggs.

5.1 Oysters

The oyster fishery is managed in New Jersey jointly by NJDEP (regulation and monitoring), Haskin Shellfish Research Laboratory (HSRL) (science) and the Delaware Bay Section of the Shell Fisheries Council (industry liaison). The process starts in the fall with a stock assessment survey conducted by the HSRL and a meeting of the Oyster Industry Science Steering Committee (a Fisheries Council subcommittee) to set the terms of reference for the assessment. HSRL scientists conduct analyses pursuant to these terms of reference and present them to an external review committee, the Stock Assessment Review Committee or SARC at a February Stock Assessment Workshop or SAW. The SARC drafts a report based on the information presented to them that includes sections on the State of the Stock and Management Advice. This report is provided to the NJDEP and Council who use the information therein to develop the regulations for the coming year, including the allocation.

The assessment is based on a biological reference point termed the constant abundance reference point that sets the management goal. This goal is no net reduction in market-size abundance. A fisheries model uses the survey data and the reference point to generate estimates of allowable harvest to meet the goal. The approach has been successful in permitting (a) rebuilding of the stock after disease outbreaks and (b) sustainability of the stock by minimizing the chance of over harvesting of a population subject to wide swings in natural mortality due to disease. The limitation on harvest today is the limitation on recruitment. The recruitment rate sets the harvest level, in essence, because the constant abundance reference point permits harvest only of the surplus production not required to replace those animals lost to natural mortality each year.

As a consequence, increased recruitment permits increased harvests. Implementing a recruitment enhancement program, based for example on shell planting and transplant of spat, will directly increase harvest by increasing surplus production without jeopardizing the sustainability of the resource (Personal communication Eric Powell).

This section summarizes the Delaware Estuary oyster seedbed sampling data from New Jersey and Delaware. **Figure 5.1-1** shows the approximate oyster abundance per bushel in Delaware Bay. Sampling in Delaware Bay takes place in the fall of each year, typically in late October, using an industry oyster dredge boat in New Jersey and the state survey boat in Delaware. While the data collected by New Jersey and Delaware are comparable, there are some differences in methodology. The sample locations for both states are based on a grid system for each bed. New Jersey uses a stratified random selection of grids within the bed while Delaware uses fixed stations. In New Jersey three one minute dredge hauls are taken in each grid and a composite bushel of material (about 1/3 from each haul) is retained. Each dredge haul is calibrated by sampling the length of the haul with a GPS system that records the position at six second intervals. The bushels of material brought up by the dredge are estimated from the volume in a calibrated hopper. In Delaware, the dredge tows are not timed, and a one bushel sample is arbitrarily selected from the material brought up in the dredge in both states. In both New Jersey and Delaware, bushels of material are sorted into volumes of oysters, cultch, and debris. Counts are made of live oysters, boxes (dead oysters), live spat, dead spat and ancillary information is collected on presence of oyster drills, *Stylochus*, crabs, sponges, barnacles, and black shell. All live and dead oysters (> 20 mm) are measured. Subsamples are set aside for condition index (Dry meat weight/oyster height), and pathology (*Perkinsus marinus*, dermo; and *Haplosporidium nelsoni* – MSX), and 3 quarts of cultch are set aside to provide a counting control for potentially missed spat.

The variability associated with the estuarine gradient makes it difficult to statistically show year to year difference in abundance, spat, disease levels, or mortality. Trends are readily apparent when several years of data are displayed (**See Figure 5.1-2**).

In general, Delaware's data are more variable **(See Figure 5.1-2).** This reflects the smaller number of beds being sampled and the more restricted areal extent of the seed beds on the Delaware side of the Bay. The numbers of oysters per bushel in New Jersey have remained in the 100 to 175 range since 1990, and are currently at the low end of that range (**Figure 5.1-3**).

Delaware oyster abundance ranged from 350 oysters per bushel to slightly less than 100, and recently these resources have shown a substantial drop to the low end of the range (**Figure 5.1-3**). Spat abundance throughout the system appears to be more tightly coupled than overall oyster abundance (**Figure 5.1-2**). The three consecutive years of modest set in the late 1990s have provided the bulk of the oyster resources that are present in the system (**Figure 5.1-4**).

The four year period of very low spat abundance from 2000 to 2003 has caused a significant loss of oyster resources in the higher salinity parts of the seed beds. A continuation of this trend will certainly yield continued reduction in oyster abundance

throughout the Delaware Estuary. Historically in the Delaware Estuary, oysters were removed from the seed beds and planted on leased grounds farther down bay. This practice has caused some difficulty in terminology in that the oysters removed (harvested) from the seed beds were differentiated from those brought to shore and sold (landed). To be clear, we have simply used oysters removed from the seed beds (**Figure 5.1-3**).

The data in this chart are not comparable because the New Jersey data for 1990, 1991 and 1995 reflect oysters of all sizes removed for planting, but beginning in 1996 a new management scheme only allowed removal of market size oysters from the seed beds. Blanks in the data reflect periods when the seed beds were closed to harvest.

The dominant force controlling oyster numbers in the 1990's and early 2000's has been the appearance of the oyster disease dermo and its proliferation into epizootic status. While this parasite has been reported from the Delaware Bay system in earlier years, it never caused serious levels of mortality. Two hypotheses have been proposed for this increasing mortality. The first is that warmer winters allow more parasites to survive. The second is there has been a change in the genetics of the oyster mortality and dermo levels parasite.

At present, there is no way to determine if the change is due to one, both or some combination of the two. The resurgence of this parasite resulted in the change in management strategies in both New Jersey and Delaware. The combination of heavy dermo losses (exceeding 50% annually on many of the higher salinity seed beds), combined with a historically unique 4 years of poor recruitment has seriously depleted oyster stocks on all higher salinity seed beds. There are currently significant numbers of oysters on the upper bay seed beds, but these are mostly in the larger size categories and natural mortality will begin to reduce these numbers through time. The major concern at present is the lack of recruitment to replace these older oysters.

5.2 Horseshoe Crab

In October 1998, the Atlantic States Marine Fisheries Commission (ASMFC) Horseshoe Crab Management Board approved an *Interstate Fishery Management Plan for Horseshoe Crab* (Interstate FMP). The objective of the Interstate Plan is to compile an accurate count of the annual horseshoe crab harvest for each of seventeen Atlantic states, and to use these data to develop a coast-wide cap on horseshoe crab landings. The ASMFC Board intended for the cap to be implemented in the year 2000.

The interstate FMP requires the seventeen Atlantic states to submit compliance reports containing steps for the plans implementation. The ASMFC Technical Committee reviewed these reports and presented their recommendations to the Management Board on March 17, 1999. Delaware's and New Jersey's reports were among only five to be approved by the ASMFC Management Board from among the seventeen submitted. Many of the plans were rejected because they failed to account for collection of the crabs for personal use, and thus, in the Board's view, could not demonstrate that an accurate count of landings would be made. Because so many of the states' implementation plans were deficient, the deadline for submission of the implementation plans was extended, postponing the likely date of

implementation of a cap on landings.

In order to implement the interstate FMP, most of the states are developing statutes or regulations which will require an accurate count of horseshoe crab landings. To further the goal of accurate monitoring, the ASMFC Technical Committee coordinated a series of workshops, which resulted in the design of a statistically valid spawner beach and egg count survey that was implemented in Spring 1999. A coast-wide tagging program was also developed, to be coordinated by the USF&WS and implemented by the biomedical industry. Evaluation of the post-release mortality of horseshoe crabs used by the industry has begun. Additionally, a research proposal was approved to examine the genetic structure of the Atlantic coast horseshoe crab population. Genetic information on the crabs will be useful in determining if geographic sub-populations exist and if regional management is possible (ASMFC, 1999).

The FMP contains a monitoring program aimed at providing the necessary data to facilitate future management decisions, and maintains horseshoe crab harvest control measures recently put in place in New Jersey, Delaware, and Maryland to protect horseshoe crab spawning within and adjacent to the Delaware Bay. The FMP directed the Management Board to implement a cap on horseshoe crab bait landings in 2000, and recommended that the Secretary of Commerce address and initiate controls over the harvest and use of horseshoe crabs in federal waters. The Management Board proceeded with developing a coastwide cap on horseshoe crab bait landings to control the harvest and fulfill the goals and objectives of the FMP. Several management options were identified by the Management Board and incorporated into a Public Information Document, which was made available to the public in December 1999, and presented at state public hearings in January 2000. On February 9, 2000 the Management Board reviewed input from the Technical Committee, Advisory Panel, and public, and approved Addendum 1. Addendum 1 of the Interstate Fishery Management Plan for Horseshoe Crab sets forth changes to the harvest level threshold for horseshoe crab bait fisheries and establishes *de minimis* criteria for those states with a limited horseshoe crab bait fishery. The Management Board established the following harvest level for horseshoe crab bait fisheries:

- A state-by-state cap on the landings of horseshoe crab for bait landings at 25 percent below the reference period landings by May 1, 2000. Individual state horseshoe crab bait fisheries would be closed once their state's cap is reached [1]

The Management Board also recommended the following management measure to provide further protection to the Delaware Bay horseshoe crab population, recognizing its importance to migratory shorebirds:

- Encourage states with more restrictive harvest levels to maintain those regulations, until such time that the state comes forward with a plan for adjusting their harvest that has been reviewed by the Technical Committee and approved by the Management Board.
- Request that the NMFS to close the harvest of horseshoe crabs in Federal waters

[1] The harvest reduction of 25% below the reference period landings would be assessted for the entire year (Jan.-Dec). The Board Would review over the harvest (i.e., overages by states in any particular year and would substract the overages from subsequent harvest thresholds.

within a 30 nautical mile radius of the mouth of Delaware Bay. The taking of horseshoe crabs for any purpose, including biomedical, would be prohibited in this area closure.

- Request that the NMFS should prohibit the transfer of horseshoe crabs at sea in federal waters.

The ASMFC Interstate Fisheries Management Fisheries Program Charter defines *de minimis* as "a situation in which, under existing condition of the stock and scope of the fishery, conservation, and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coastwide conservation program required by a Fishery Management Plan or amendment."

States may apply for *de minimis* status if, for the last two years, their combined average horseshoe crab bait landings (by numbers) constitute less than one percent of coastwide horseshoe crab bait landings for the same two-year period (for 2000, Reference Period Landings would be used and for 2001, the average of reference period landings and 2000 landings would be used). States may petition the Board at any time for *de minimis* status, if their fishery falls below the threshold level. Once *de minimis* status is granted, designated States must submit annual reports to the Board justifying the continuance of *de minimis* status. States that qualify for *de minimis* status are not required to implement any horseshoe crab harvest restriction measures, but are required to implement components A, B, E and F of the monitoring program (Section 3.5 of the FMP). Since *de minimis* states are exempt from a harvest cap, there is potential for horseshoe crab landings to shift to *de minimis* states and become substantial, before adequate action can be taken. To control shifts in horseshoe crab landings, *de minimis* states are encouraged to implement one of the following management measures:

- Close the respective horseshoe crab bait fishery when landings exceed the *de minimis* threshold;

- Establish a state horseshoe crab landing permit, making it only available to individuals with a history of landing horseshoe crabs in that state; or

- Establish a maximum daily harvest limit of up to 25 horseshoe crabs per person per day. States which implement this measure can be relieved of mandatory monthly reporting, but must report all horseshoe crabs harvests on an annual basis.

This addendum also requires that all state programs include adequate law enforcement capabilities for successfully implementing the jurisdiction's horseshoe crab regulations. The adequacy of a state's enforcement activity will be measured by annual reports to the ASMFC Law Enforcement Committee and the PRT.

Horseshoe Crab Status

According to Swan, et al. (2003) the 2002 year's estimate of the visiting population of horseshoe crab was higher than the previous two years of 2000 and 2001, an increase

attributed to greater numbers observed spawning along the upper bay beaches of the New Jersey shoreline. This was undertaken by trained volunteers recording the numbers of crabs on 13 beaches in Delaware and 10 beaches in New Jersey. The counts were performed during night hours enumerating male and female animals along the water's edge. In 2002, the spawning activity was greatest on May 28th, 2 days after the full moon, with 333,553 spawning individuals estimated. Delaware spawners were calculated to be 203,389 and New Jersey animals were 130,164 for this date. Compared to the past two years, this estimate surpassed 2001's estimate of 216,929 individuals and 2000's estimate of 272,770. New Jersey's peak estimate of 130,164 individuals on May 28th was higher than both the 2000 and 2001 estimates.

Consistent with previous years, the shoreline of Delaware supported more spawning activity than the New Jersey side. Spawning numbers were most numerous during the May survey dates in both New Jersey and Delaware, almost three times the June spawning numbers.

Swan et al (2003) noted that the 2002 peak spawning estimate was a very welcome sight with approximately 30% more spawners than the 2001 estimate and 20% more than in 2000.

A summary of the volunteer Horseshoe Crab Counts on the spawning beaches in New Jersey and Delaware are presented over the period 1996 to 2003 in **Figure 5.2-1.** As reported by Swan, et al (2003), after viewing the 2002 peak spawning estimate, which is an indication of the current horseshoe crab plight, they suggests that t**he restrictive measures introduced in the Delaware Bay region on harvesting, the implementation of the Carl N. Shuster Jr. Horseshoe Crab Reserve (CNSJrHSCR) and the utilization of bait bags seem to be benefiting the horseshoe crab. However, the increase is not substantial enough to warrant any less restrictive measures in the management of the species (Swan et al, 2003).**

The State-specific spawning activity of horseshoe Crabs was reported by Smith and Bennett (2004). Over the 1999 to 2003 period in the states of Delaware and New Jersey the levels show relative stability in spawning activity and appear to be somewhat offsetting **(Figure 5.2-2)**. The change in spawning activity in New Jersey is slight and positive, although not significantly so (slope = 0.02, SE = 0.040, P = 0.73), and in Delaware the change is negative, although again not significantly so (slope = -0.06, SE = 0.025, P = 0.12).

As reported by Smith and Bennett (2004), spawning has tended to peak in late-May, although there has been considerable year-to-year variation in the timing of spawning activity. The peak Horseshoe Crab spawning in 2003 occurred later in the year and the percent of spawning in May was lower than in previous years. In 2003, there was very little spawning until the end of May. **Smith and Bennett (2004) concluded that spawning activity in Delaware Bay over the past 5 years has been either stable or declining at a rate less than 8% per year. Spawning activity appears more stable in New Jersey than in Delaware.** Patterns of decline in spawning activity on Delaware beaches show up when examining data from beaches individually and when data are summarized statewide.

5.3 Blue Claw Crab

The Blue crab (*Callinectes sapidus*) inhabits near-shore coastal and estuarine habitats throughout the western Atlantic, Caribbean, and as far south as Ecuador. In 2003, almost 7 million pounds of blue crab was landed in Delaware Bay (**Figure 5.3-1**). Despite the fact that Delaware Bay is near the northern extremity of its distribution, blue crab catches produce the largest dockside value of any fisheries resource in the bay. Cole (1998) estimated that commercial landings of blue crab in Delaware from 1988-1995 averaged 4.5 million pounds and produced an annual dockside value of $2.5 million. Commercial landings of blue crab in Delaware over the past ten years have averaged 4.6 million pounds, with an annual estimated value of $4.3 million dollars. With an increasing demand for crab meat, coupled with declines of harvests in the Chesapeake Bay stock, effort on the Delaware Bay stock has increased markedly since the mid-1980's (Cole 1998).

In 1999, amid raised concerns about declines in Delaware Bay blue crab landings (Cole 1998), the Delaware Bay Blue Crab Fishery Management Plan (FMP) was jointly developed by the State of Delaware Division of Fish and Wildlife and the State of New Jersey Division of Fish, Game, and Wildlife. This document was submitted to the Delaware State Legislature (Delaware Division of Fish and Wildlife 1999). The goal of the FMP is to conserve the bay-wide blue crab stock, insure the long-term sustainability of the resource, and provide fair allocation among the commercial and recreational user groups from New Jersey and Delaware. This document put forward the following ten objectives:

1) Maintain limited entry in the commercial fishery to prevent overcapitalization.
2) Until additional information is available to demonstrate otherwise, maintain bay-wide fishery yields within the ranges of 6.8 to 14.5 million lbs.
3) Complete and continually update a stock assessment based on the best available scientific information and computer models available.
4) Improve the knowledge of early life history stages for blue crabs (including environmental factors influencing growth and survival).
5) Evaluate the biological and socioeconomic effects of gear controls to discards and by-catch.
6) Improve fisheries dependent data collection.
7) Enhance inter-state resource management efforts and data collection protocols.
8) Exchange biological and fisheries-related information between Delaware and New Jersey on a regular/continuing basis.
9) Coordinate data analysis and establish peer review teams to review stock assessment analyses.
10) Implement comprehensive, complementary management approaches based on cooperative, synchronized efforts from New Jersey and Delaware natural resource agencies.

The FMP recommends that both Delaware and New Jersey review their mandatory harvest reports each year in order to determine how many dredge and pot licenses have not been fished within the previous years. License holders who have not reported within the preceding three-year period would not be permitted to renew their license. This action would

help prevent any increases in fishing effort from the activation of latent licenses. The FMP also supports the use of cull rings to increase escapement and thus survival of juvenile blue crabs. At present, the plan recommends voluntary use of cull rings. Continued mandatory use of turtle excluder devices in New Jersey and the tidal streams and inland bays of Delaware is encouraged.

The Division of Fish and Wildlife was tasked with providing an analysis of available blue crab data, assessment of the stock, and the estimation of biological reference points and fishery management benchmarks in support of the FMP. This assessment was completed in 1999 and has been updated annually (Helser and Kahn 1999, Helser 2000, Helser and Kahn 2001, Bancroft and Kahn 2002, Kahn 2003).

The bi-state Delaware Bay blue crabs population is presently treated as two separate management units, with New Jersey and Delaware implementing separate fishery regulations. Because the larval stage is transported to the coastal shelf before re-entering the Bay to settle, mixing with other stocks in the region may occur at this stage. Kahn et al. (1998) discussed the hypothesis that the Delaware Bay stock should be considered part of a metapopulation. Considering the significant stock-recruitment relationship for Delaware Bay, the stock is probably the primary source of its own recruits.

The blue crab stock assessment for 1999 (Helser and Kahn, 1999) represented the first successful attempt at deriving estimates of stock sizes and fishing mortality rates, and at estimating biological reference points from which a fishing target and overfishing threshold can be derived for the Delaware Bay blue crab stock. The blue crab stock assessment for 2000 (Helser 2000) extended this framework by incorporating an uncertainty analysis. These assessments served as the basis for the development of the Delaware Bay Blue Crab Fishery Management Plan which was submitted to both Delaware and New Jersey (Delaware Division of Fish and Wildlife, 1999). There is currently no accepted method of aging blue crab; therefore an age-structured assessment could not be conducted. Instead, the catch-survey model was employed, or modified-Delury model, which models the population using two stages (Collie and Sissenwine, 1983; Conser and Idoine, 1992). Auxiliary information of relative abundance of the size groups from research surveys and annual catches are integrated into a single model framework to estimate stock sizes, stock biomass, and fishing mortality rates. Overfishing definitions based on biological reference points were developed from other methods such as yield and SSB-per-recruit analyses and standard spawning stock-recruitment plots. A mixed Monte Carlo-Bootstrap procedure was developed to incorporate uncertainty in the terminal year fishing mortality rates and the biological reference points to which they are compared (Helser and Kahn 2001; Helser et al 2002). A probabilistic framework was then used to evaluate decisions regarding the overfishing status of the Delaware Bay blue crab resource. Bancroft and Kahn (2002) updated the assessment through 2001. Kahn (2003) updated the assessment through 2002.

In summary, the assessment consists of examination of landings, fishing effort, and survey indices of relative abundance. A catch-survey model, or modified DeLury model, was employed to estimate the catchability coefficient used to convert survey indices to estimates of absolute abundance for the period 1979-2003. These estimates were combined with catch

data to estimate total mortality and instantaneous fishing mortality (F) annually from 1979-2002. The assessment includes an update of the stock-recruitment model with additional data for 2002 and recovered data for 1979 and 1980.

The catch-survey model fit the Delaware Bay blue crab data fairly well; NLLS estimates of recruit and fully-recruited stock sizes were relatively precise (CV range: 30-48%). The NLLS CV for the catchability coefficient was 25%, indicating a relatively precise fit. Stock sizes were estimated for January 1. Final estimates of recruit stock size in the last 3 years were equal to the 1979-2002 average of 95 million until 2003, when the estimate dropped to 50.6 million. Estimated fully-recruited stock sizes ranged from 6 to 49 million with an average of 22 million crabs from 1979-2002 **(Table 5.3-1)**. **Over the last 3 years, annual estimates of fully-recruited stock size ranged from 14 million to 28 million, with the estimate for January 1, 2003 dropping to 14 million, prior to the winterkill of 2003. Estimated biomass of fully-recruited crabs (exploitable biomass) ranged from 4 million to 23 million pounds, with an average biomass of 11 million pounds from 1979-2003. While exploitable biomass has trended upward over time since 1979, the last five years have shown a declining trend since a peak in 1998. For 2003, the estimate was well below the long-term average at 5.9 million pounds, prior to the winterkill, which certainly reduced both abundance and biomass substantially.**

Fishing mortality rates on fully-recruited blue crabs ranged from 0.23 to 1.18, with an average of 0.73 over the 1979-2002 period. Average F in recent years (2000-2002) for fully-recruited blue crabs was 0.62 and the F for 2002 was estimated at 1.18, the highest value in the time series. Recent estimates of spawning stock biomass, prior to 2003, have been moderate. These are levels that on average should produce relatively high recruitment according to the Ricker stock-recruit model. However, recruitment to the fully-recruited stock has been moderate to low, due to environmental factors producing lowered survival (**Figure 5.3-2**).

The severe winter of 2003 inflicted heavy overwintering mortality on mature crabs, which, combined with harvest, resulted in a spawning stock biomass index of zero, for the fifth time during the 1978-2003 period. Based on past patterns of spawner-recruit data, this indicates a reduced probability of high levels of recruitment in the fall of 2003, although favorable environmental effects may mitigate the low levels of spawning biomass as occurred in 1996, when recruitment was relatively good despite a zero index of spawning biomass.

Currently in 2003, the winterkill and relatively low survival of recruits in 2002 have contributed to a stock reduction.

Biological reference points in Helser and Kahn (1999) were calculated from the Thompson and Bell model as: $F_{0.1}$ = 0.6, F_{MAX} = 1.0, while F_{REP} calculated from SSB-per-recruit and SSB-Recruitment indices was 1.3. An appropriate overfishing threshold mortality rate is 1.3 (F_{REP}) and fishing mortality rates in excess of this value would increase the likelihood of jeopardizing the resource. The recent average fishing mortality rate is below $F_{MAX,}$ is equal to $F_{20\%}$ and is below the overfishing threshold mortality rate of F_{REP} =1.3. The F_{2002} = 1.18 exceeded all reference points except the overfishing threshold. Based on yield and SSB-per-

recruit considerations, recent assessments recommended a fishing target somewhere between $F_{0.1} = 0.6$ and $F_{MAX} = 1.0$.

The assessment suggests that the Delaware Bay blue crab stock is being fished at a level that is sustainable in most years, with some years of quite high F that approach, but do not meet, the overfishing threshold. Therefore, it is recommended that increases in fishing effort should be avoided and consideration should be given to reducing fishing effort (Figures 5.3-3). Further, targeting of mature female crabs in the fishery, particularly when they are concentrated, should be discouraged, in order to protect the spawning stock. The 2003 YOY index is approximately equal to the long-term average. If it continues to remain at or below the long-term average, additional consideration should be given to protection of the spawning stock (**Figure 5.3-4, 5.3-5**).

5.4 American Shad

Monitoring programs for juvenile American shad are conducted annually throughout the Delaware River from Artificial Island to Milford, Pennsylvania, a distance of approximately 180 miles. All sampling programs document good recruitment of American shad.

Seining for juvenile American shad in the Delaware River was completed for 2003. A total of 16,657 shad were collected from four sites. At the most downstream site, Trenton: 1,157 (6.95%) shad were collected; Phillipsburg: 4,275 (25.66%) shad; Delaware Water Gap: 2,036 (12.22%) shad; Milford PA: 9,189 (55.17%) shad. The largest number of shad was collected during the month of August: 9,436 (56.64%) shad; September: 5,961 (35.79%) shad; October: 1,260 (7.57%) shad. The overall catch per seine equaled 347 shad which is the third highest ever recorded. It is well above the average of 215 shad per seine. Colder than normal spring water temperatures prolonged the spawning period, enabling more adult American shad to migrate farther upstream. This is evident in the highest numbers being collected at the Milford, PA site and the fact that the juvenile shad were smaller in size than previous years (Personal communication M. Boriek, NJDF&G).

As determined by hydroacoustic methods, an estimated 300,000 American shad returned to the Delaware River to spawn in 2003 indicating a decline of approximately 40 percent from the 2002 population **(Figure 5.4-1)**. The fluctuation in population over the report period likely reflects natural variation.

Figure 5.4-1 presents the catch per unit of effort (CPUE) from seining for juvenile American shad in the Delaware River above Trenton, for the time period 1991- 2003. The 1998 CPUE of approximately 60 is the lowest recorded since 1979. It is dramatically lower than the CPUE of 450 recorded two years earlier in 1996 and well below the CPUE of approximately 275 recorded in 1997. No explanation has yet been determined for the apparent decline in population. One theory is that improved water quality has allowed spawning to occur in the lower reaches of the river, resulting in fewer shad in the upper reaches where sampling has been undertaken. Anomalous events, such as weather patterns or "incidents at sea" could account for variability as well. The results could also be an artifact of sampling design or the product of a combination of factors. A Fisheries Technical Committee of the Delaware River

Basin Fish and Wildlife Management Cooperative, which includes representatives from New Jersey, Delaware, Pennsylvania and New York, has been established to focus on these questions and the overall strength of the resource. A discussion of the population estimates based upon hydroaccoustics is presented in **Appendix 12.3.**

5.5 Striped Bass

The population of striped bass in the Delaware River has experienced a remarkable recovery within the last decade, largely attributable to improved water quality and strict fishery management measures. The striped bass spawning stock in the river is monitored by both Delaware and Pennsylvania during the spring migration. Young-of-year recruitment surveys conducted by both New Jersey and Delaware show the resurgence in spawning success for the species**. Figure 5.5-1 a, b** presents the year class of striped bass in the Delaware River during the report period for recreational striped bass. Approximately 34 percent of individuals (both sexes) collected were five-year-old fish. The next largest class included 8-year-old fish (10.6 percent), followed by 4-year-old fish (9.7 percent), and 9-year-old fish (9.5 percent). The smallest numbers collected were 14- and 16-year-old fish (0.2 percent each), with no 15-year-old fish collected.

Striped bass were declared restored in the Chesapeake Bay since 1995. Abundance levels have been high since. However evidence has accumulated that the resident population, comprising primarily younger fish primarily through age 5, predominantly male, is affected by disease and a suboptimal forage base. A complex of mycobacterium species currently infects a significant portion of resident stripped bass. Infected bass may exhibit external lesions and have internal granuloma pathology. The condition factor or weight at length, may be lower than optimal. Young Atlantic Menhaden, a primary forage species for striped bass, have been at relatively low abundance for several years and have shown disease manifestations themselves in significant numbers, at least in some years. Current estimates of the coast wide Atlantic menhaden spawning stock are significantly lower than estimated abundance in the 1950s and early 1960s, when striped bass were last at high abundance levels. Recent tag-recapture data indicates that survival of resident striped bass has declined, yet tag-recapture estimates of fishing exploitation have not increased, suggesting that natural mortality has increased. (Dr. Desmond Kahn personal communication).

5.5.1 Status of Delaware Bay Stocks of Striped Bass

A coast-wide stock of striped bass is comprised of several populations, primarily in the Hudson River, Delaware Bay and Chesapeake Bay. It is equally important to maintain individual stock at healthy level so that over-fishing does not occur at the local level. For that purpose we report estimates of fishing mortality and population characteristics for each individual stock. The full assessment can be found in Kahn (2003). The recreational catch is presented in **Figure 5.5-1 a**. **Over the past 5 years the striped bass harvest has stayed at approximately 2,500,000 to 3,500,000 fish.** Only the status of the Delaware Bay Stock will be discussed below.

The Delaware River Fishing mortality utilizes tag-recapture data in two analyses, a Petersen

exploitation estimate and an estimate of F based on survival modeling with MARK program software. The two sets of estimates have been the highest on the east coast of the United States for the last several years. Both estimates, when translated into F (fishing mortality), are F weighted by N (natural mortality). The exploitation estimate for 2002 was 24%, which translates into F2001 = 0.29. The 2002 F estimate from the MARK program with trend models included was F2002 = 0.37.

If trend models are eliminated, the MARK estimate is F_{2002} = 0.26.

Striped Bass spawning stock

The spawning stock survey occurs in April and May on the spawning grounds in the tidal freshwater Delaware River from Wilmington through Philadelphia. Two agencies co-operate in this survey, which tags fish and develops Catch per Unit Effort estimates of abundance in standardized surveys. The Delaware Division of Fish and Wildlife (DDFW) employs electrofishing gear in a formal systematic sampling design (this type of design is randomized), while the Pennsylvania Fish and Boat Commission (PFBC) also employs electrofishing gear, but in a fixed design. Trends in overall abundance are flat from 1995-2001 for the PFBC and indicate a slow decline in the DDFW estimates for the period 1996-2002. However, the 2003 samples had an increase in mean catch per station. Catch rate of females in particular was markedly increased over recent years. Females of age 10 (1993 year class) were the most abundant. Males ranged to over 1000 mm, with ages to 16 years. Overall abundance of males appeared lower than females. Recent years have seen larger catches of larger males with a decline in catches of smaller males.

Recruitment

The New York and New Jersey Striped Bass juvenile indices are presented in **Figure 5.5-2.a.b.** Both indices suggest a decline in 2002. A YOY survey for striped bass is conducted annually by the New Jersey Division of Fish, Game, and Wildlife using beach seine gear. The geometric mean index was extremely low at the beginning of the time series in 1980, and then gradually climbed to a value of 1.03 in 1989. Since then, it has fluctuated without trend between about 1.00 and 2.00. The 2002 index was low, at 0.51 (see **Figures 5.5-2, 5.5-3 and 5.5-4**), but the 2003 index will apparently be a record high value. The Delaware River stock suffers high levels of entrainment mortality from the Salem Nuclear Generating Station. This mortality on YOY larvae and juveniles has been estimated as averaging 32% per year, in the worst case of no compensatory increase in survival of those YOY fish escaping entrainment and impingement (Kahn 2003).

The results of the VPA analysis indicate that the overall fishing mortality (0.35) for fully-recruited ages 8-11 in 2002 exceeded the F target of 0.30, but the population is not over fished since F is below the threshold of 0.41. Recruitment of age 1 bass was at record levels in 2001 and 2002, but may be low in 2003. The spawning stock biomass estimates are at the highest level in the time series, but appear to be leveling-off. Removals by the recreational fishery (harvest and dead discards) are high but may be declining.

Kahn (2003) noted several sources of uncertainty associated with the estimation of survival and recovery parameters in the tagging analysis for striped bass. The uncertainty associated

with ageing striped bass with scales still remains a problem. Attendees of the ASMFC striped bass ageing workshop in March, 2003 made many recommendations on how to improve scale impressions, but also agreed that ageing bias is an issue after ages 10-12. Recommendations to develop conversion keys using scale-otolith ages, or to use otoliths as a primary ageing structure were made, and a subcommittee was formed to determine the feasibility of using either approach. Some members of the ASMFC Technical Committee were concerned that the VPA is not adequately robust when dealing with a mixed stock such as coastal striped bass. It is possible that the assumption of mixing and dispersal is not being adequately met to provide a comprehensive estimate of mortality. Some members of the ASMFC Technical Committee were concerned that the distribution of larger striped bass has shifted to offshore waters as the population has increased in abundance. Since the EEZ is closed to harvest and there is limited fishery independent survey data for older striped bass beyond state waters, these fish may not be represented in the assessment. The Technical Committee of ASMFC has begun to conduct additional analyses to reduce the number of indices used in the assessment, and criteria are being developed that would be objectively used for the inclusion/exclusion of current and future indices (Kahn 2003).

5.6 Weakfish

The Delaware Estuary provides a vital spawning and nursery habitat for weakfish, and is one of the most economically important fishery resources in the Delaware Bay.

Figure 5.6-1 presents the weakfish catch by year (all ages) for the period 1966-2002 (Stewart Michels, DNREC, personal communication). From a relative abundance of approximately 30 in 1991 and 50 in 1992, the catch increased to a high of approximately 310 in 1997. It fell by more than half – to 150 – in 1998, however, and dropped again in 1999 to approximately 130. Over the report period the abundance level has ranged from approximately 220 weakfish per nautical mile in 2001 to 100 in 2002 (the last year reported). Some of the fluctuation in abundance may be due to changes in fishing pressure. From the 1950s to the present, the weakfish has been one of the most desired recreational and commercial species in the Delaware Bay. In addition, the weakfish population may have benefited from the decimation of the menhaden populations in the late 1950s (Killam and Richkus, 1992).

The weakfish young of the year indices are presented on **Figure 5.6-2**. Over this report period the YOY ranged from a mean catch / tow of 11 to 8 juveniles in 2002.

5.7 Atlantic sturgeon

A yearly tag and recapture program for Atlantic sturgeon in the lower Delaware River was conducted by the State of Delaware from 1991 through 1998. An estimate of the annual population of primarily sub-adult Atlantic sturgeon utilizing the lower Delaware River declined from 5,600 in 1991 to a low of 862 individuals in 1995. Population estimates were not calculated from 1996 through 1998 due to the absence of recaptures and obvious violations of several critical assumptions of the mark and recaptures methodology. Tag returns from a variety of commercial fisheries extending from southern Maine to Cape Hatteras, North Carolina delineated probable migratory patterns of sub-adult sturgeon that

had utilized the Delaware River Estuary for at least some portion of their life history.

Beginning in 1996 and continuing through 1998, sturgeon were tagged with sonic transmitters and their movements were monitored throughout the summer and early fall. One of the benefits of this program was the identification of an additional area where numerous sturgeons tend to concentrate for a prolonged period during the summer. This area extended from roughly Oldmans Point downriver to the vicinity of the Delaware Memorial Bridge. Both shortnose sturgeon and Atlantic sturgeon were taken in this reach of the River in follow-up gill net collections.

The focus of sturgeon sampling efforts has been adjusted to delineate the abundance of juvenile or pre-migratory age classes of Atlantic sturgeon as recommended in the ASMFC management plan. These studies employ the use of relatively small mesh gill nets and sample throughout the summer at the two locations where sturgeon were found to concentrate in the telemetry studies. This program was first conducted in 2001 and is being repeated during 2004. The levels for 2001 show levels similar to those of 1997 (see **Figure 5.7-1**) (source: Craig Shirey, DE Division of Fish and Wildlife, personal communication).

5.8 Short Nosed Sturgeon

Mark and recapture studies are currently under way to assess the size of the shortnose sturgeon population in Delaware Bay. The work is being funded through NOAA and the USACOE.

5.9 American eel

American eels (*Anguilla rostrata*) are abundant and wide spread in the Delaware Estuary. Eels live most of their life in freshwater and brackish water, leaving only to breed in the Sargasso Sea (located in the Central North Atlantic Ocean), after which the adults die. The larvae drift at sea for a time, and then metamorphose into glass eels and migrate to near shore waters. As the eels move upstream they become pigmented and are known as elvers. As they grow and become adult like they become known as yellow eels. After living for 2 to 4 years in freshwater and brackish water, they become sexually mature and finally metamorphose into silver eels in preparation for their migration back to the Sargasso Sea.

Eels were an important food resource for Native Americans and later the colonists. By the late 1960s, export of American eels to Europe and Asia began to increase, due to declines in those populations. During the mid 1970s and again in the mid 1990s, harvest of glass eels and elvers also increased to satisfy Asian markets. In 1995, the Atlantic States Marine Fisheries Commission (ASMFC) began development of an Interstate Fishery Management Plan for eel, due to concerns that eel's life history made it vulnerable to overexploitation and that some data indicated declines in portions of their range. In 2000 the Fishery Management Plan (FMP) was established, which includes harvest, reporting, and monitoring requirements. The Plan manages eels on a coast-wide basis.

Both New Jersey and Delaware allow commercial harvest for eel. Commercial Landings, in pounds, were as follows:

Year	Delaware	New Jersey	Total
2000	119,180	45,393	164,573
2001	121,513	57,700	179,213
2002	89,381	64,600	153,981
2003	155,516	unavailable	

Note: These landings represent state wide totals, which include landings from outside the Delaware River Basin.

All three states (Delaware, New Jersey, and Pennsylvania) allow recreational harvest. This harvest is relatively small and is believed to be declining. In addition the states conduct annual fishery independent young-of-the-year abundance surveys.

These surveys are designed to assess coast-wide annual recruitment. Survey locations for New Jersey and Delaware are outside the drainage basin of the Delaware River. The total numbers of eels captured during the surveys are as follows:

Year	Delaware	New Jersey	Pennsylvania
2000	151,176		98
2001	343,066	8,141	No Survey
2002	216,657	61,090	0
2003	81,233	3,206	0
2004	148,642	3,795	6

Notes:

Delaware: Site location is Millsboro Dam on Indian River. The Survey began in 2000, but the survey was started after eel passage had already begun, so numbers do not compare well with later years. In 2003 the low numbers are likely due to unusually cold water temperatures and increased water flow.

New Jersey: Site location is Patcong Creek, Linwood. Although survey work was carried out in 1999 and 2000 were not available in time for this report. Numbers for 2003 and 2004 are preliminary.

Pennsylvania: For 2000 the survey site was Long Hook Creek, Essington. In 2003 and later the survey site is the Fairmount Fish Ladder, Philadelphia.

6.0 HABITAT AND LAND MANAGEMENT

6.1 Habitat

The Delaware Estuary Program contracted with A.D. Marble & Co. for an assessment of non-aquatic habitat within the estuary watersheds, and their report was accepted in December 2002. The data sources used to create the Primary Habitat Unit Map and to perform the subsequent habitat analysis are listed in **Table 6.1-1.** Digital data sets were evaluated to determine which should be used to develop an initial community base map representing habitats and land covers of the entire study area. The guiding principles that were used to determine which data sets to include were:

- Data that was the most up-to-date available;
- Data that could be reasonably transformed into The Nature Conservancy (TNC) Classification System;
- Data which accurately represented the habitats, both spatially and qualitatively, of most importance to the Delaware Estuary Priority Species;
- Data which was comparable among all three states (DE, PA, and NJ); and
- Data sets with a high potential for being updated in the future

The community base map classifications will be referred to as Primary Habitat Units (PHU's). The selected data sets were reclassified into the TNC Classification System. The final community classifications comprising the finished PHU base map and their relative acreages and percentages in the Delaware Estuary Study Area are included in **Table 6.1-2** and **Figure 6.1-1.** The primary base data used to create this PHU base map was the National Land Cover Dataset (NLCD), National Wetland Inventory (NWI) wetland polygons, Delaware Wetland Mapping (SWMP) Data and New Jersey Freshwater Wetland data.

Due to its higher level of detail, state and NWI wetland data was used in place of NLCD wetland data in all cases. The remainder of the base data listed in **Table 6.1-2** was used in subsequent habitat analysis tasks associated with creation of the habitat preference mapping.

Habitat preference mapping

The finished habitat preference mapping represents the combined habitat needs of 83 terrestrial and wetland species or species assemblages, collectively the "Priority Species" residing in the Delaware Estuary Study Area. These 83 Priority Species were obtained from a list that was created by a DELEP Habitat Task Force. Each of the priority species are considered "important enough to the functioning of the Estuary that the ecosystem would lack wholeness or integrity without them." For the purpose of this analysis, only the habitats of terrestrial and wetland species were modeled. The preferred habitat of truly aquatic species, such as fish, was not modeled because the digital data necessary to accurately map their preferred habitat is not available.

The PHU define the broadest level of species habitat preference. For each species, one of the following preference values was assigned to every PHU in the analysis:

- Strongly preferred
- Neutral
- Avoidance

Strongly preferred habitats represent a primary habitat type for the species that is crucial in its life cycle. In the neutral preference, the habitat may not be preferred by this species, but the species would not necessarily avoid this habitat and in some cases, such as lack of primary habitat, the species may even be abundant in the habitat. The avoidance values were reserved for Primary Habitat Units where the species would rarely be found. This process essentially sets up a range of available habitat for each species within the study area, based on land cover and broad vegetative communities defined by the TNC Classification System. This preference assessment is described thoroughly in A.D. Marble (2003).

The results of the habitat preference analysis are shown graphically on the Final Habitat Preference Composite Map (**Figure 6.1-1**) of this report. As this map illustrates, estuarine wetland habitats adjacent to the Delaware Bay and its tidal tributaries have generally received the highest habitat preference rank of "4." Riparian corridors throughout the Study Area often receive this rank as well. These results are not surprising, since many of the 83 Priority species rely very heavily on these two general habitat types. These highest habitat preference areas are often surrounded by regions that received a habitat preference rank of "3" on the Final Habitat Preference Composite Map. Other areas with this rank include certain forested portions of the study area, especially wetland forests and forested land associated with the New Jersey Maurice River, New Jersey Pine Barrens, and certain portions of the Ridge and Valley Province in Pennsylvania.

Regions of low to moderate habitat preference as indicated by ranks of 0 to 2 on the Final Habitat Preference Composite Map include highly developed urban and suburban areas, mining regions, non-forested land, and areas not in close proximity to riparian habitats. Again, these results are not unexpected, considering the habitat needs of the Priority Species as summarized in the Habitat Matrix for Priority Species of the Delaware Estuary.

6.2 Protected Lands

Two of the major factors in the comprehensive planning and protection of habitat and open space in the Delaware Estuary are the size and location of protected lands. Data presented in section 6.2 was collected by the Delaware Valley Planning Commission (DBRPC) for their own purposes and doesn't cover the entire Estuary area however, it provides a valuable indicator of development patterns and provides a stimulus for additional data collection in the future Data available for 2000-03 shows that all three states and most of the counties and local governments within them have invested new resources in the acquisition of land for its aesthetic, habitat and recreation value. Additional protection has been achieved through the substantial action of non-governmental land trusts and other private efforts. There are several gaps in the land protection data that are readily available, but the consequence of many municipal and county bond and dedicated tax investments shows through clearly.

As of 2002 a total of 750,689 acres (public and private) in New Jersey were protected (over 25% of the area of the 11 counties providing data), 52,010 acres in New Castle County, Delaware were protected (over 19%) and 453,982 acres in Pennsylvania were protected (almost 13% of the 11 counties providing data) **(see tables 6.2-1 and 6.2-2).**

Public land

Since 2000, protected public parkland was increased by over 25,000 acres in the 9 county DVRPC Region with the greatest gain attributed to municipal parklands.

Table 6.2-2 shows that protected parklands in three of the 23 counties providing data for 2002 exceeded 25% of the total county land area (including Cape May, with over 32%, and Burlington, with over 28%).

Table 6.2-3 shows that between 2000 and 2003, open space protected by municipalities increased by over 40% in five counties (Burlington, with a 96% increase, Gloucester with a 68% increase, Delaware, with a 56% increase, Mercer, with a 43% increase, and Bucks, with a 42% increase) of the nine counties providing data for this time span. Open space protected by counties increased by more than 30% in two counties (Burlington, with a 66% increase, and Camden, with a 32 % increase) of those same nine counties that provided data for 2000-03.

Private protected land

Table 6.2-1 shows that preserved farmland in the nine counties that provided data for 2000-03 increased by approximately 84% in Chester, 72% in Bucks, 36% in Gloucester and 33% in Burlington County. Open space protected by land trusts and private land owners in those same counties increased by 143% in Burlington County, 76% in Gloucester County and 24% in Mercer County.

Table 6.2-3 shows that protected private lands (i.e. preserved farm land, trust owned and leased lands) in seven of the 23 counties providing data for 2002 exceeded 5% of the total county land area (including Cumberland, with over 10%, Chester, with almost 10%, Salem, with almost 9%, and Berks, with almost 7%).

7.0 IDENTIFICATION OF DATA GAPS

The following discussion identifies in formation needs for both scientific recommendations and additional data:

7.1 Science Gaps

- We need to clearly define eutrophication in quantitative terms of water quality impairment in the Delaware Estuary. The current guidance does not identify the actual effects related to nutrient impacts to the waterbody. This could include documentation regarding nuisance algal blooms and aquatic plants, spatial and temporal extent of fish kills, sporadic water quality impairments etc.

- Additional habitat mapping for the 13 Counties encompassing the Delaware Estuary needs to be provided. This will insure that a clear picture of habitat protection for the entire estuary will be developed.

7.2 Data Needs

- The nutrient loads from groundwater inputs need to be investigated more fully.
- Stimulatory studies of phytoplankton growth to assess limiting nutrients and the potential for nutrient enriched growth.
- We need to promote the use of more automatic monitoring devices in the estuary.
- Protected lands data, estuary wide is needed.
- Improved knowledge of early life history stages for blue crabs (including environmental factors influencing growth and survival).
- Improve fisheries dependent data collection for blue crab.
- Several near-shore areas at the mouth of some tributaries of Delaware Bay need to be monitored more frequently for dissolved oxygen to establish whether water quality standards are being met.
- Validation of hydroaccoustic data regarding American shad abundance estimates.

8.0 MANAGEMENT CONSIDERATIONS

The following are management options for consideration by the Steering Committee of the Delaware Estuary Program:

- Provide for complete and continual updates to resource stock assessment based on the best available scientific information and computer models available.
- Evaluate the biological and socioeconomic effects of controls on fishing gear to discards and by-catch.
- Enhance inter-state resource management efforts and data collection protocols for blue crab.
- Exchange biological and fisheries-related information between Delaware, New Jersey, and the private sector on a regular/continuing basis.
- Coordinate data analysis and establish peer review teams to review stock assessment analyses. Implement comprehensive, complementary management approaches based on cooperative, synchronized efforts from New Jersey and Delaware natural resource agencies.
- Develop a consistent approach to harvest needs. There continues to be significant concern regarding the sustainability of the current horseshoe crab bait harvest by many user groups. However, the management recommendations supported by different user groups varies substantially, from unrestricted harvest to a coastwide cap on landings 60-80% below the reference period landings.
- Avoid increases in fishing effort for blue crab and give consideration to reducing fishing effort. In addition, targeting of mature female crabs in the fishery, particularly when they are concentrated, should be discouraged, in order to protect the spawning stock
- Set a threshold to identify whether resource protection measures need to be pursued with any species whose population is documented as declining over the previous five years.
- Increase coordination and data sharing among environmental groups, regulatory agencies, and officials who are collecting data in the estuary.
- Implement a broad based effort to achieve PCB reductions from point and non-point sources to move towards reduction of fish advisories in the estuary.
- Employ regional approaches for sediment management by improving the beneficial use of dredged materials for habitat restoration.
- Improve coordination and monitoring for invasive species management.

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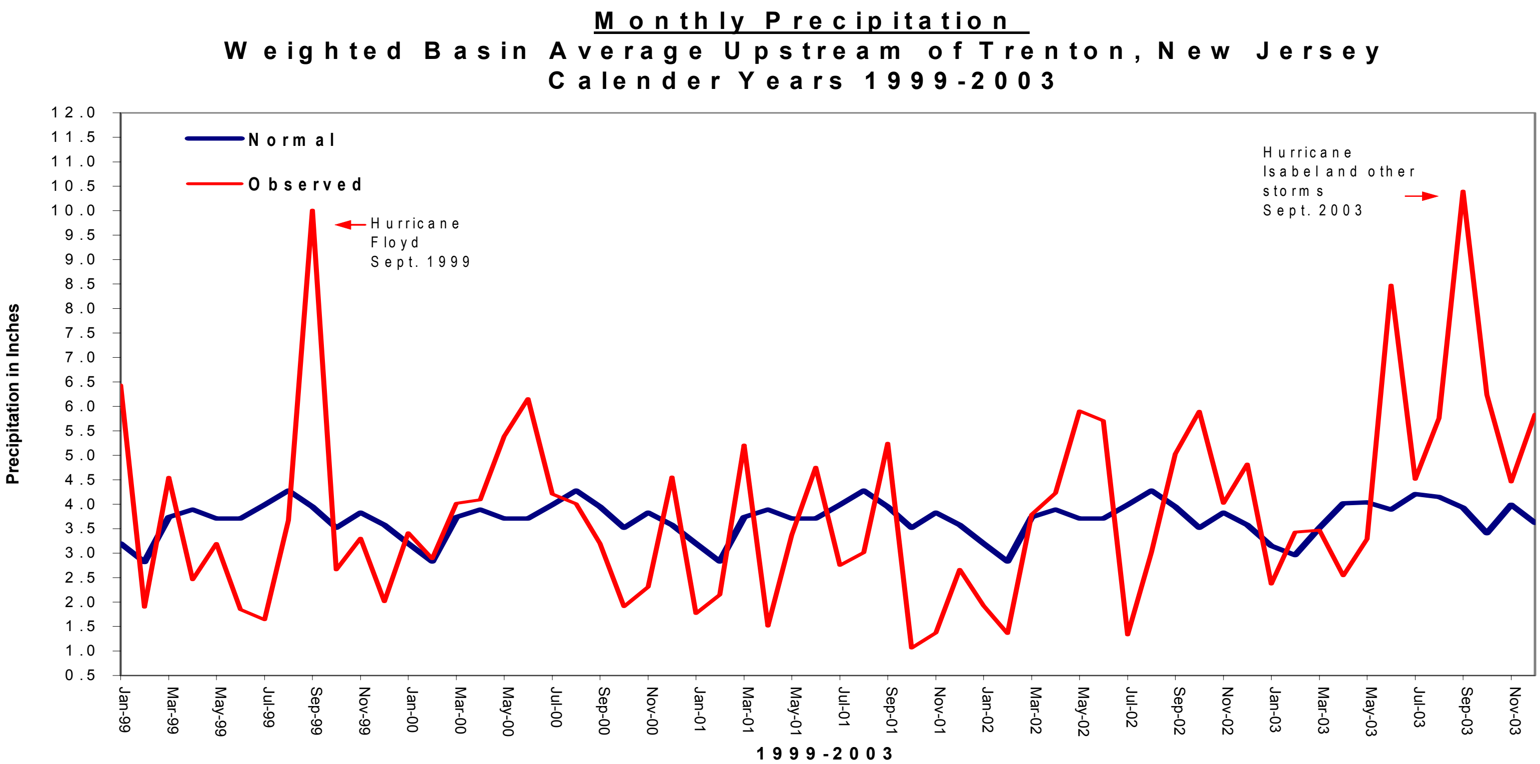
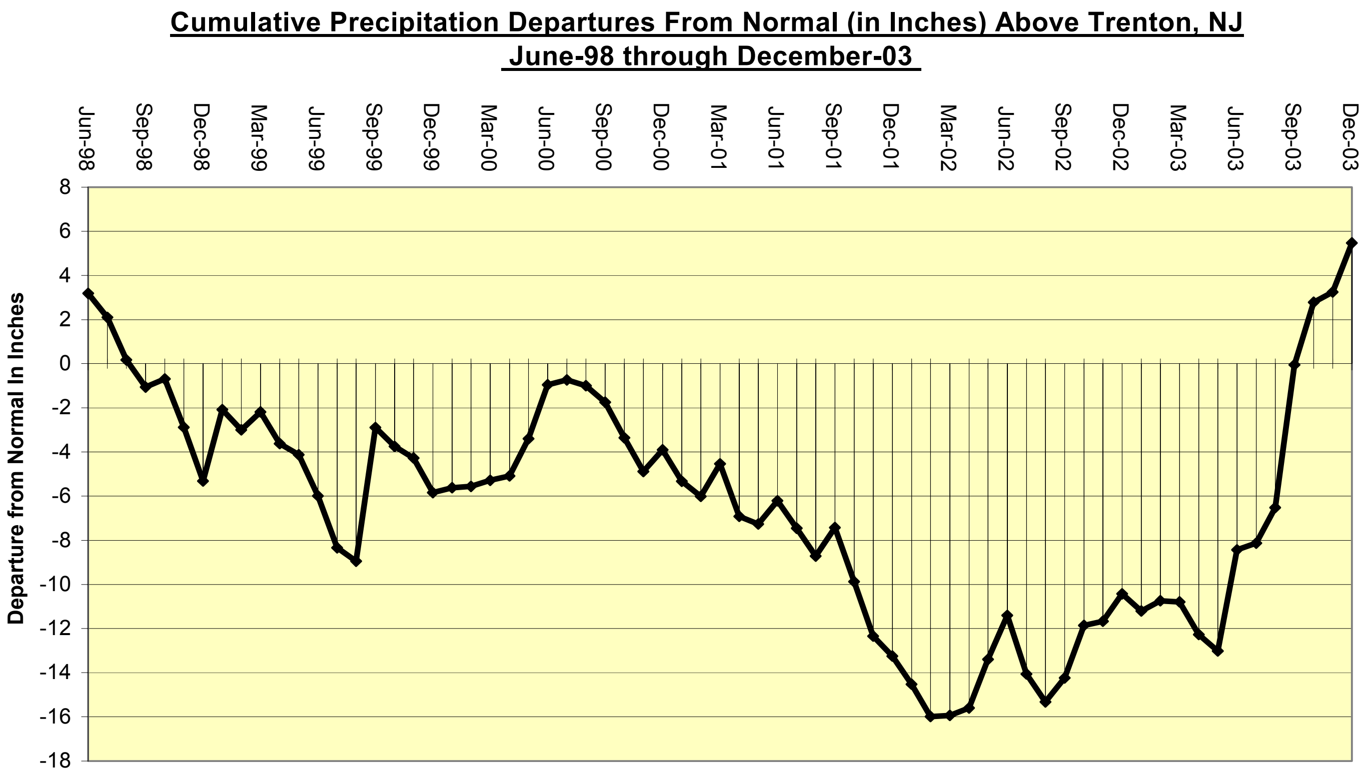
10.0 FIGURES

Figure 1.1.1



ata Source: National Weather Service. Normal values are means for period of record from 1971-2000.

Figure 1.1-2



Normal values are based on National Weather Service data for the period 1971-2000.

Figure 1.1-3

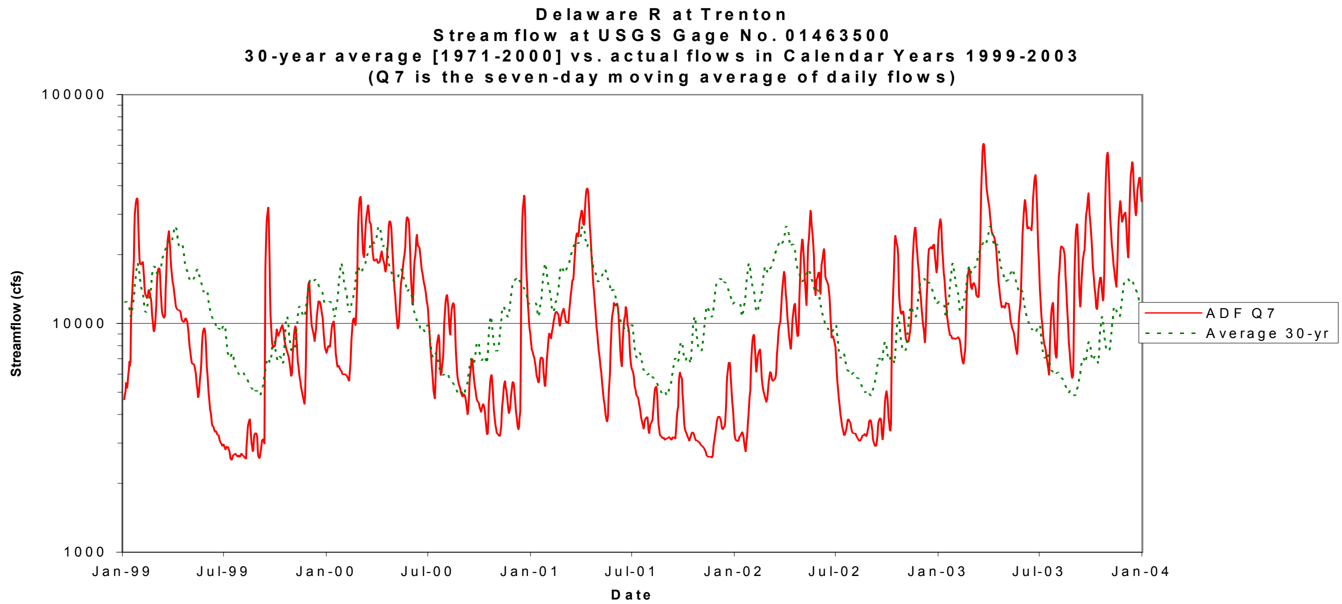


Figure 1.1-4

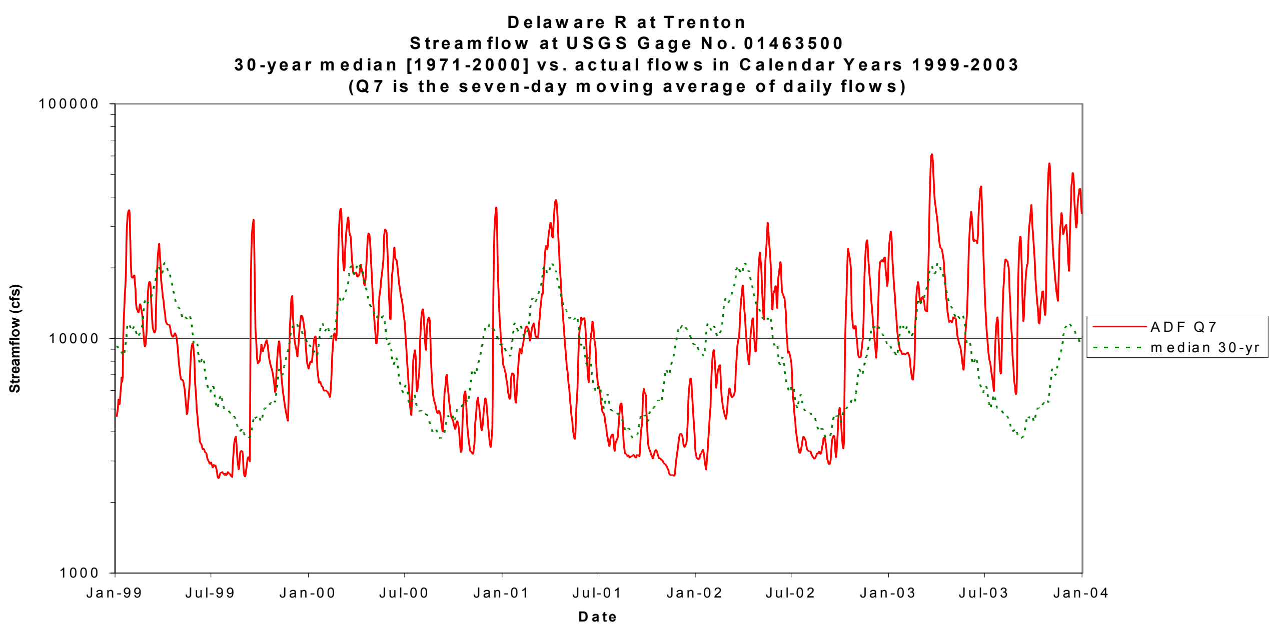
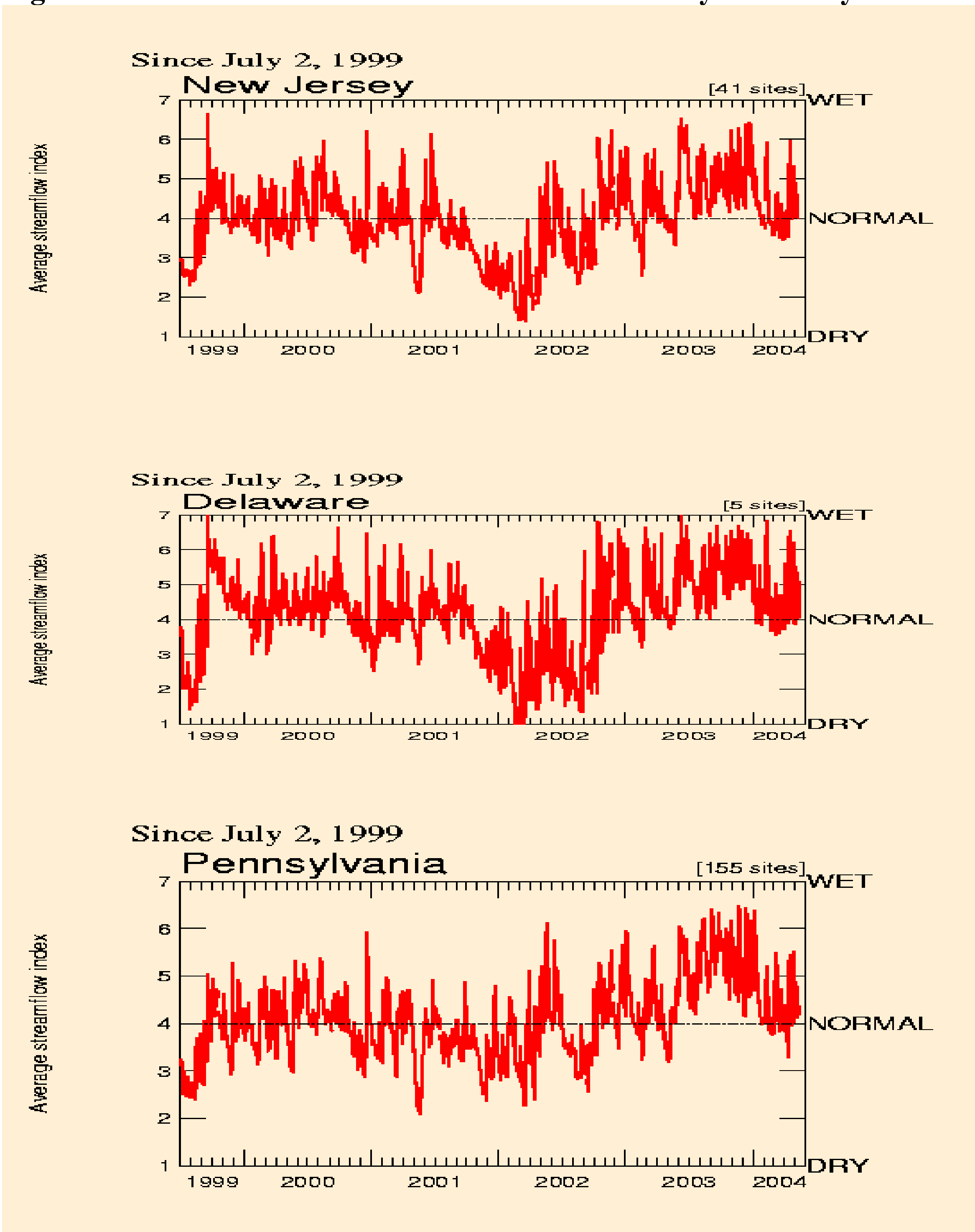


Figure 1.1.5 USGS Streamflow Conditions Index July 1999-May 2004



Con’t figure 1.1.5

Note:
The plots represent the average of all stations in the respective state. Accordingly, they do not reflect conditions exclusively in the Delaware Estuary. The New Jersey and Delaware plots are believed most representative of conditions in the Estuary watershed during the dry conditions of 1999 and 2001-2002.

Explanation - Percentile classes						
1	**2**	**3**	**4**	**5**	**6**	**7**
New low	< 10	10-24	25-74	75 - 89	≥ 90	New high

Plots and definitions provided by the U.S. Geological Survey

Figure 1.2-1 1999-2003 Location of the 7-Day Average of the 250-ppm Isochlor

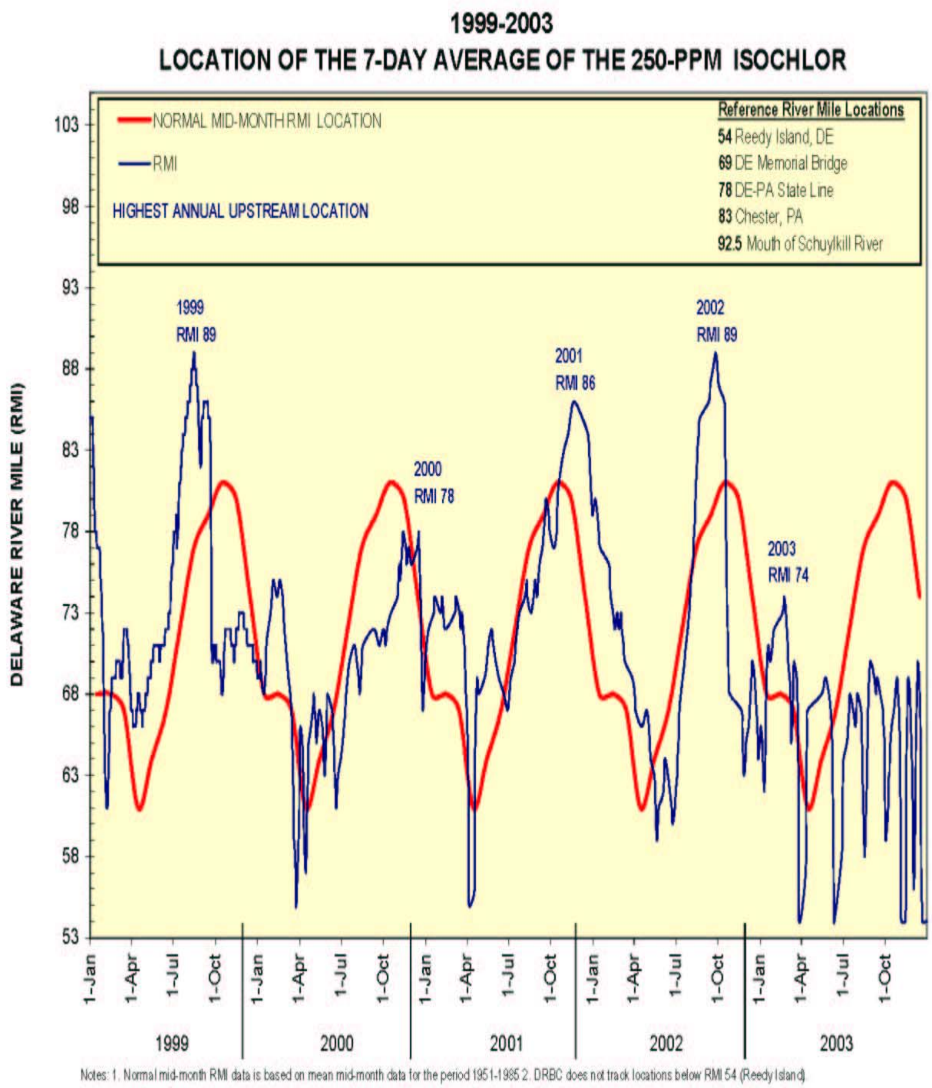


Figure 1.2-2 Furthest Upstream Locations of the 250-ppm Isochlor in the tidal Delaware River over the period 1999-2003

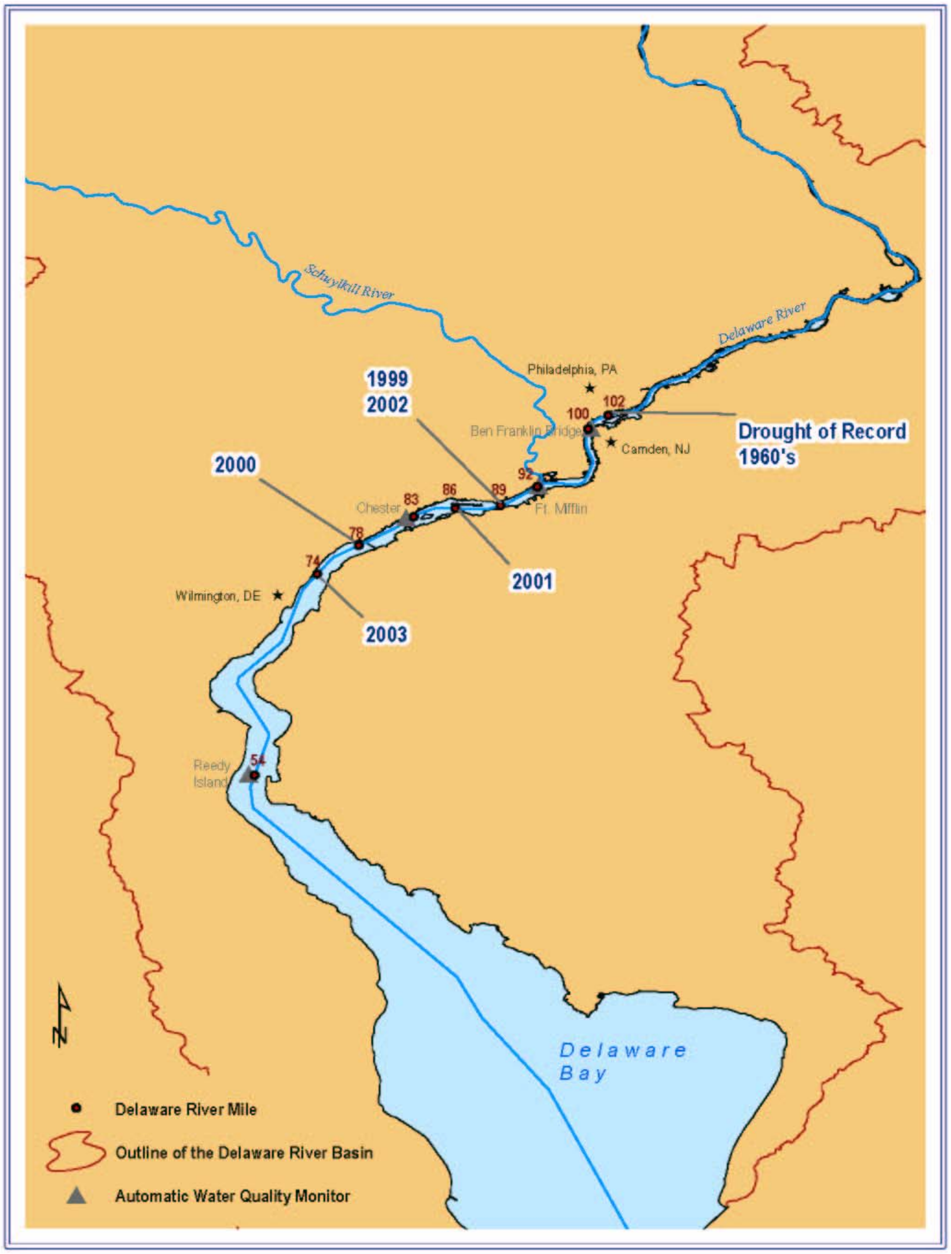
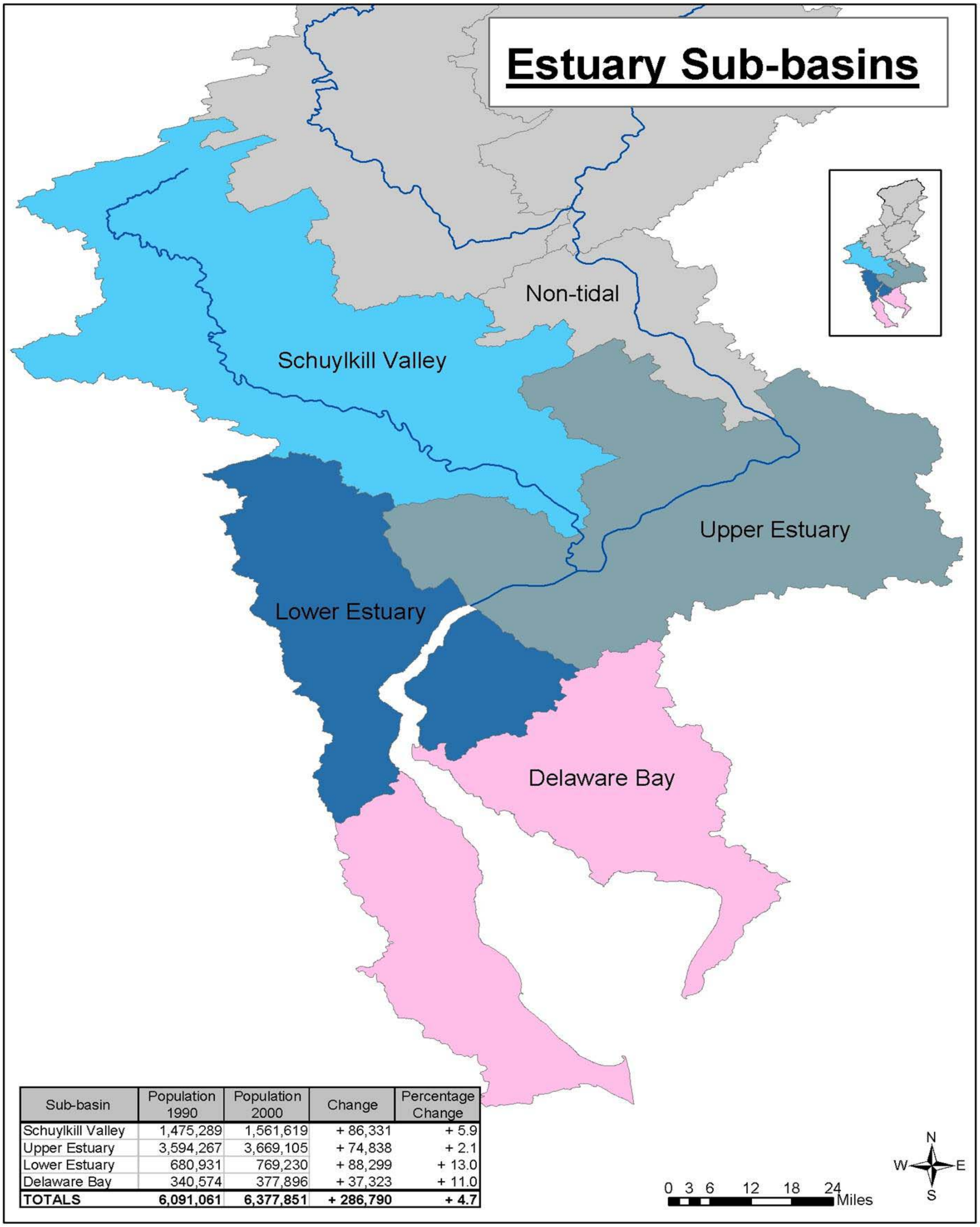


FIGURE 1.3-1 Delaware Estuary Sub- Basins



Sub-basin	Population 1990	Population 2000	Change	Percentage Change
Schuylkill Valley	1,475,289	1,561,619	+ 86,331	+ 5.9
Upper Estuary	3,594,267	3,669,105	+ 74,838	+ 2.1
Lower Estuary	680,931	769,230	+ 88,299	+ 13.0
Delaware Bay	340,574	377,896	+ 37,323	+ 11.0
TOTALS	**6,091,061**	**6,377,851**	**+ 286,790**	**+ 4.7**

Figure 1.3-2 a-f Water Use Withdrawals

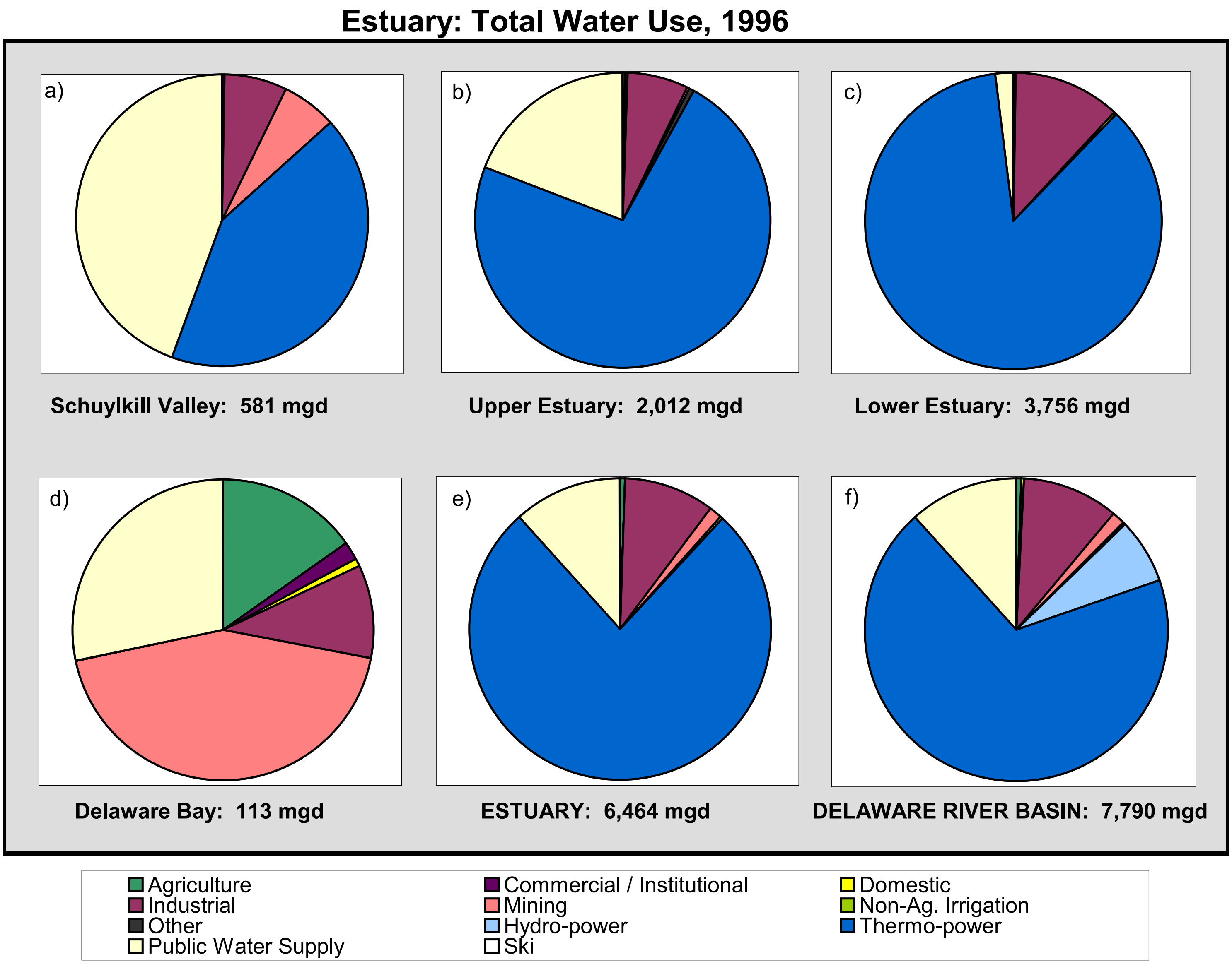


Figure 1.3-3 a-f Consumptive Water Use

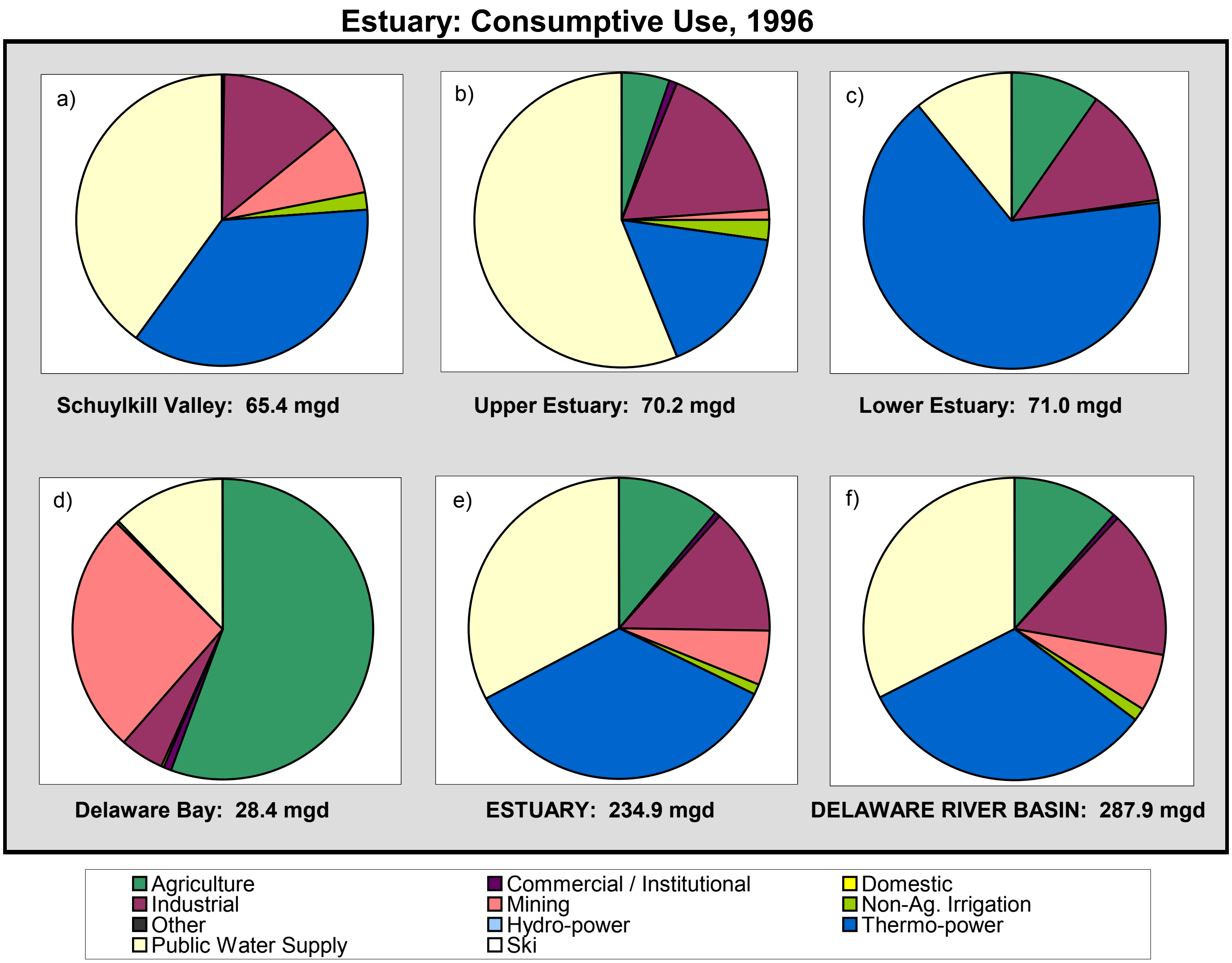


FIGURE 2.1-1 ESTUARY BOAT RUN MONITORING SITES

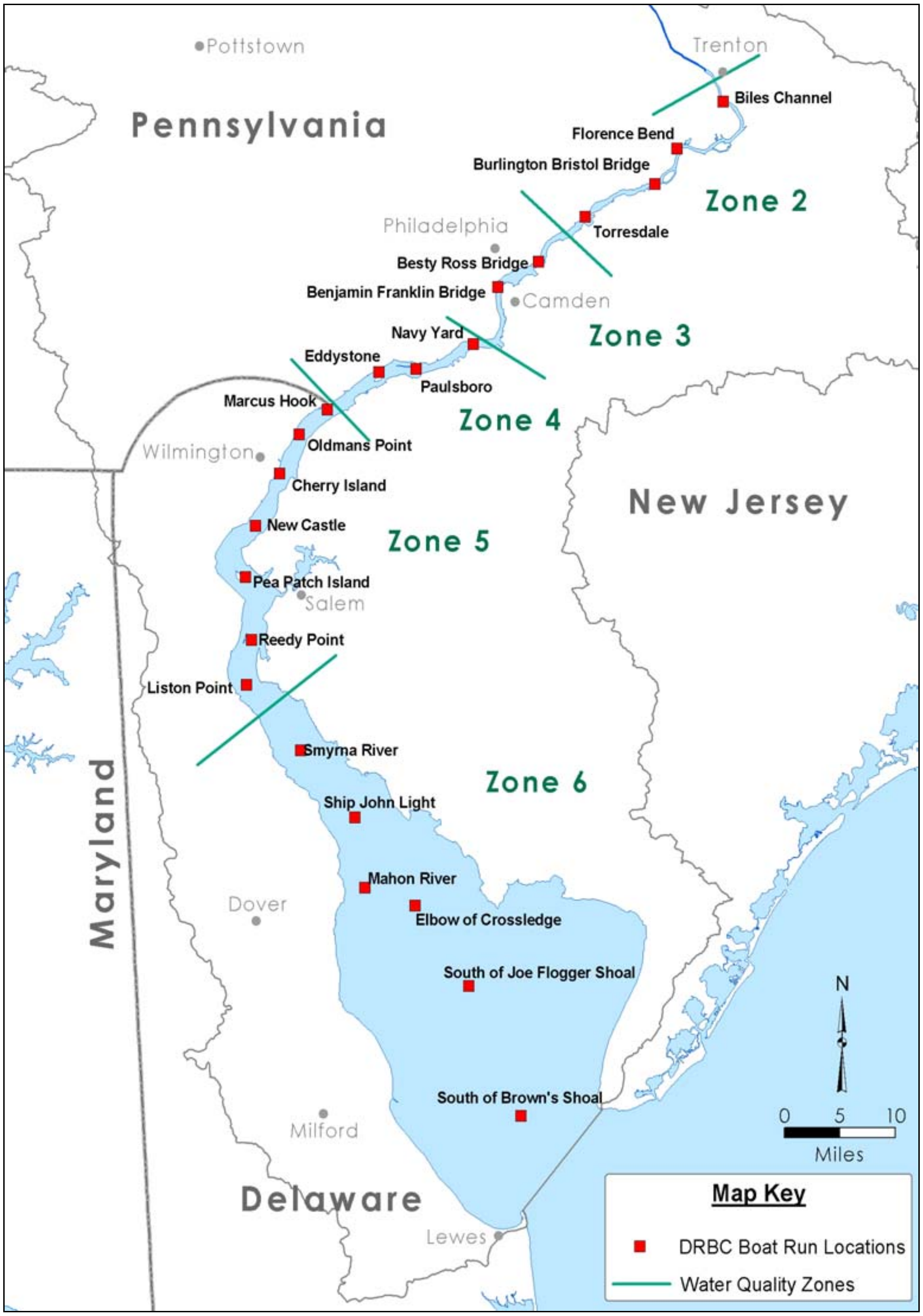
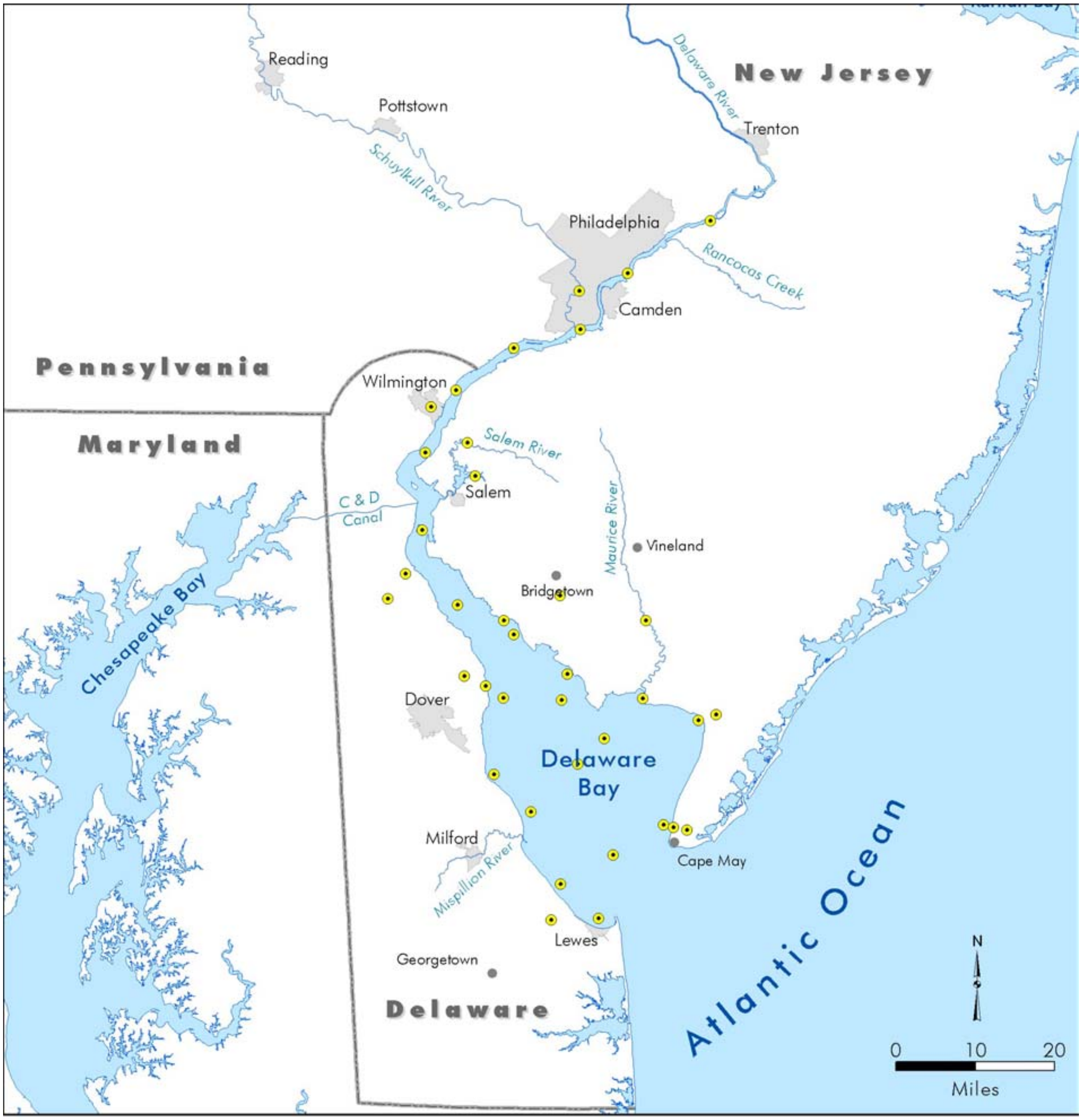


Figure 2.2-1 the Delaware Estuary 2000 National Coastal Assessment Program Sampling Stations



2000 National Coastal Assessment Locations

Figure 2.2-2 Numerical Abundance of Fishes Collected Under the National Coastal Assessment Program 2000

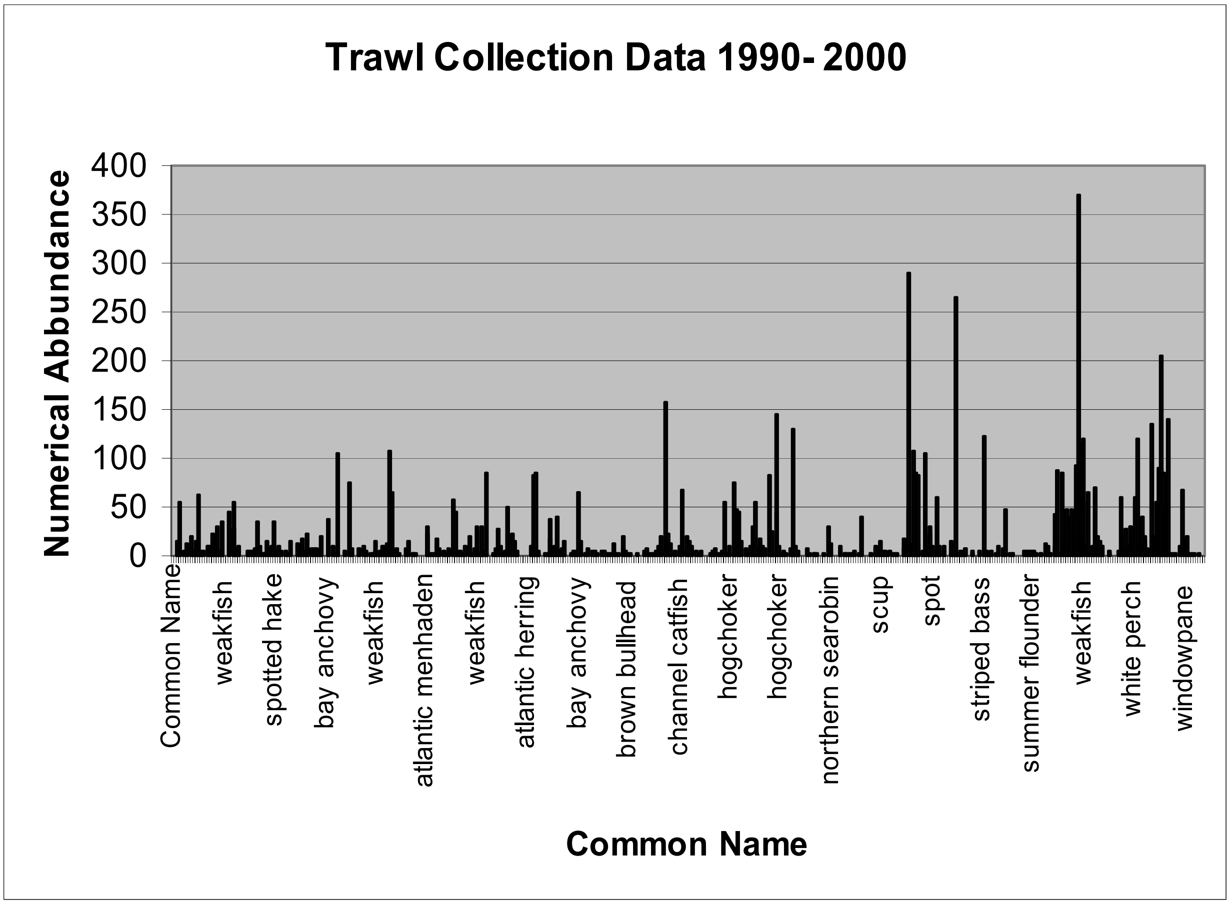


Figure 2.3-1 Distribution of Habitat Nodes in Delaware Bay

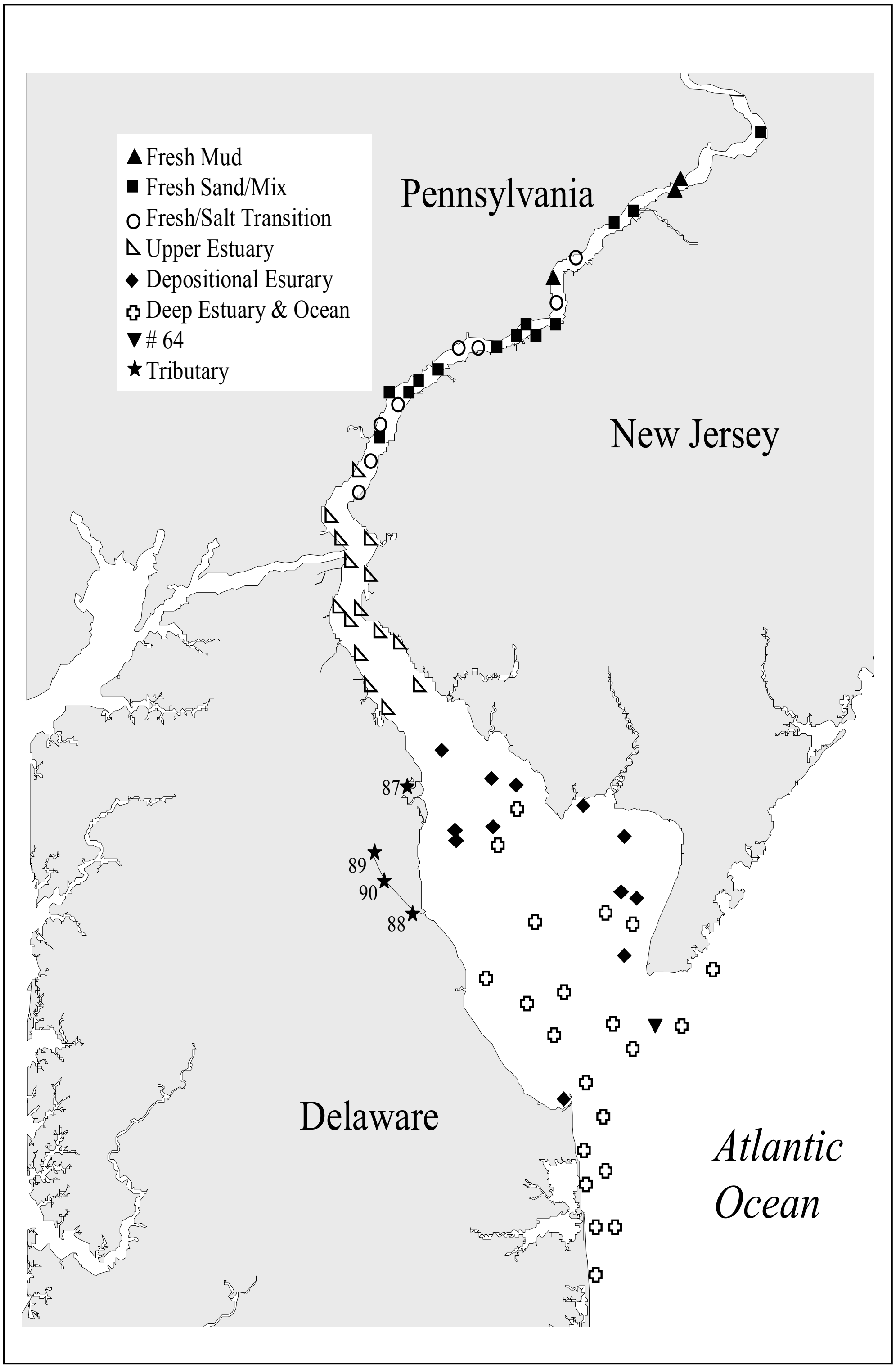


Figure 2.3-2 Nodal Analysis of Delaware Bay Benthic Communities

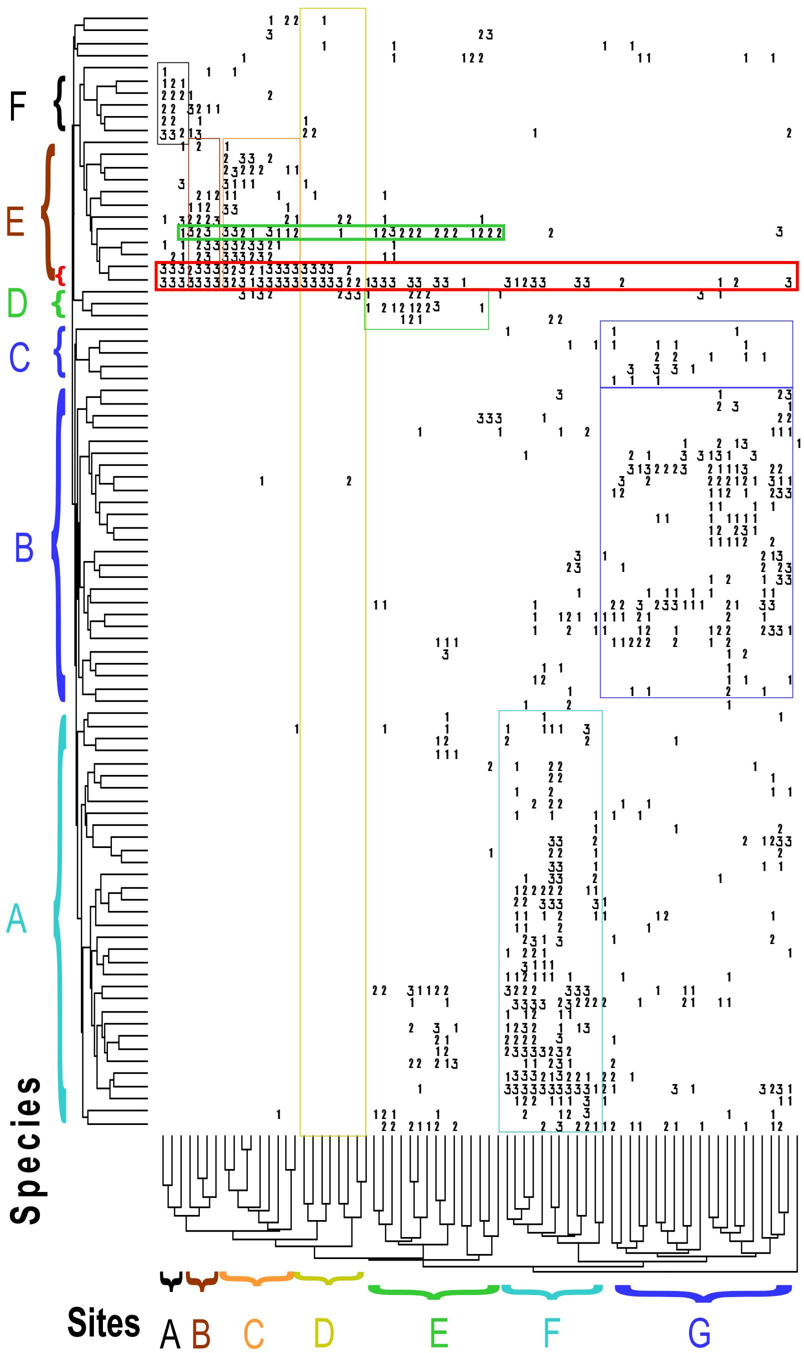


Figure 2.3-3 Number of Species Collected During the MAIA Program

NODAL ANALYSIS SPECIES ABUNDANCE DATA FILTERS

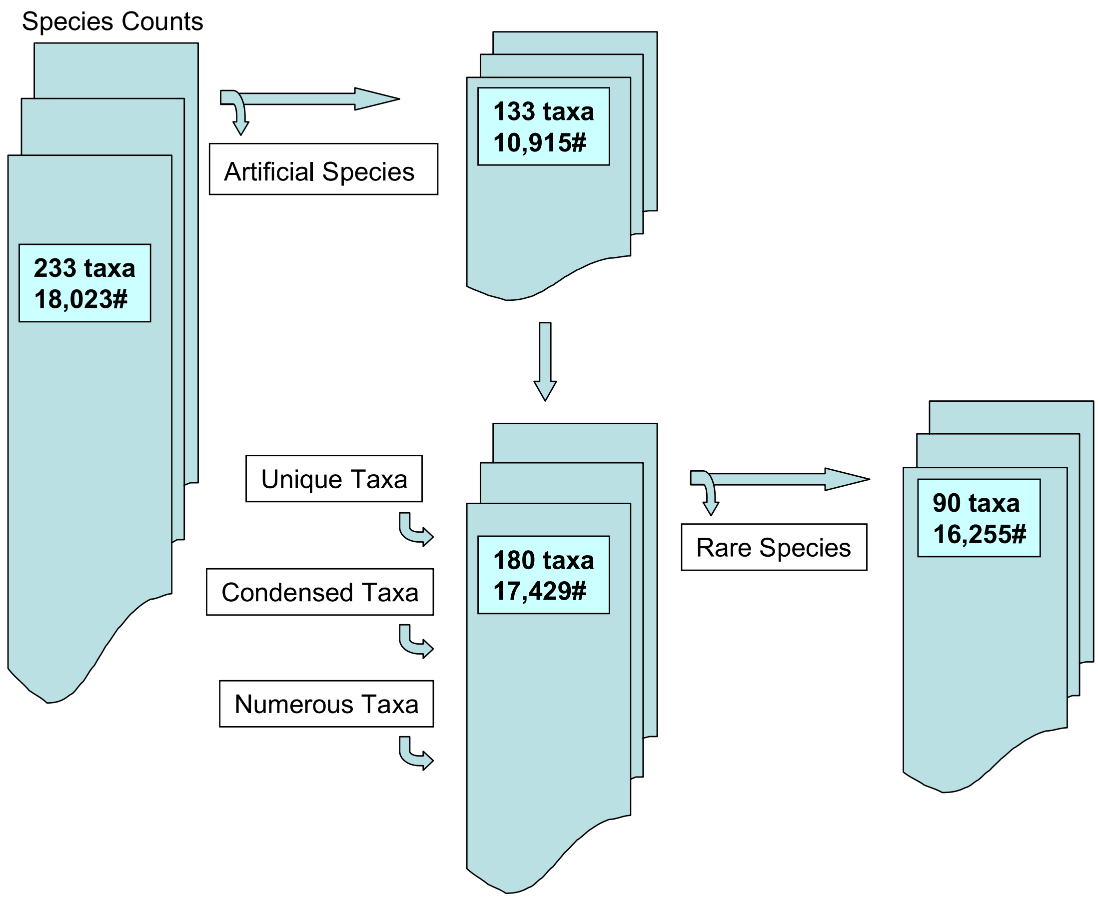


Figure 2.3-4 Species/Site Clusters

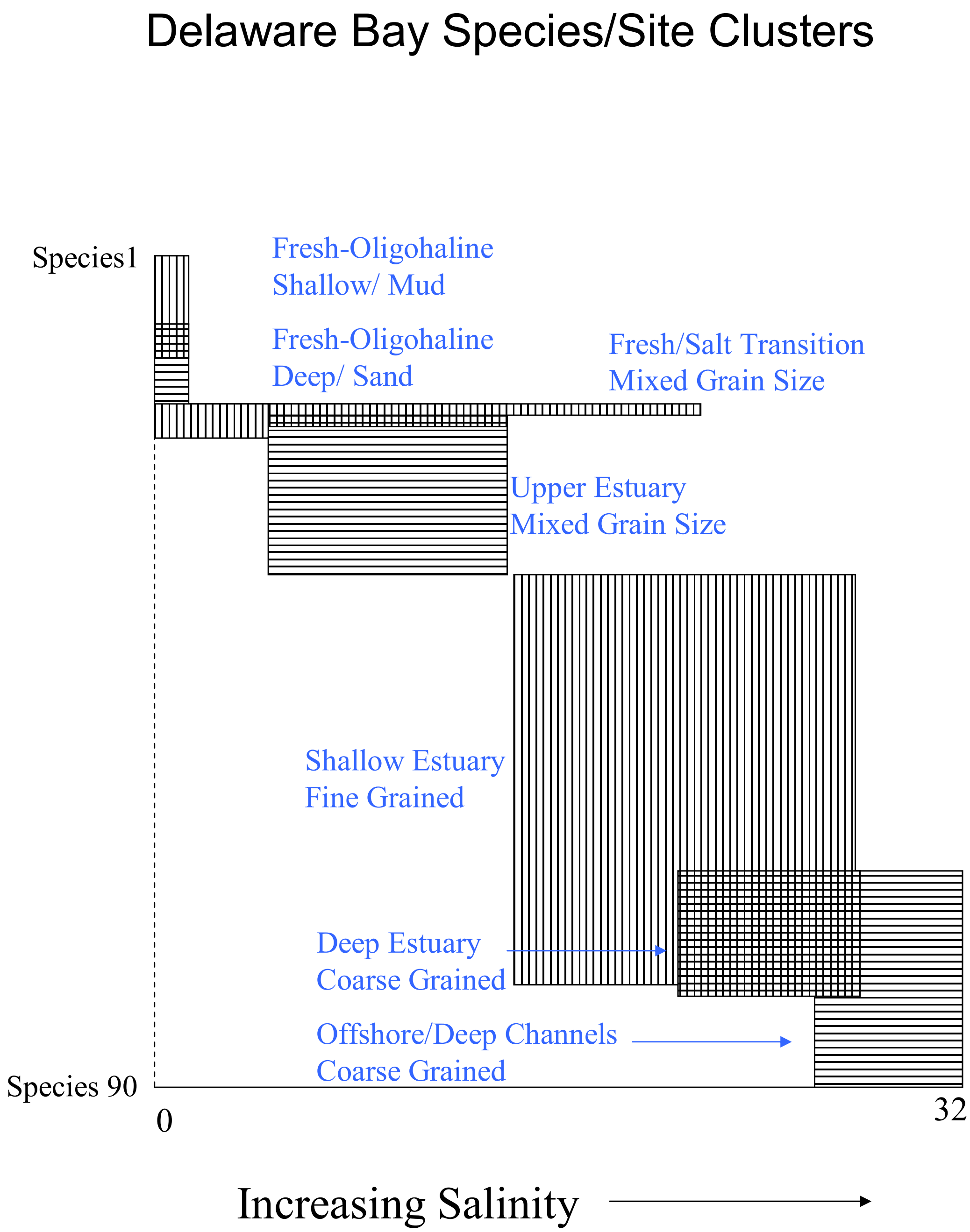


Figure 2.4-1 Spatial Distribution of Sediment Types in the Tidal Delaware River

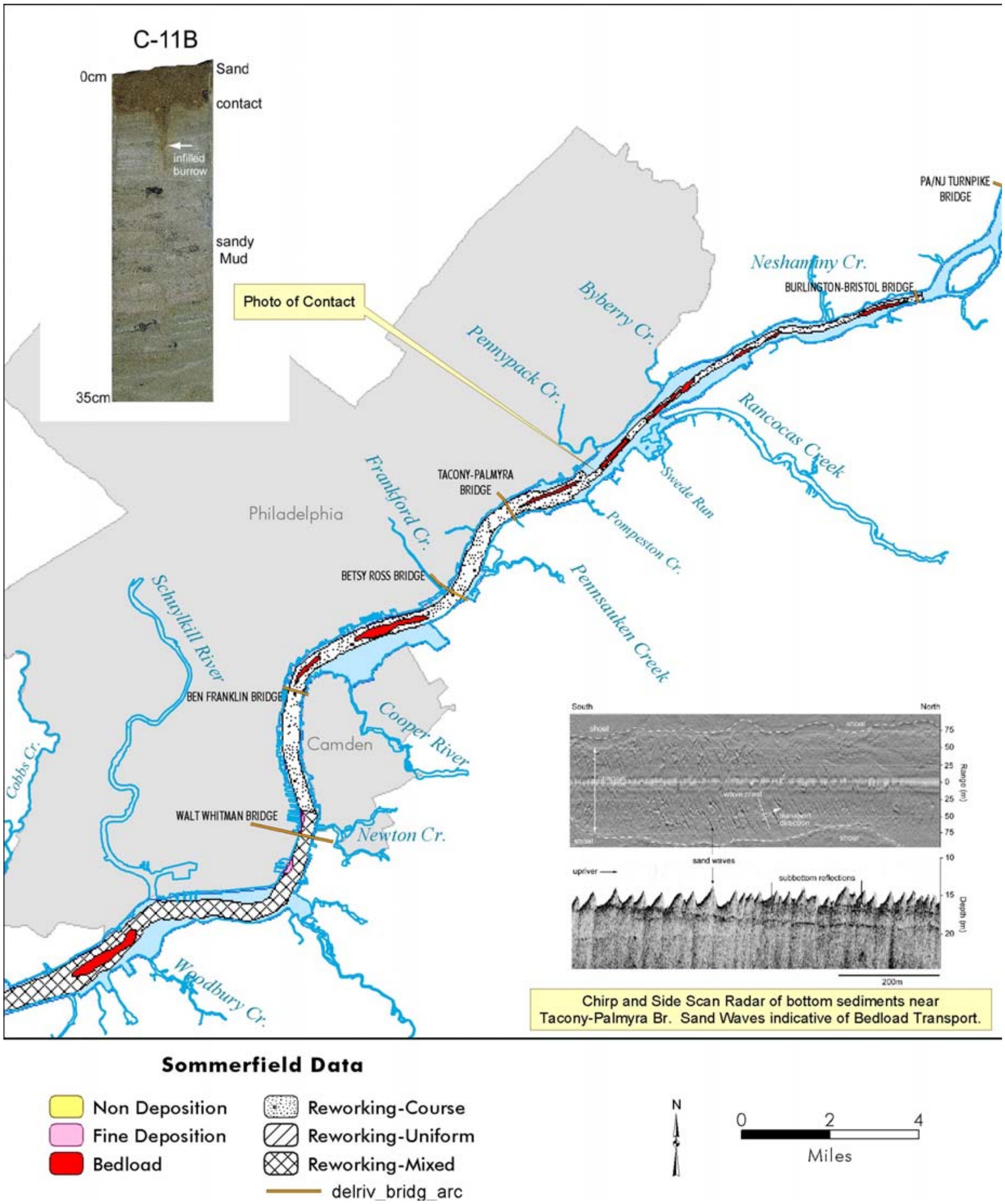


Figure 2.4-2 Sedimentation Rates in the Tidal Delaware River

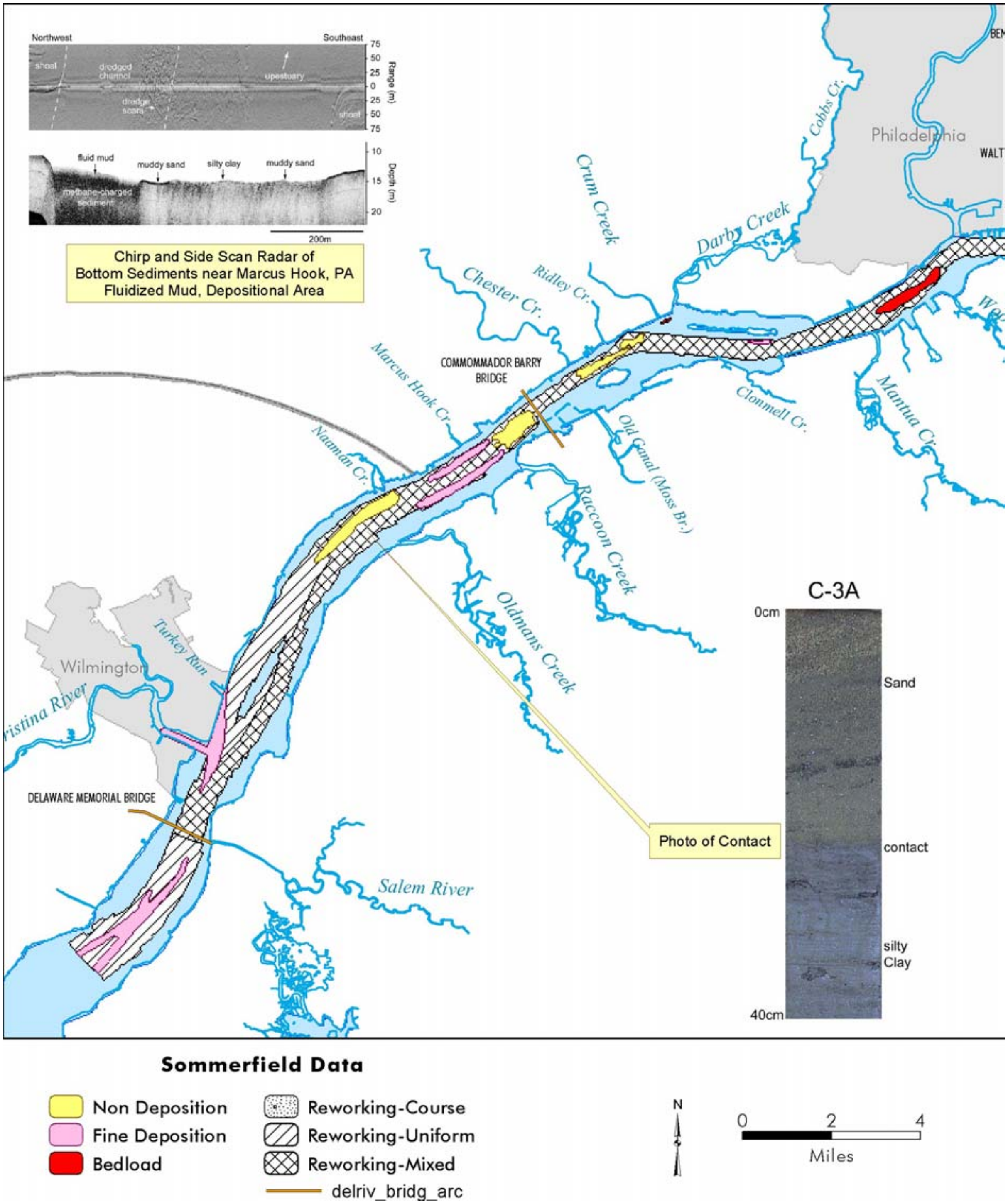


Figure 2.4-3 Analysis of PCB Concentration in Sediment Cores Collected in the Delaware Estuary

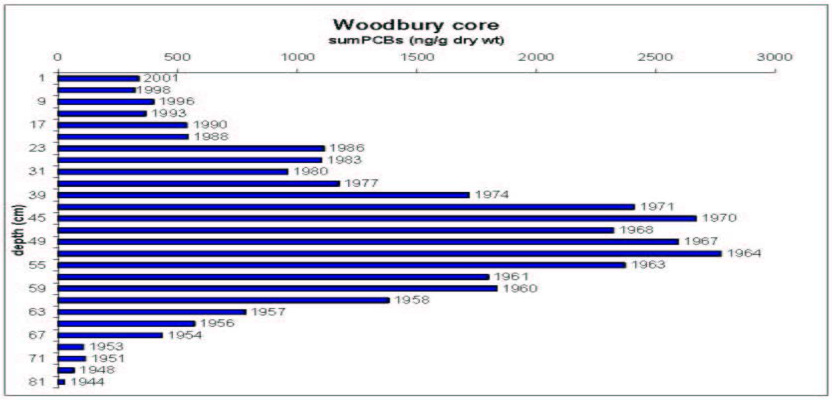


Figure 2

Figure 3.1-1 Delaware River Basin Commission Water Quality Zones

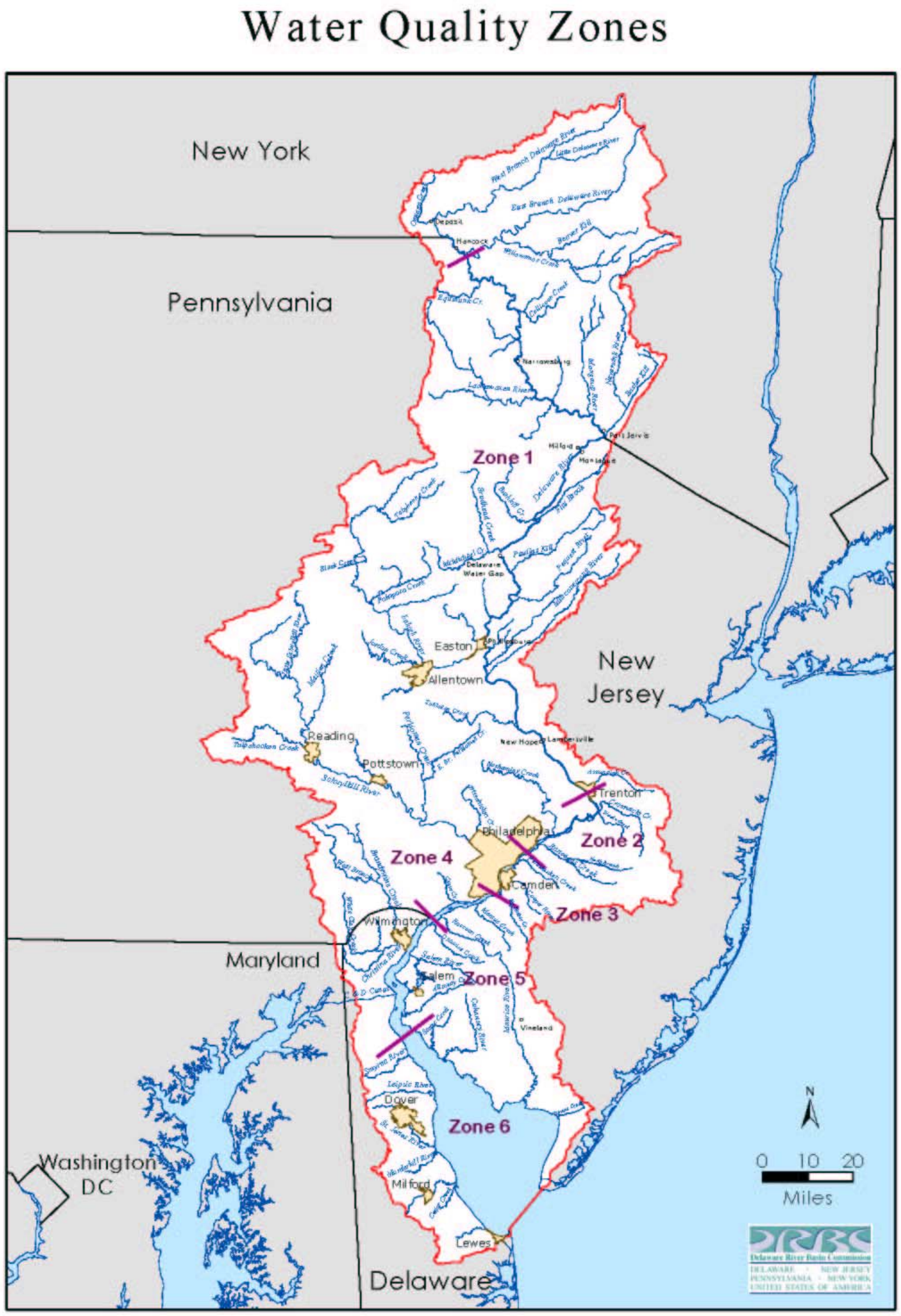


Figure 3.1-2 Summertime Dissolved Oxygen in the Delaware Estuary over the Report Period

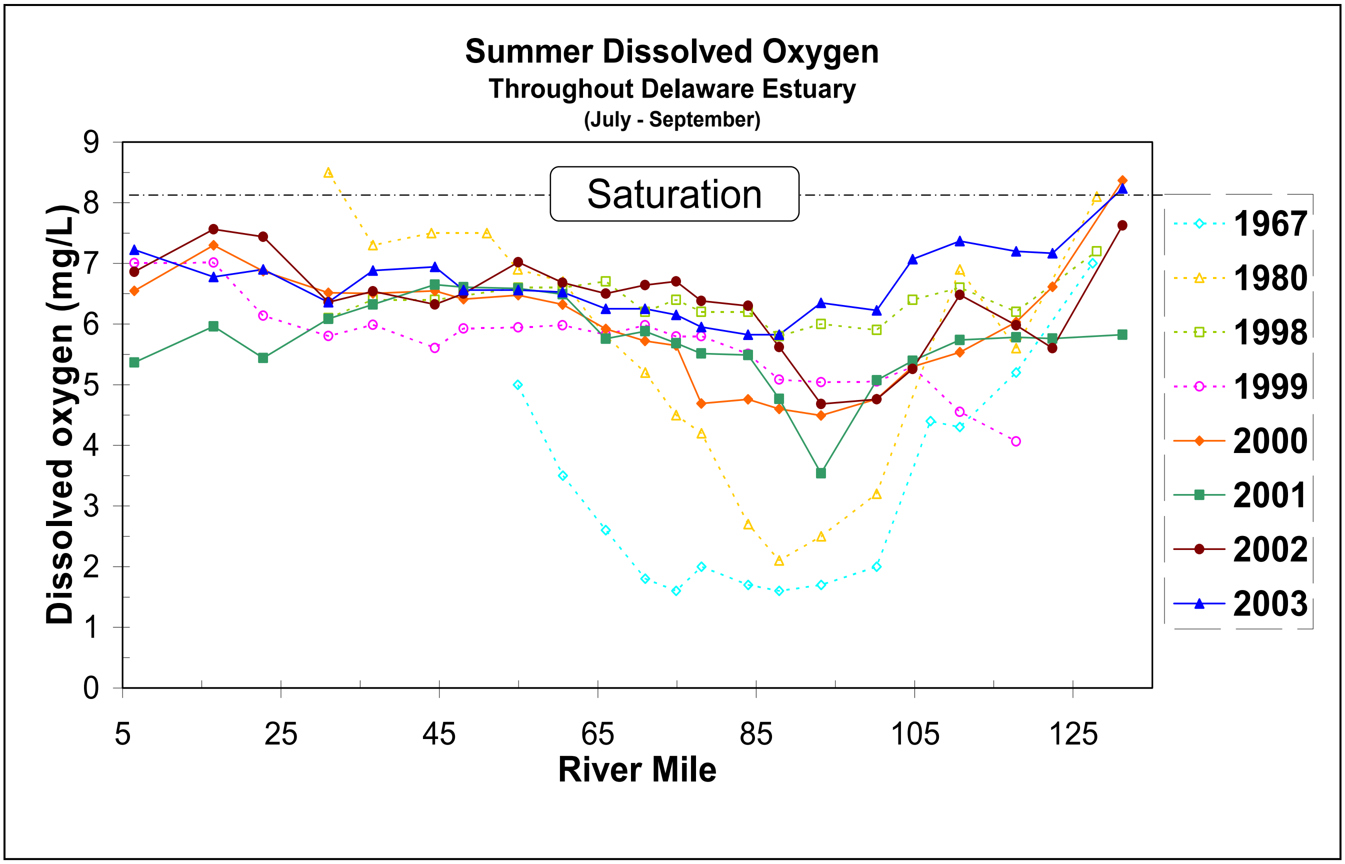


Figure 3.2-1 Fecal Coliform Levels in the Delaware Estuary

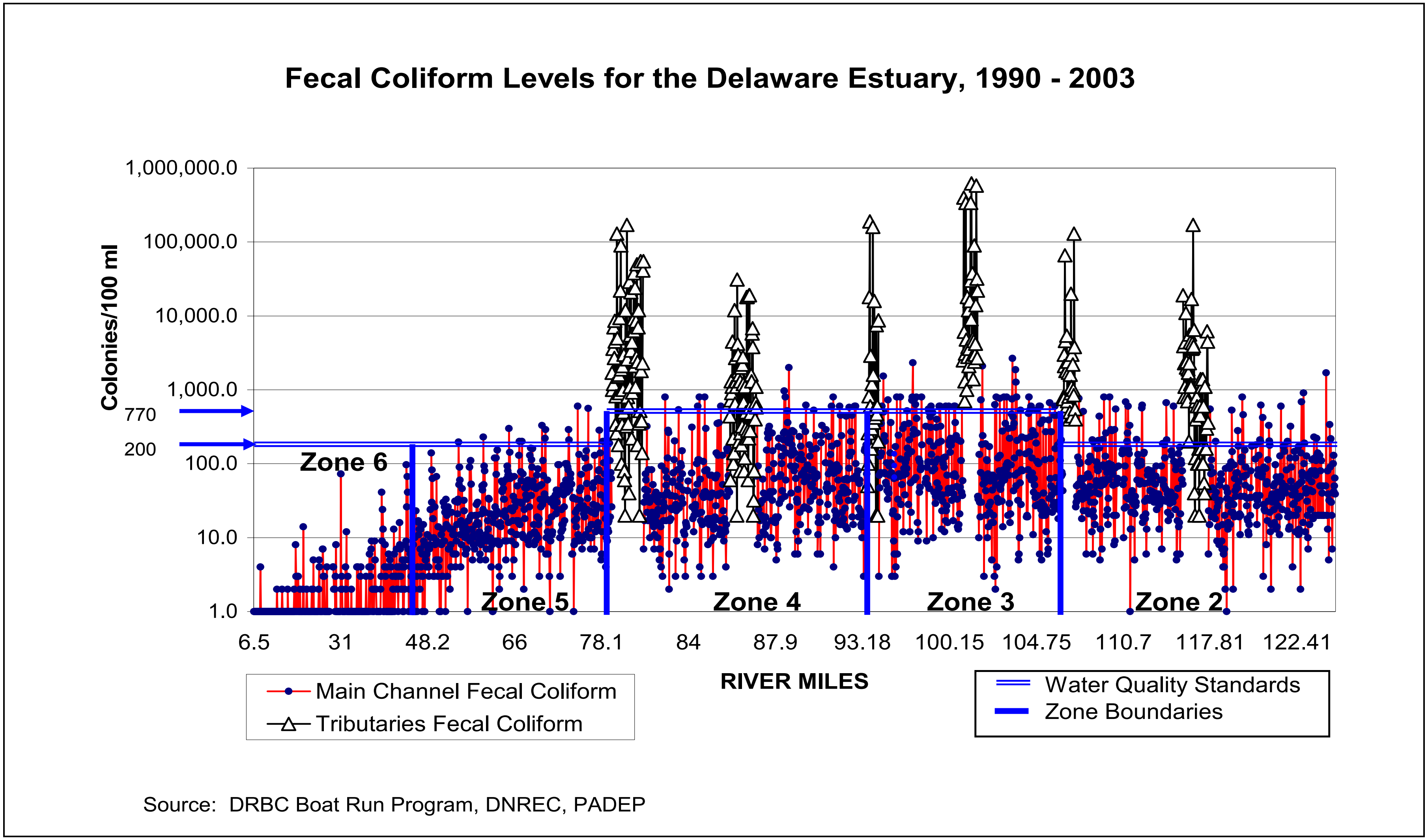


Figure 3.3-1 Shellfish Approved/Probitied Areas in the Delaware Estuary

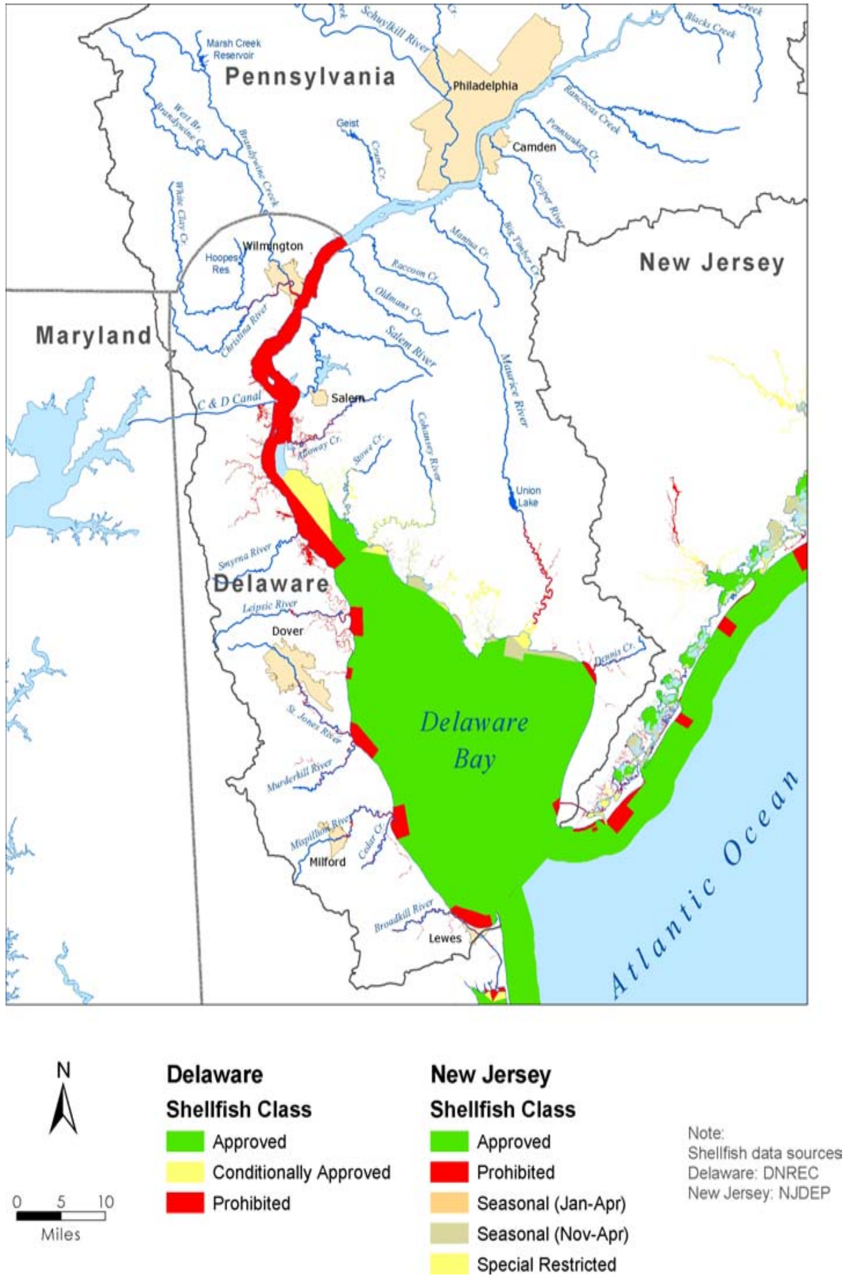


Figure 3.3-2 Graph of the Acreage of Approved and Prohibited Shellfishing Areas in Delaware Bay over the Period 1999-2003

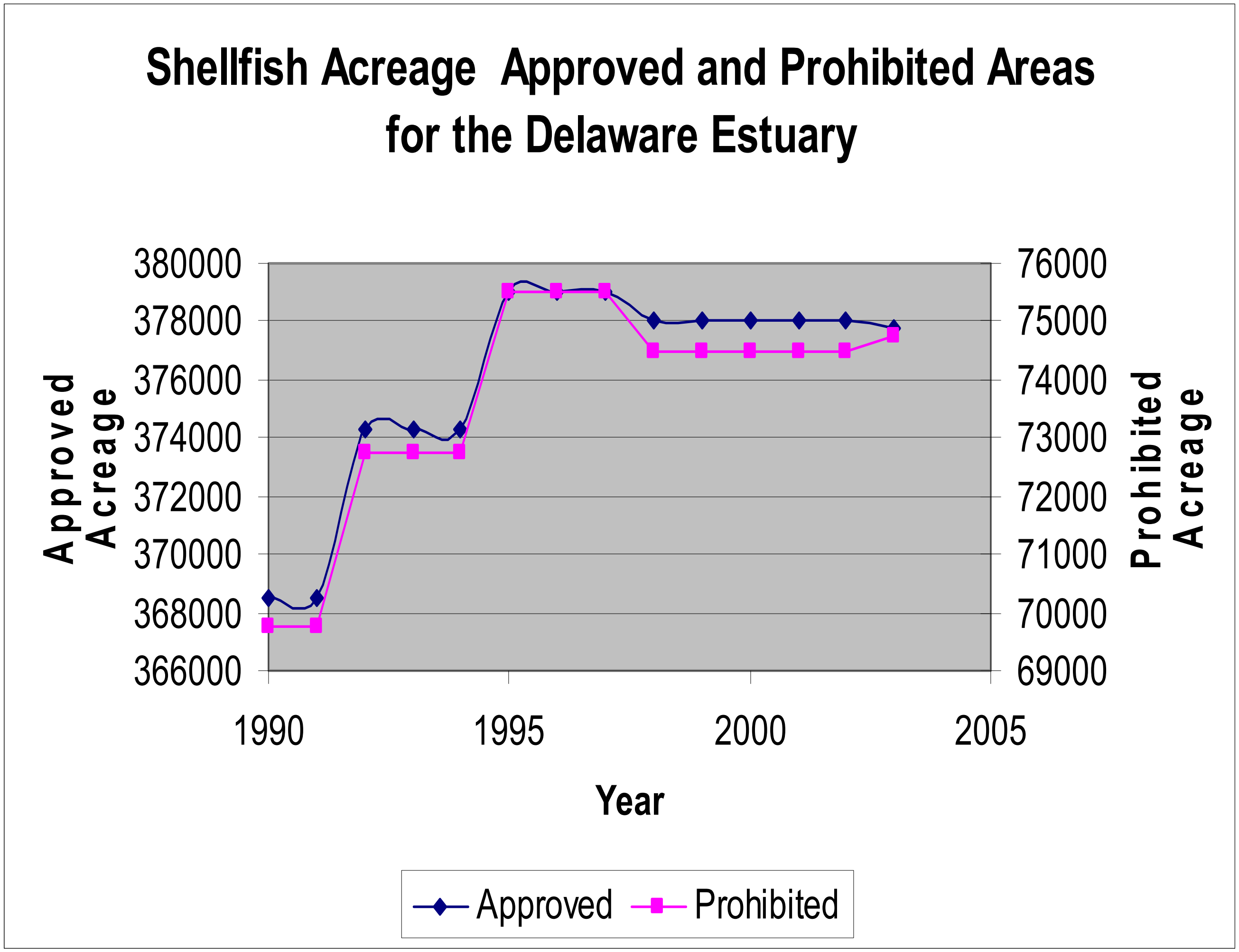
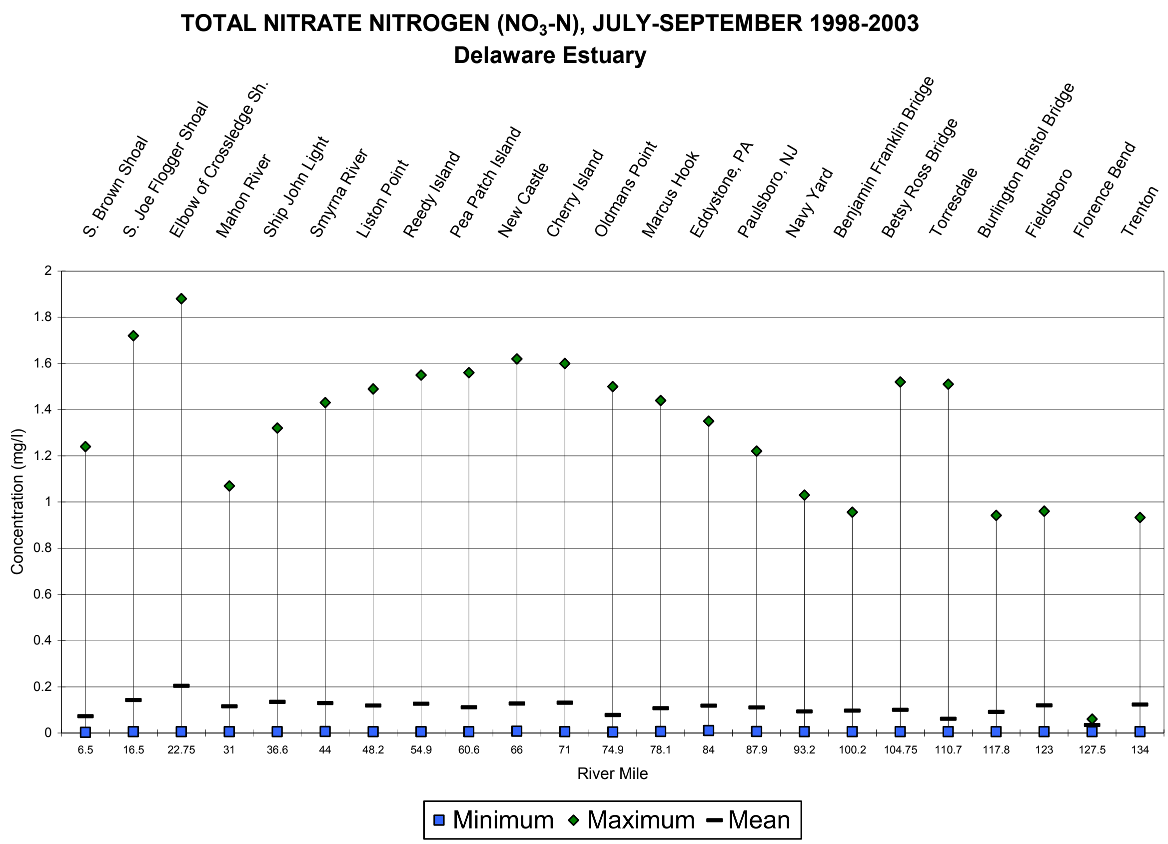
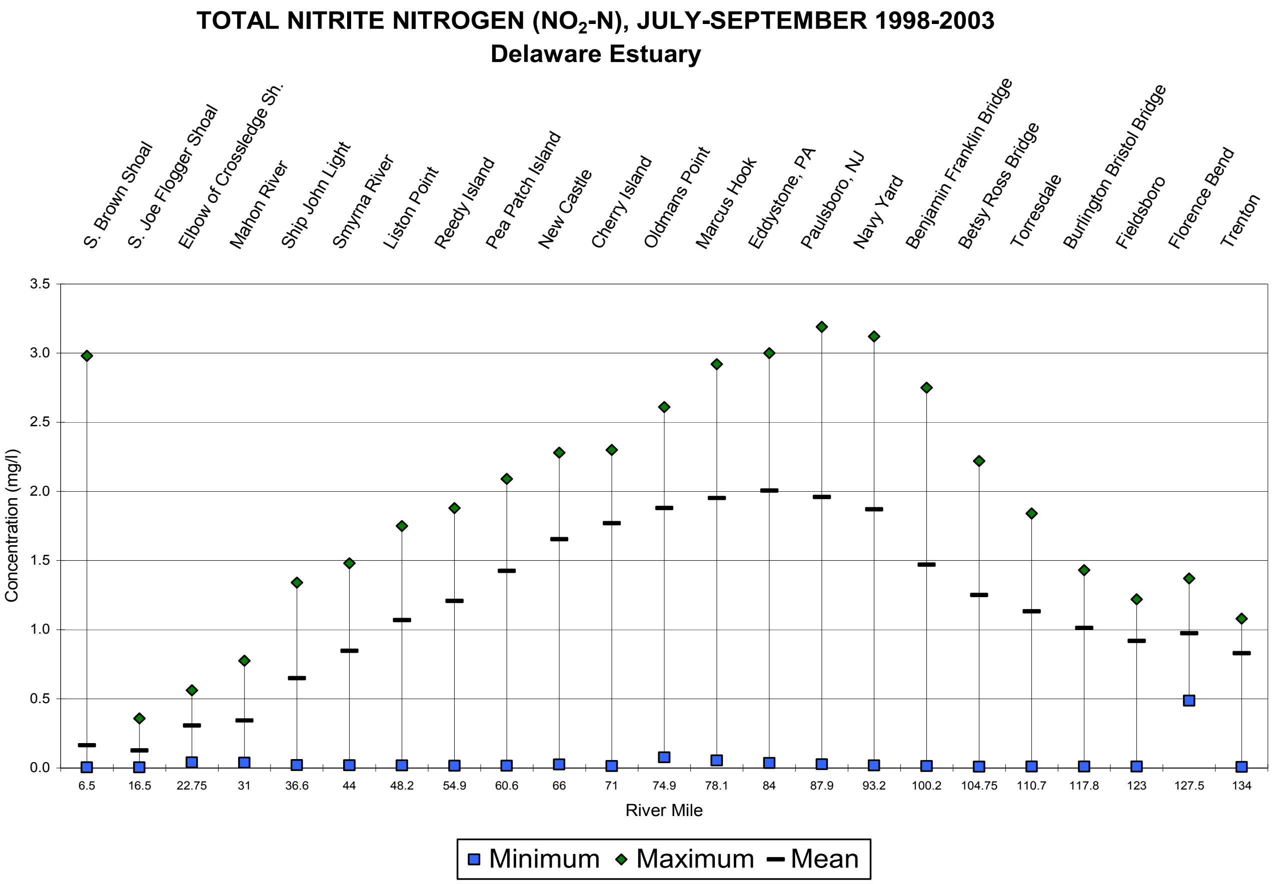


Figure 3.4-1 The Range of Nitrate Nitrogen over the period 1998-2003



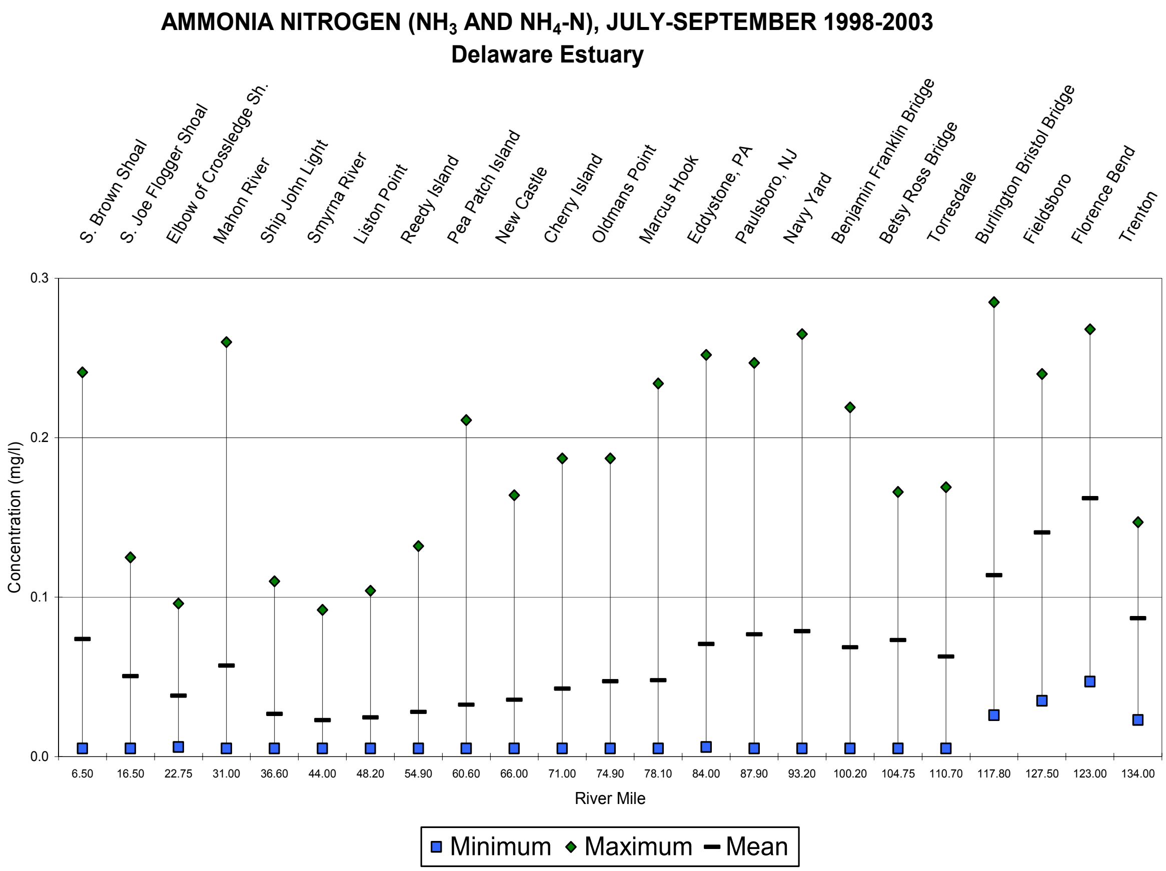
Source: DRBC Boat Run Program

Figure 3.4-2 The Range of Nitrite Nitrogen over the period 1998-2003



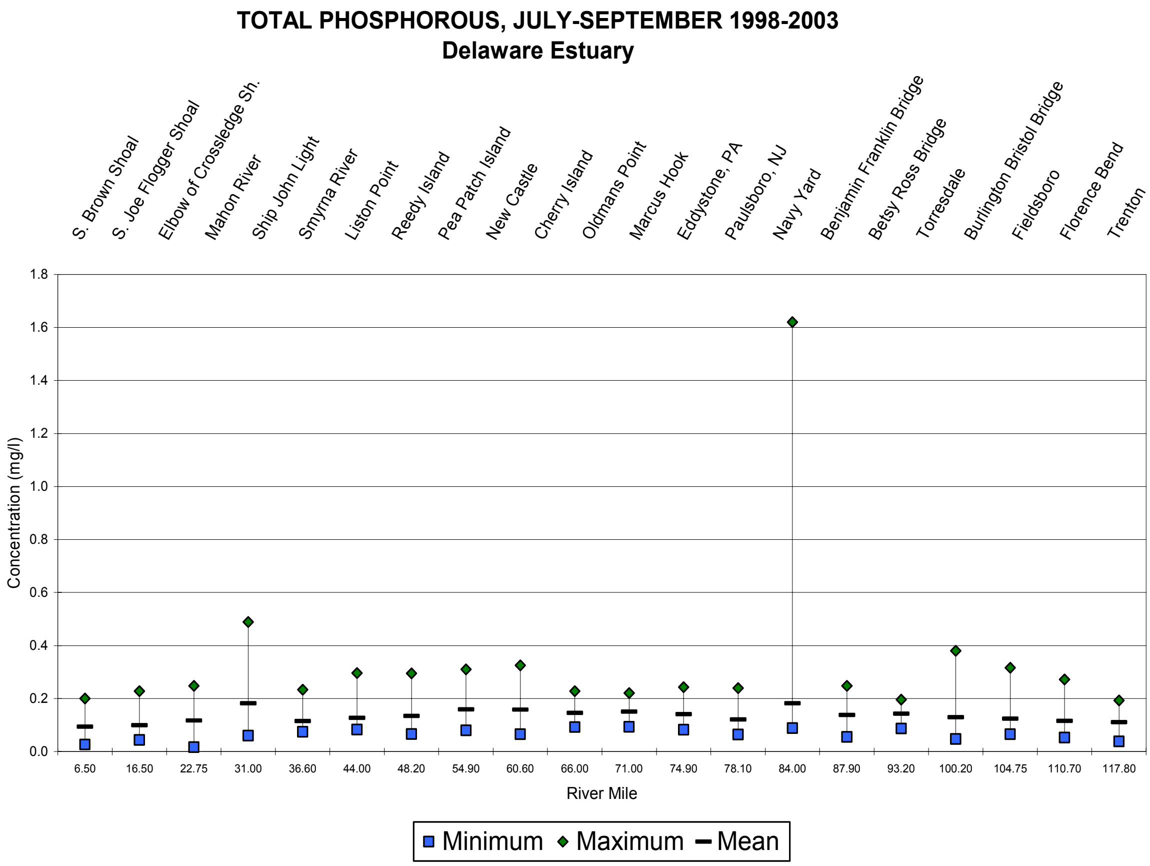
Source: DRBC Boat Run Program

Figure 3.4-3 The Range of Ammonia Nitrogen over the period 1998-2003



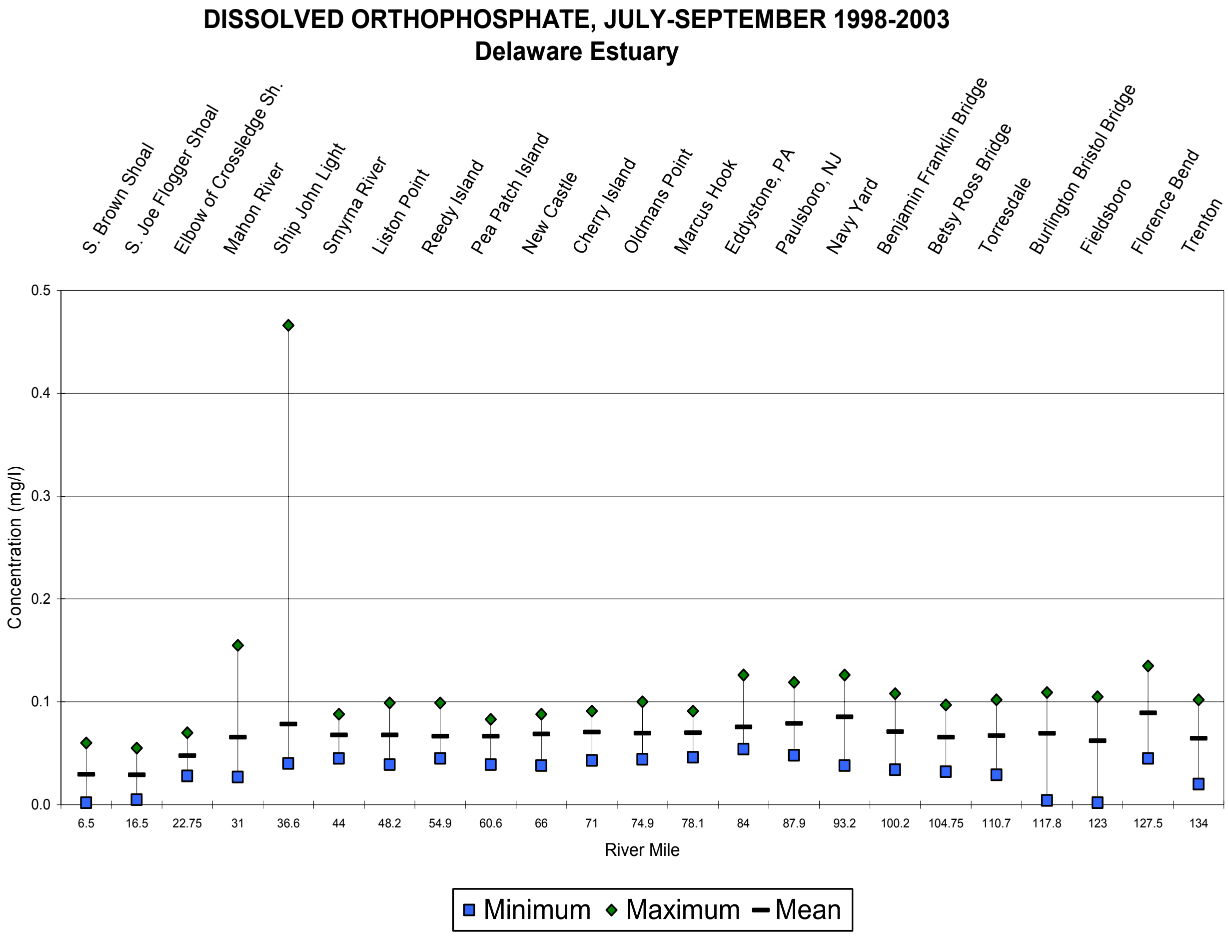
Source: DRBC Boat Run Program

Figure 3.4-4 The Range of Total Phosphorus over the period 1998-2003



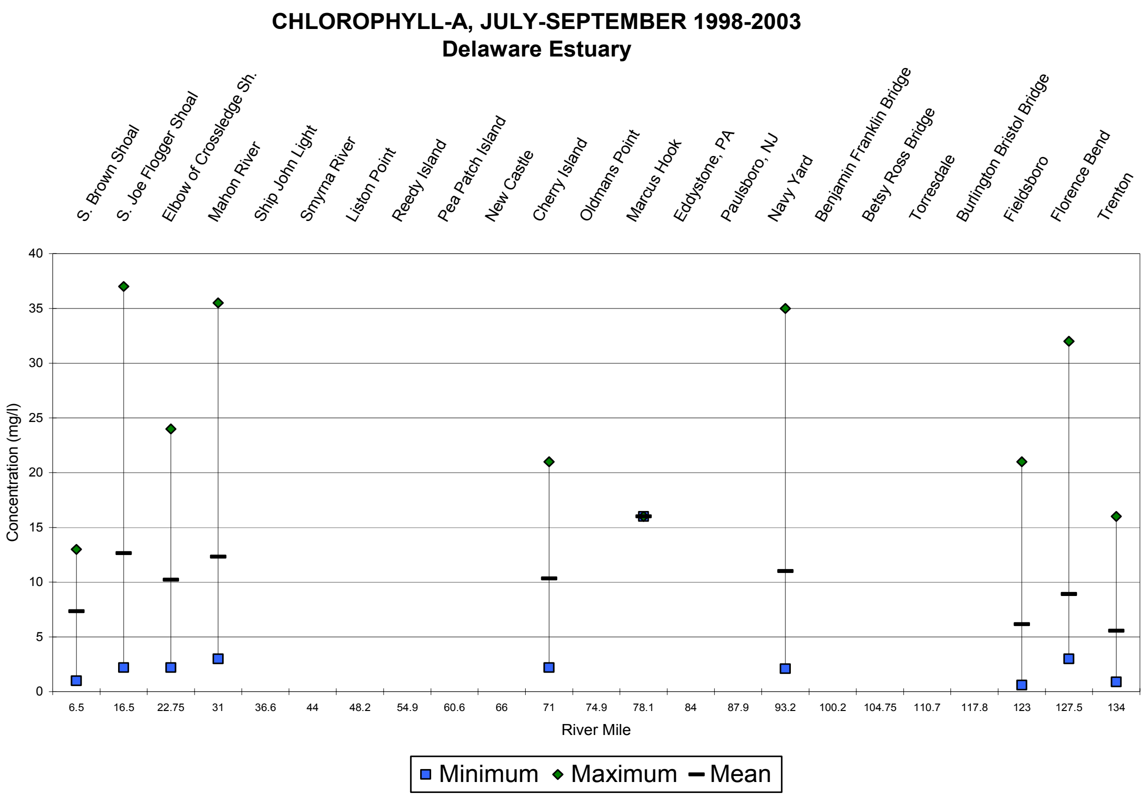
Source: DRBC Boat Run Program

Figure 3.4-5 The Range of Dissolved Ortho-Phosphate over the period 1998-2003



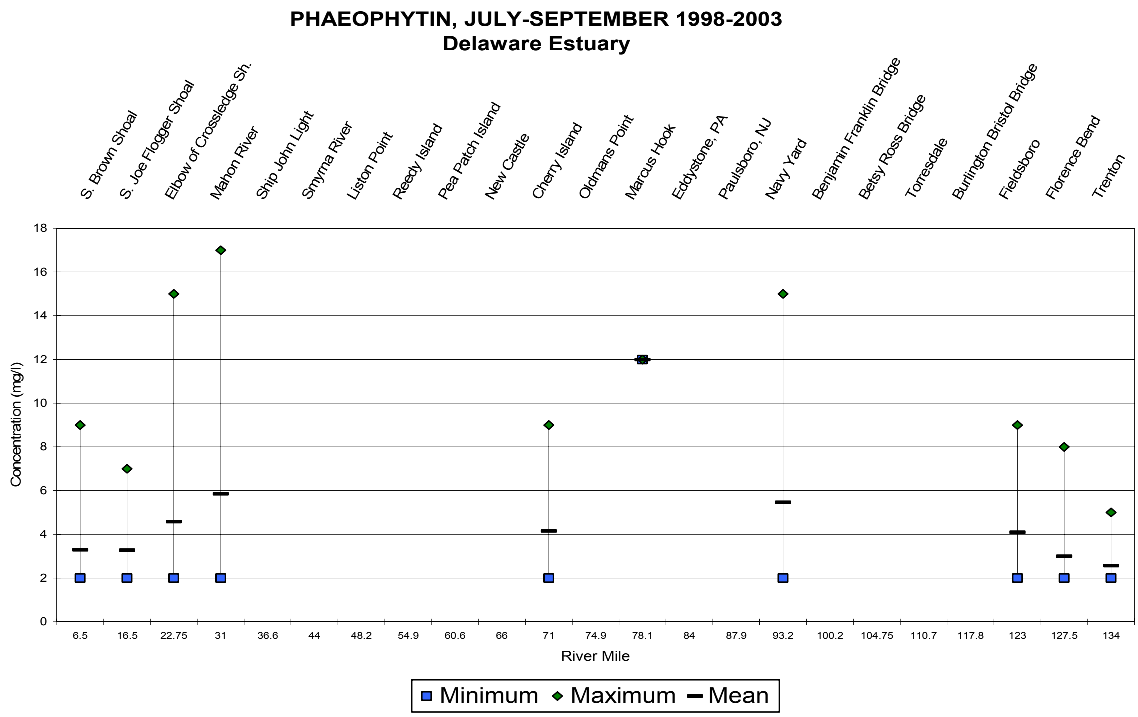
Source: DRBC Boat Run Program

Figure 3.4-6 The Range of Chlorophyll-a over the period 1998-2003



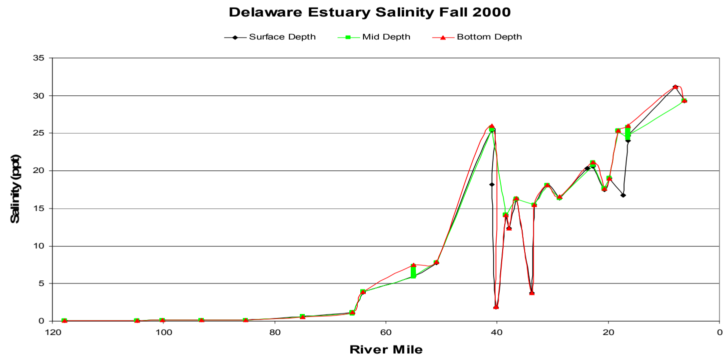
Source: DRBC Boat Run Program

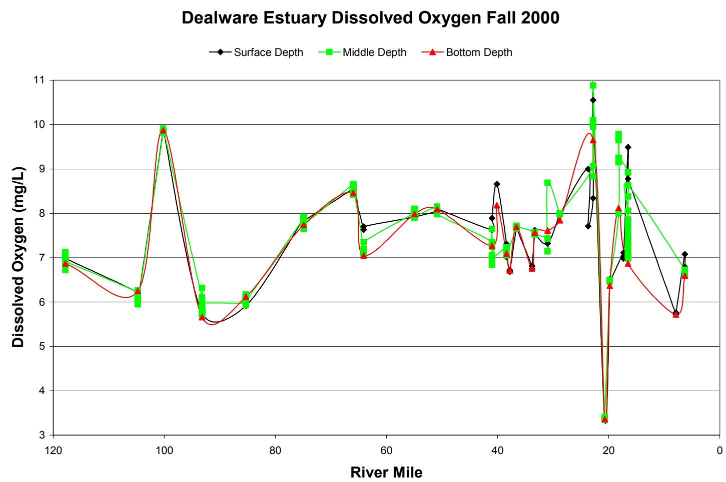
Figure 3.4-7 The Range of Phaeophytin over the period 1998-2003



Source: DRBC Boat Run Program

Figure 3.4-8 a-c Depth Related Data for Salinity, Dissolved Oxygen and pH from the Delaware Estuary





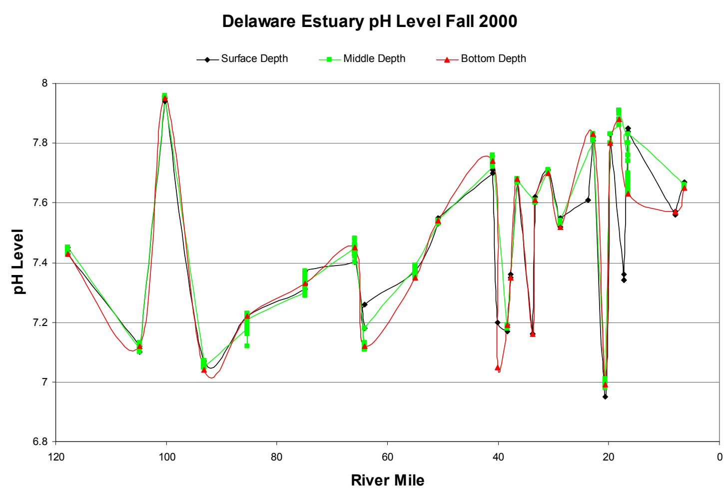


Figure 4.1-1 PCB Monitoring Locations in the Delaware Estuary

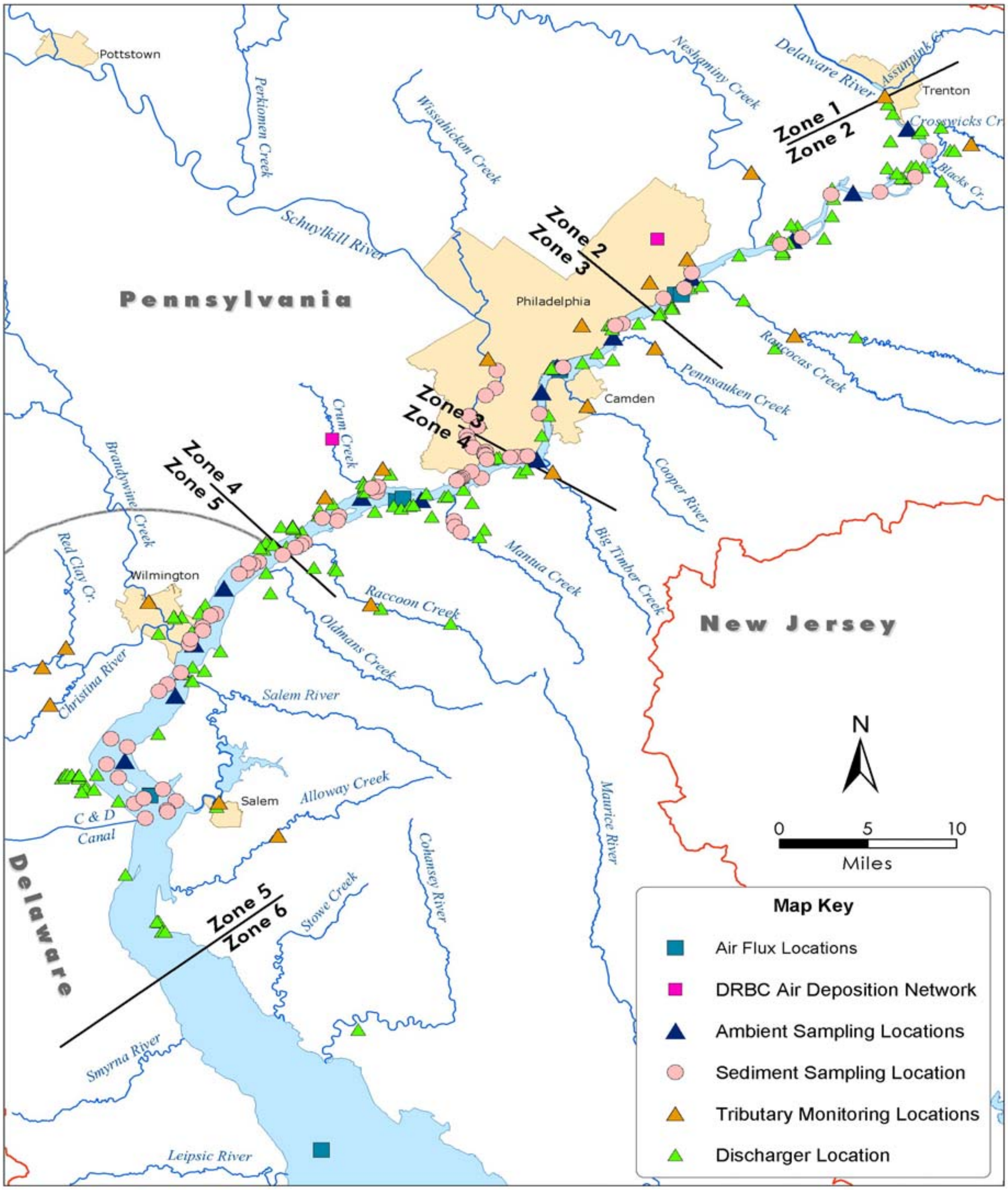


Figure 4.1-2 Air Deposition Sampling Sites

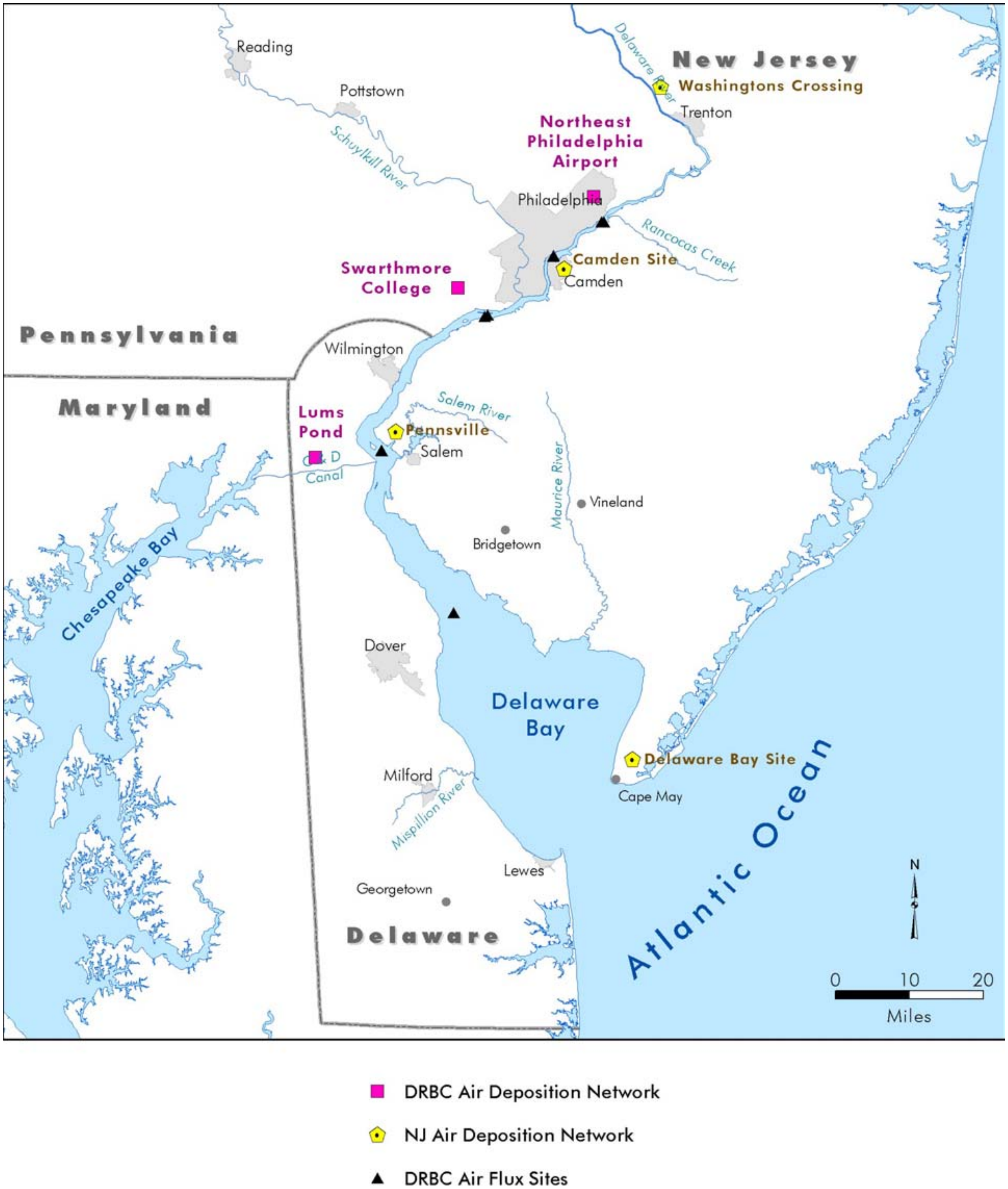
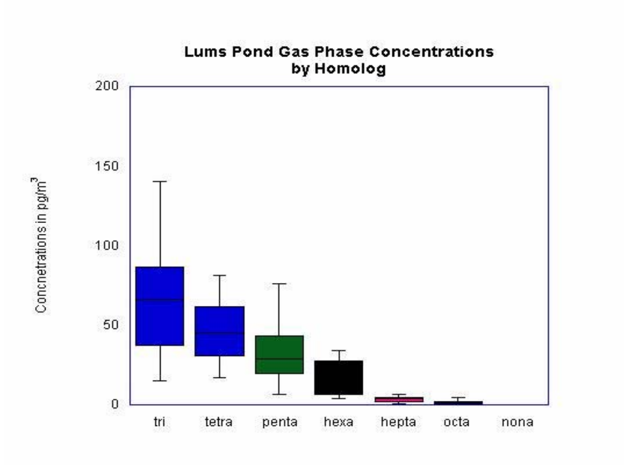
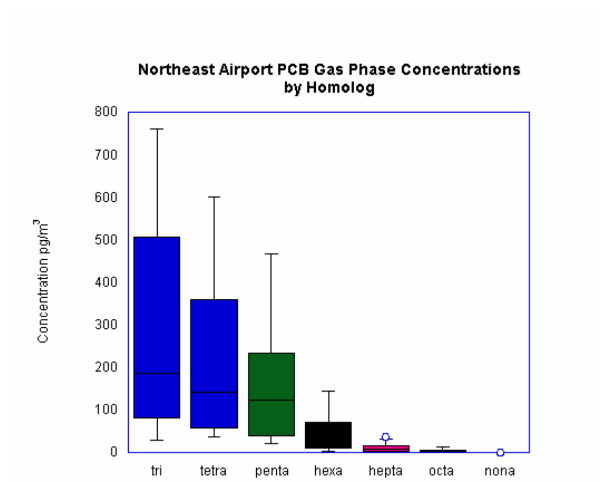


Figure 4.1-3 PCB Air Data for the 3 DRBC Monitoring Sites





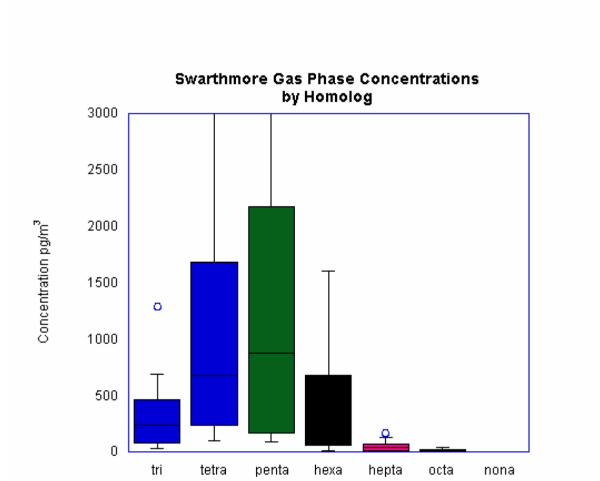


Figure 4.1-4 Percentile of Flow for the Schuylkill River

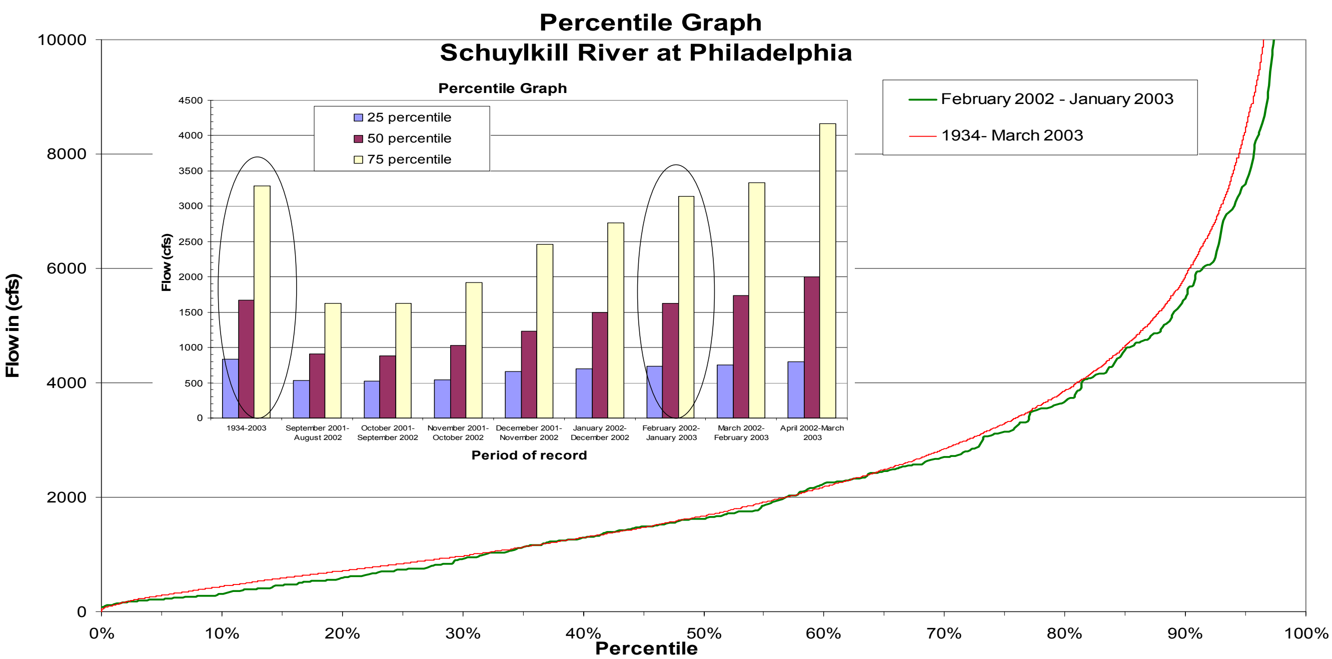


Figure 4.1-5 Percentile of Flow for the Delaware River

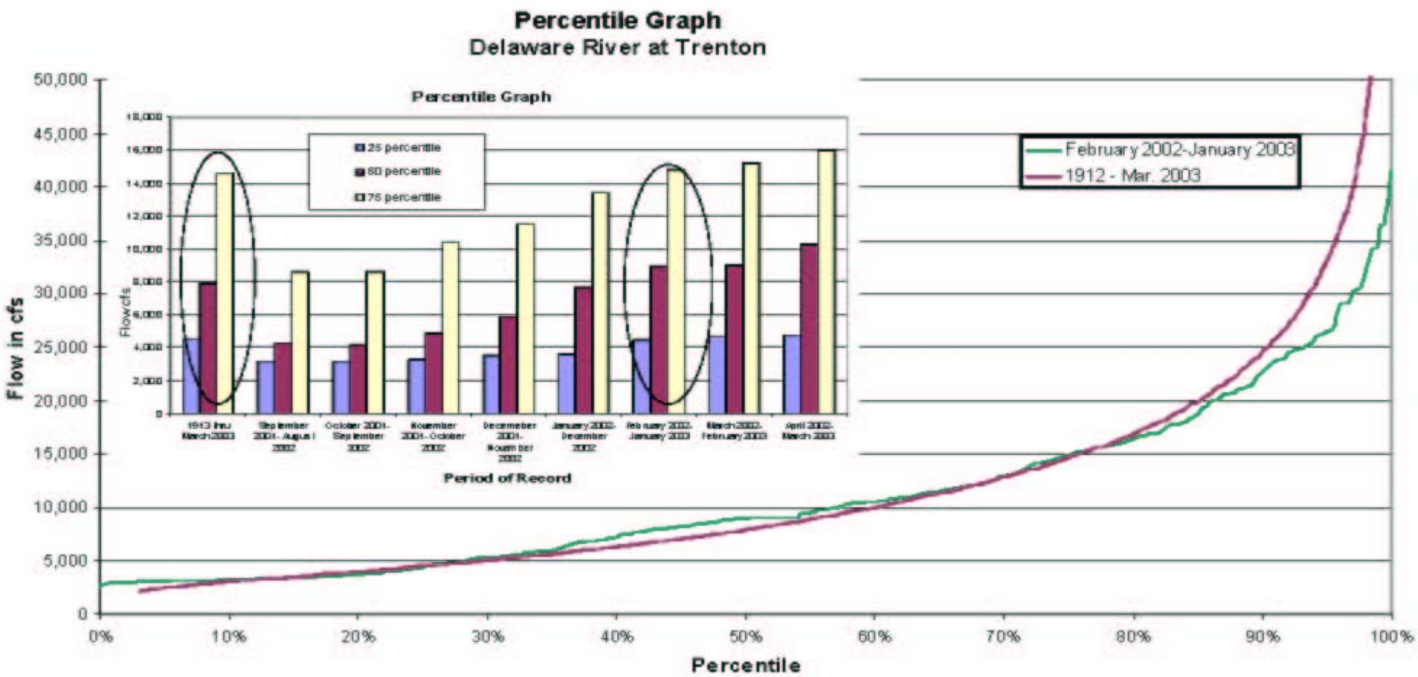


Figure 4.1-6 Total PCBs in the Water Column at Four Flow Regimes

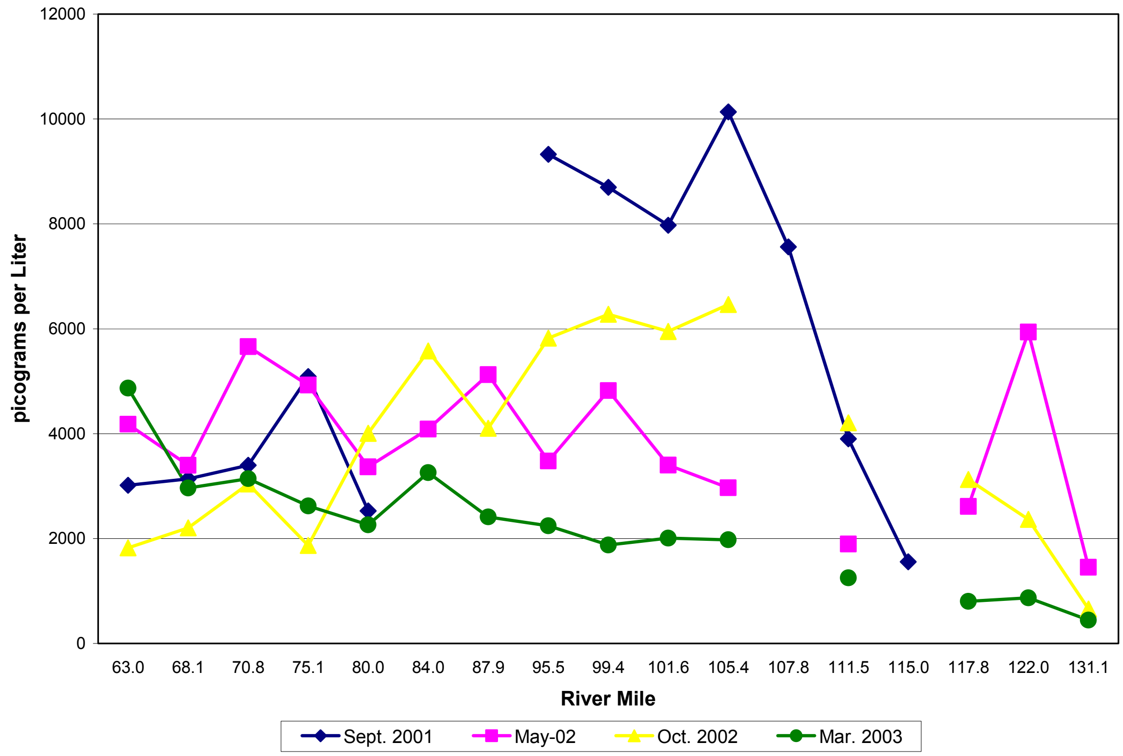


Figure 4.1-7 Fish Tissue PCB Congeners 2000-2001 normalized to lipid %

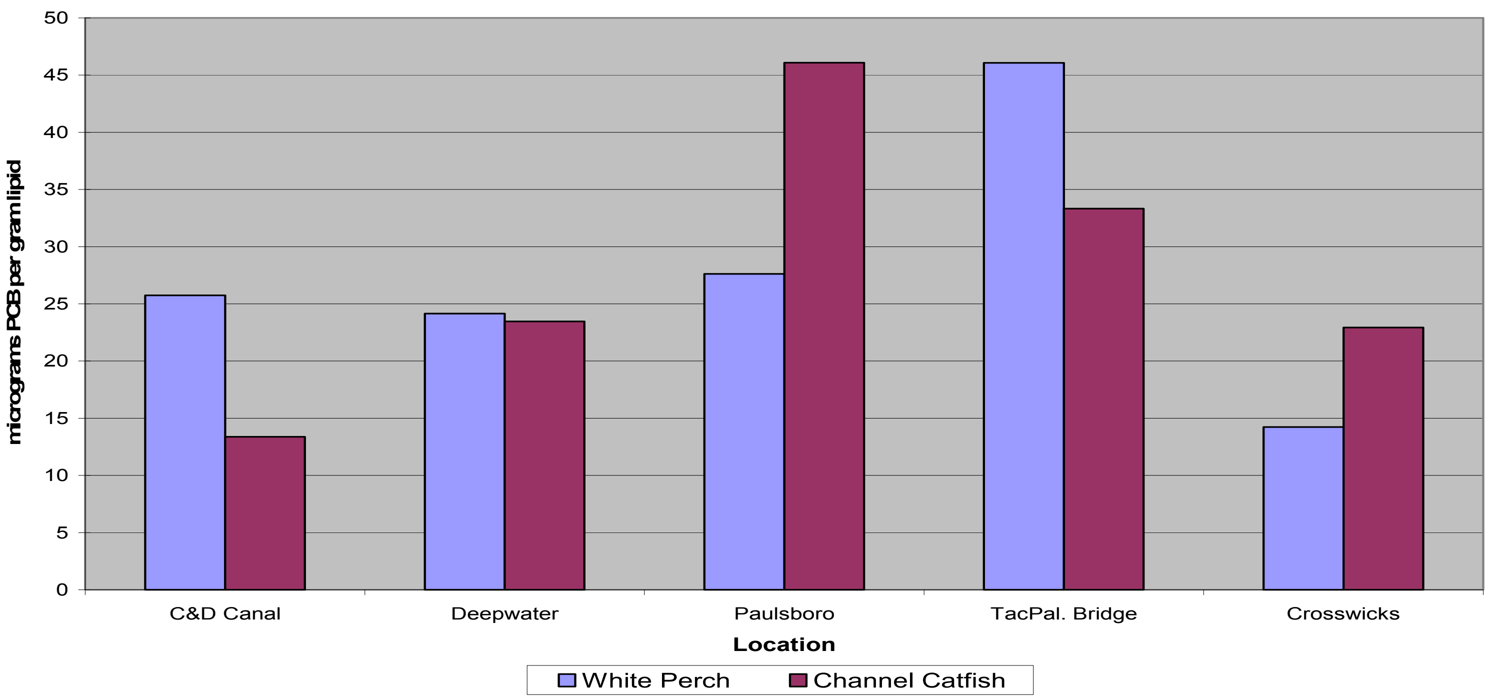


Figure 4.1-8 DRBC White Perch (<u>Morone Americana)</u> Tissue Metals Analyses 2000-2001

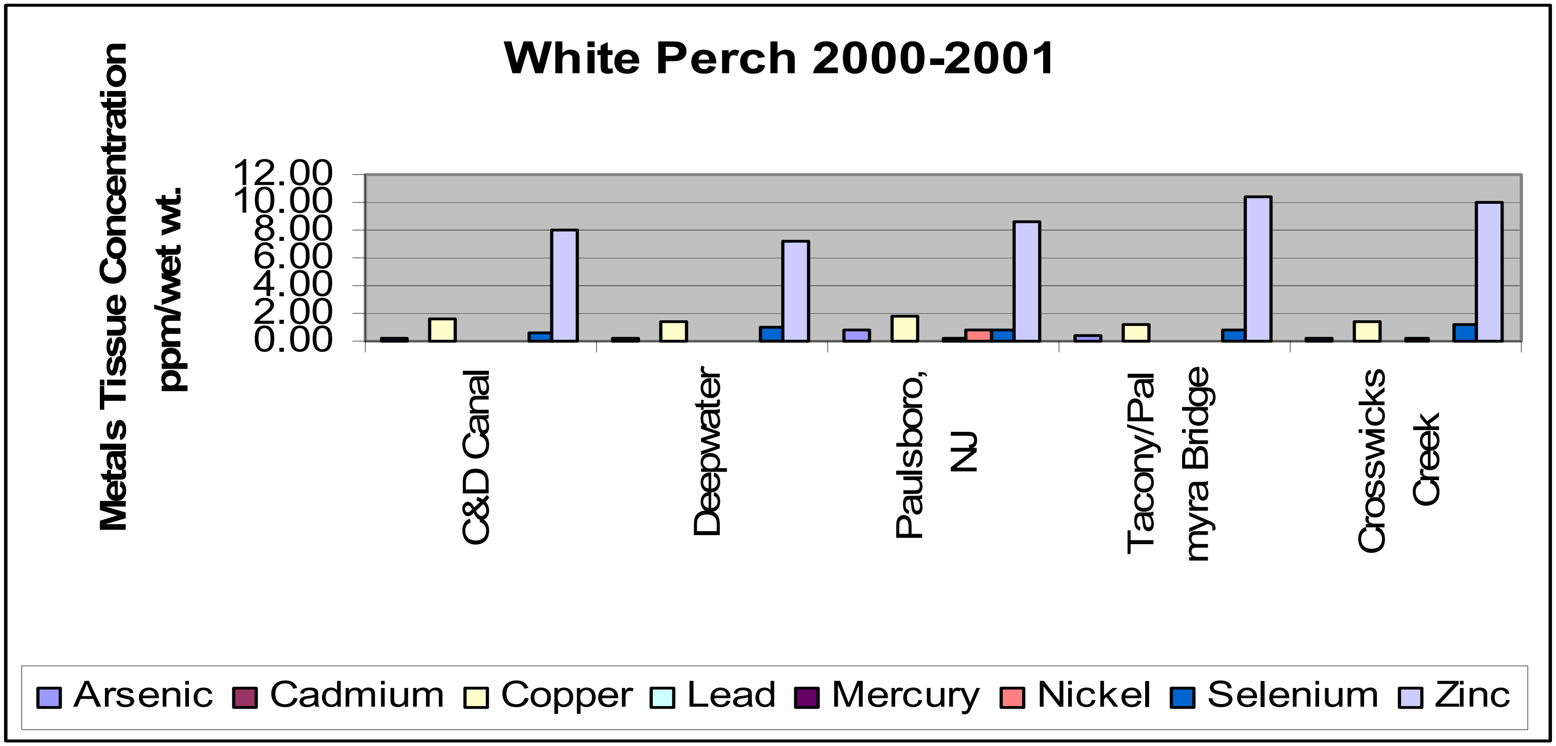


Figure 4.1-9 DRBC Channel Catfish (Ictalurus Punctatus) Tissue Metals Analyses 2000-2001

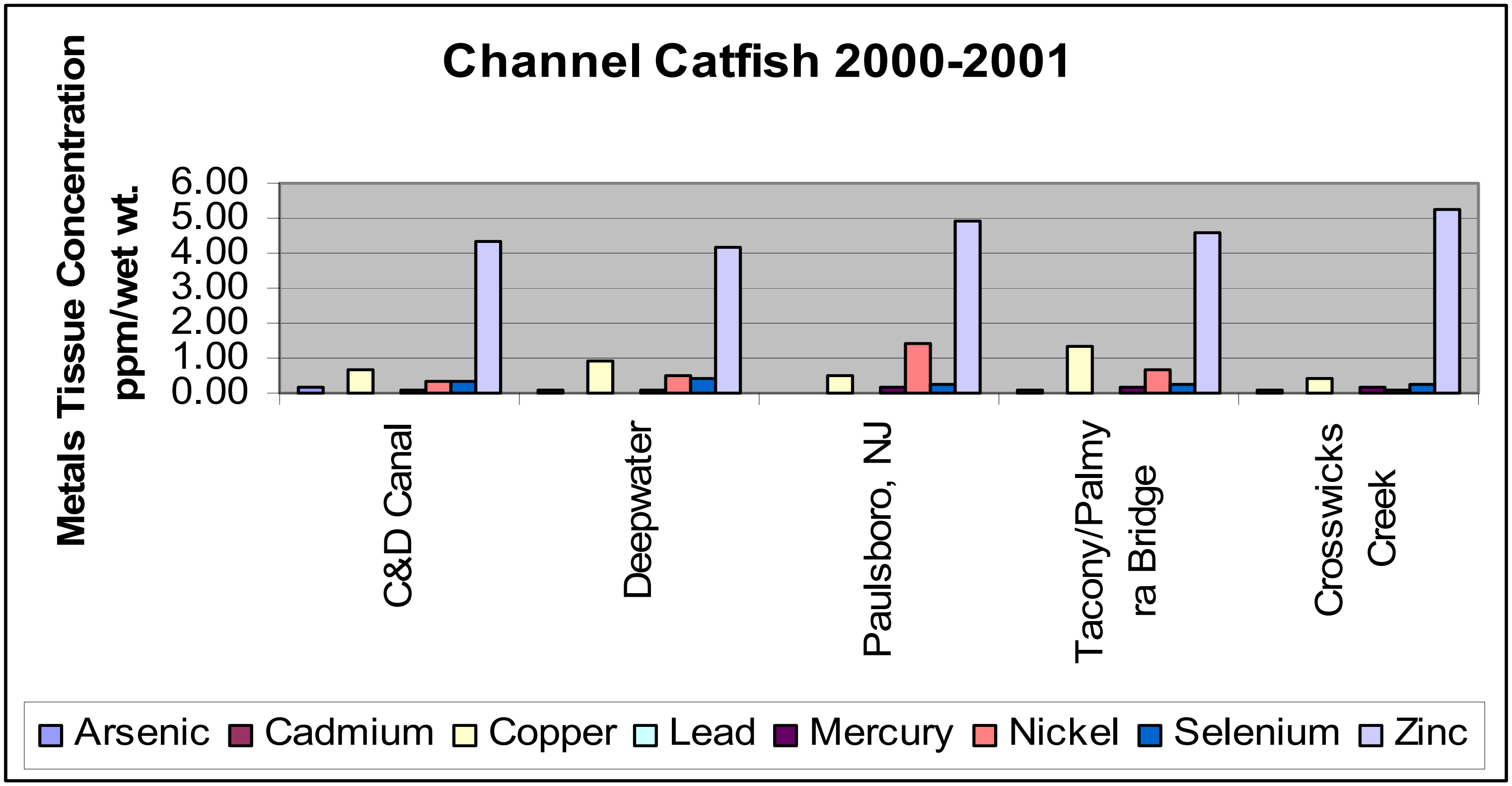


Figure 4.2-1 Sediment Toxicity of Samples Collected During the 2000 National Coastal Assessment Program

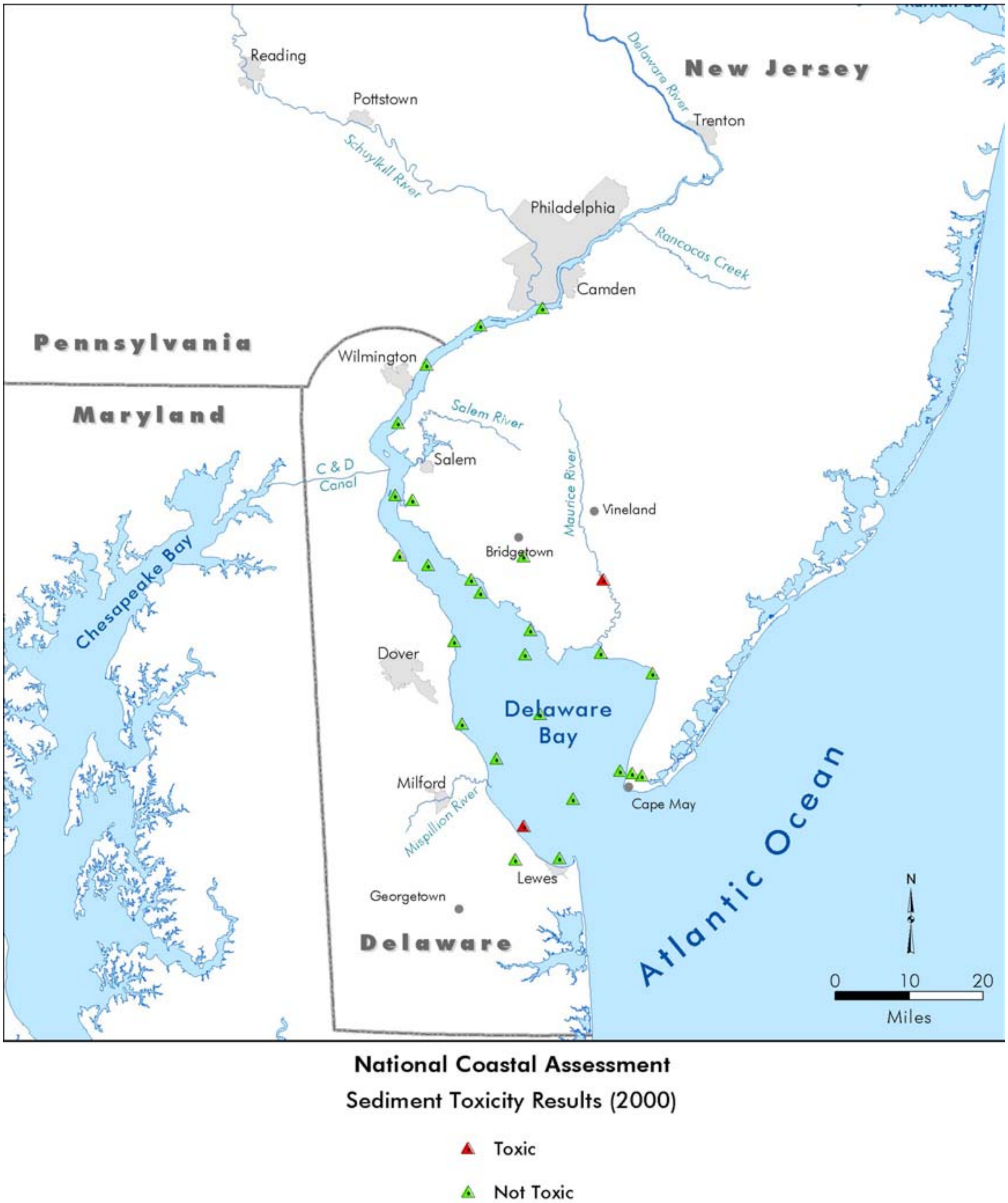


Figure 5.1-1 Oyster Abundance in Delaware Bay

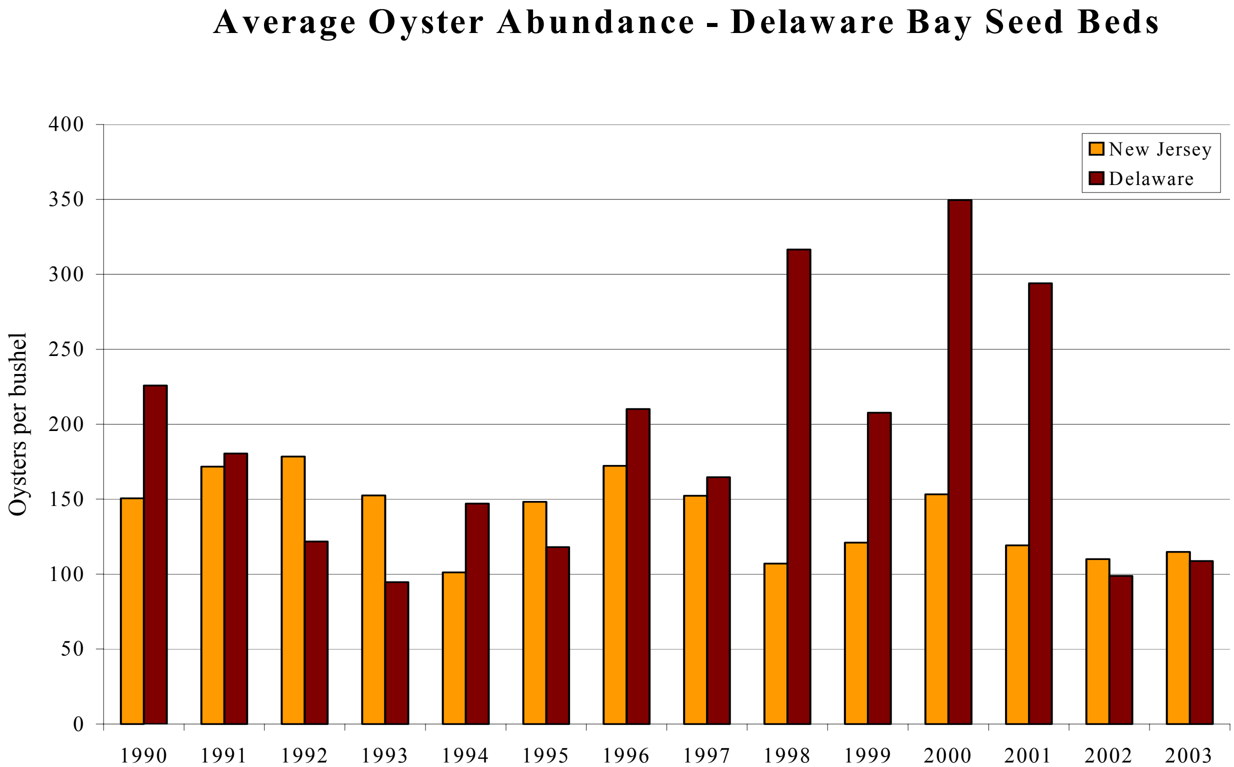


Figure 5.1-2 Average Oyster Spat Abundance in Delaware Bay

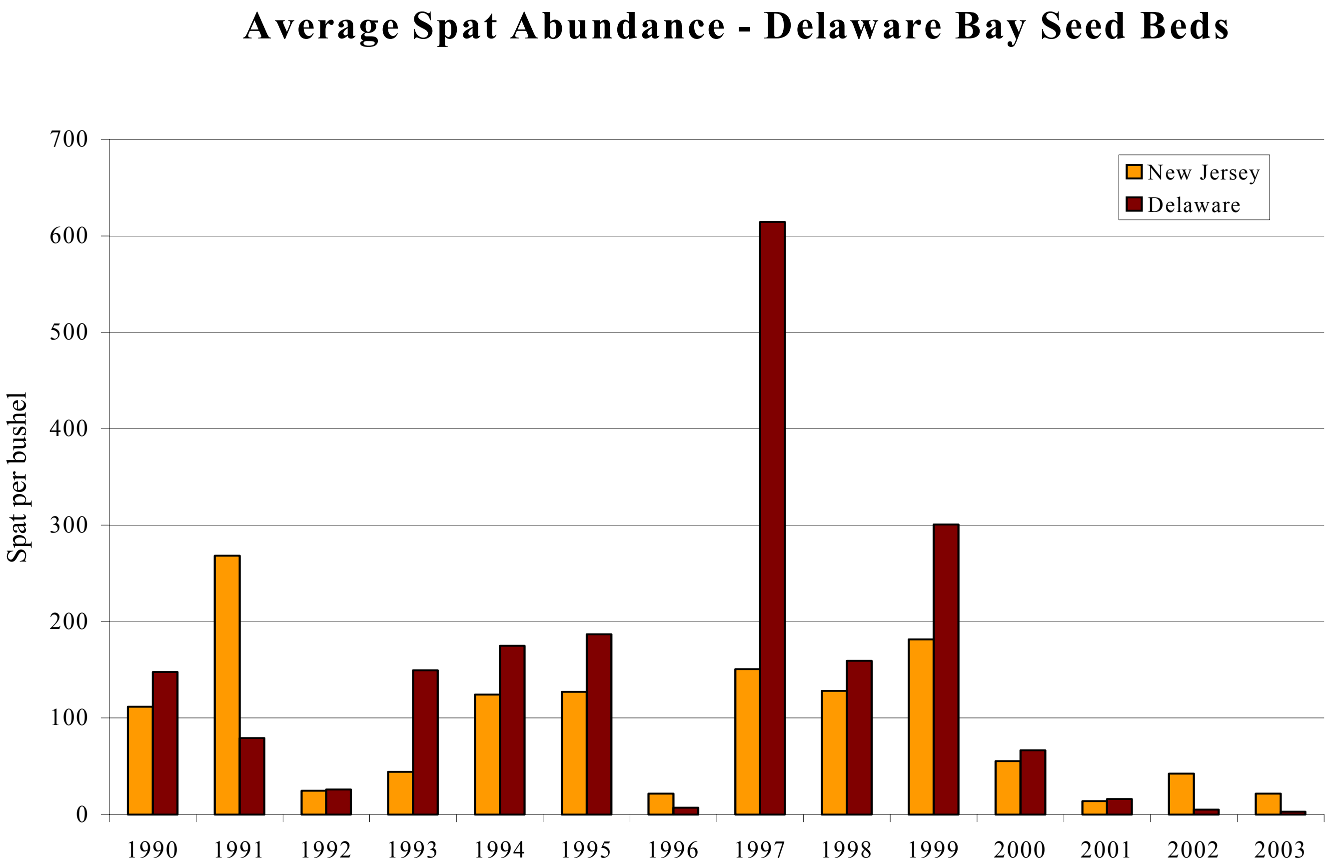


Figure 5.1-3 Oysters removed from Delaware Bay Seed Beds

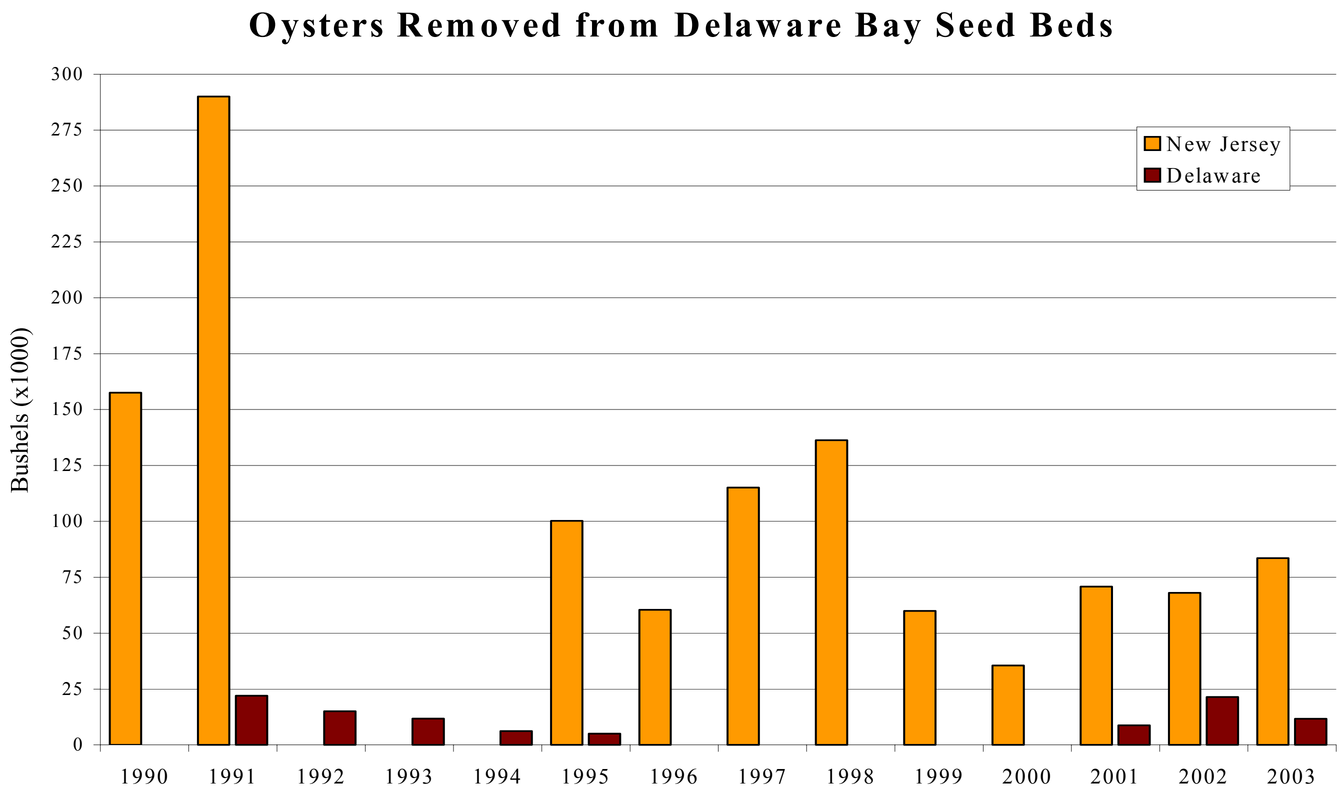


Figure 5.1-4 Average Oyster Mortality Delaware Seed Beds

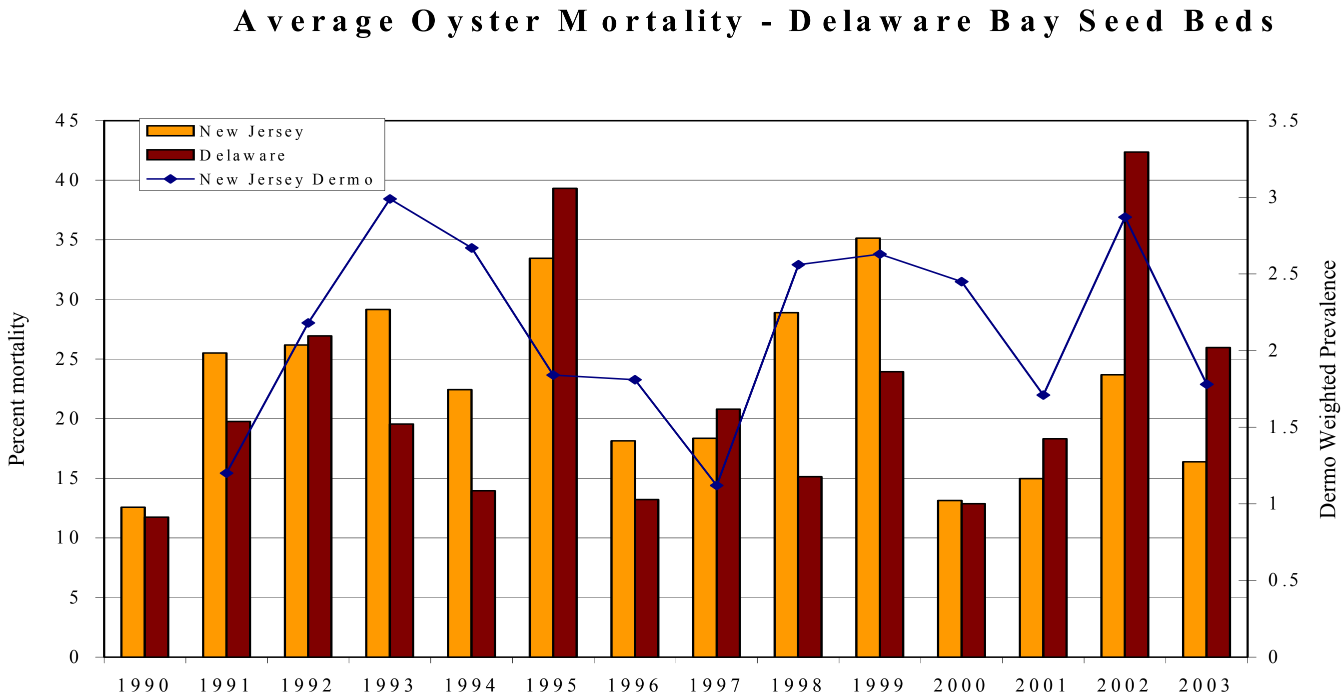


Figure 5.2-1 Delaware Bay Horseshoe Crab counts 1996-2003
(Source Swan, et. al. 2003)

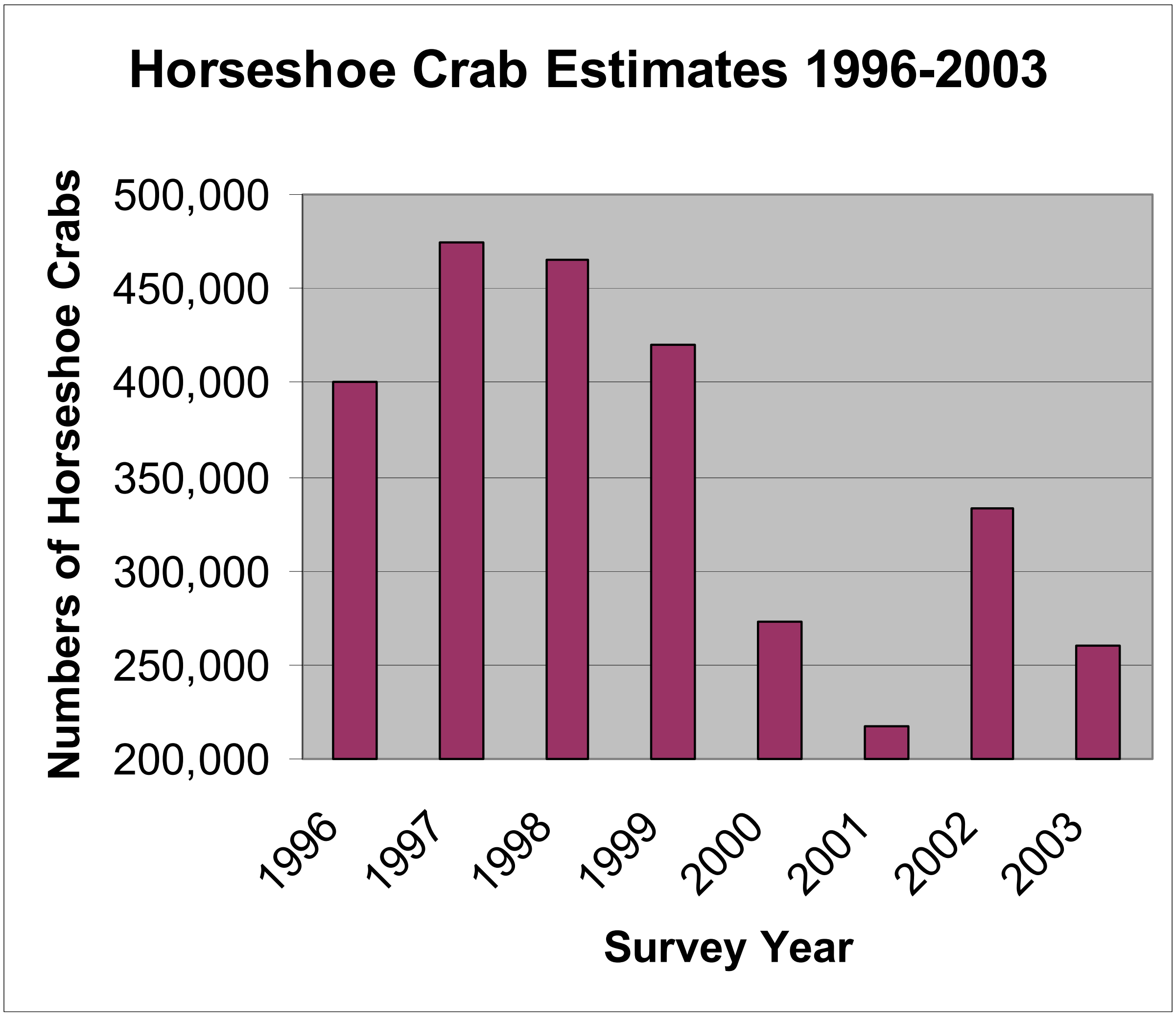


Figure 5.2-2. State-specific index of spawning activity (ISA) for New Jersey and Delaware from 1999 to 2003. Vertical bars show 90% confidence intervals. (Source: Smith and Bennett 2004)

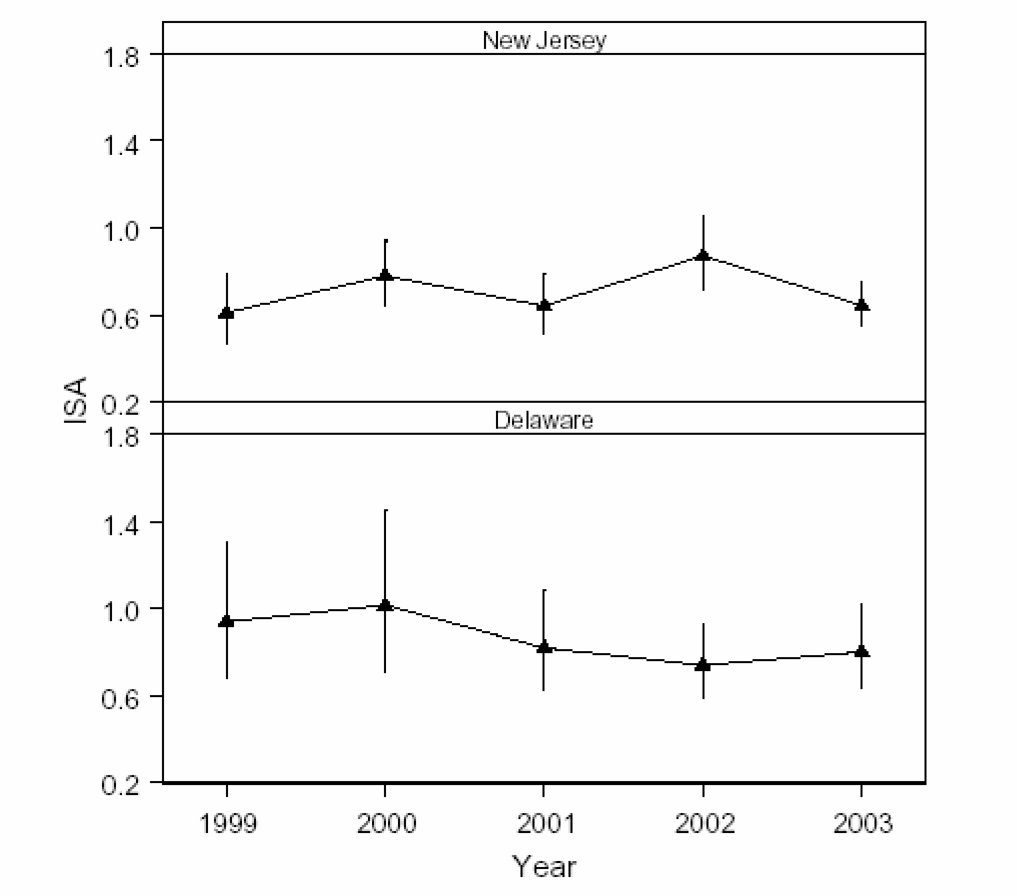


Figure 5.3-1 Delaware Bay Blue Crab Landings (1000s pounds) by State (Source: Helser, and Kahn. 2001)

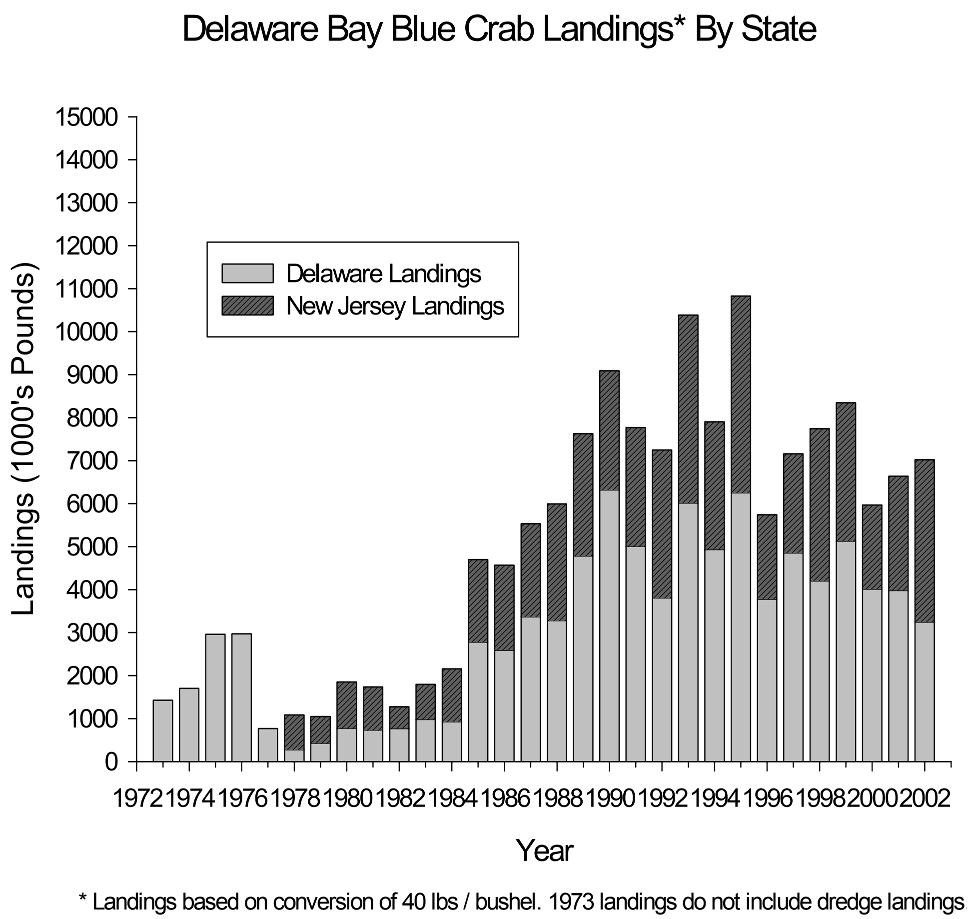


Figure 7. Delaware Bay blue crab landings (000's pounds) by state from 1970-1997.

Figure 5.3-2 Blue Crab Index of Recruits in Delaware Bay

(Source: Helser, and Kahn. 2001)

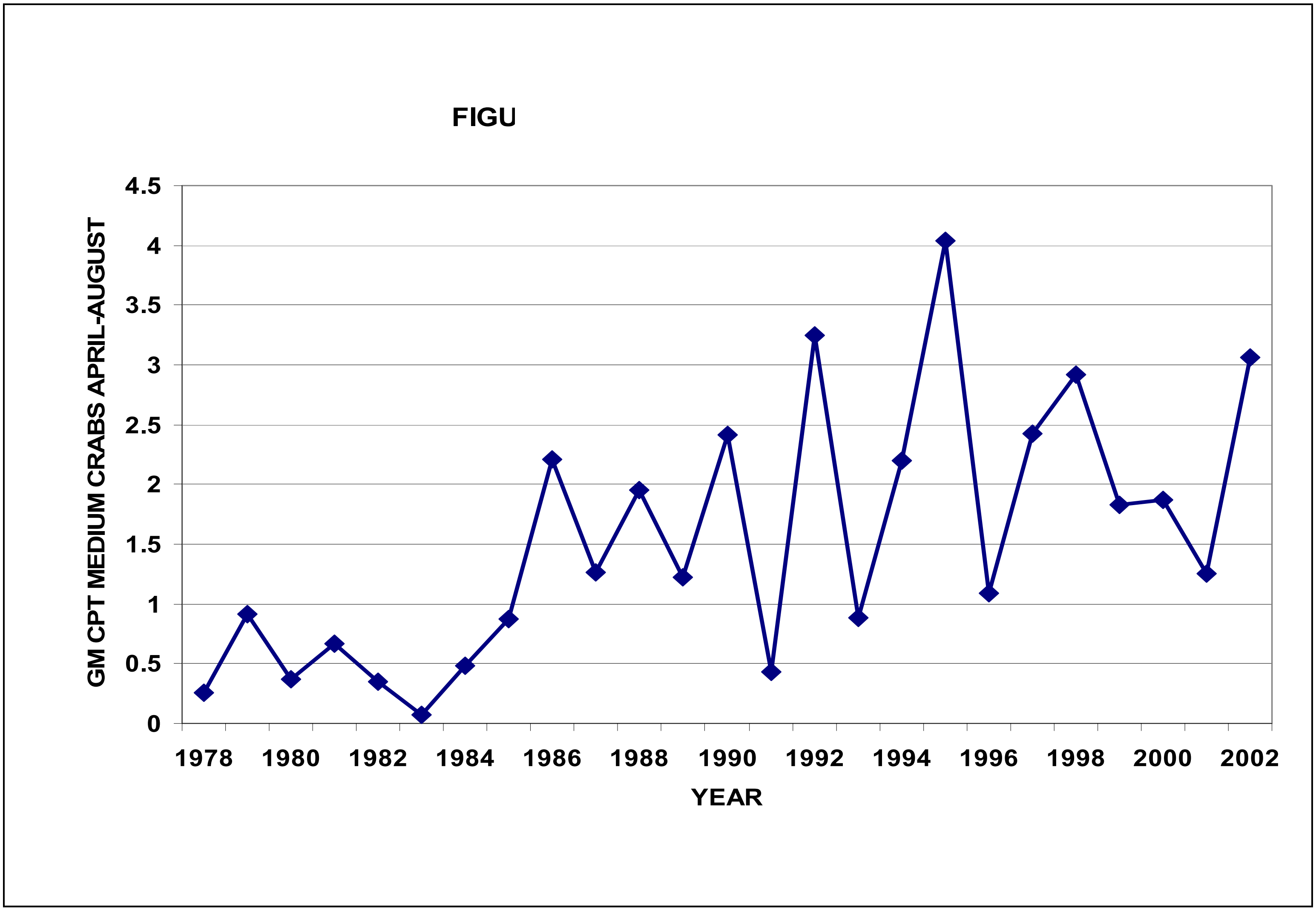


Figure 5.3-3 Blue Crab Young-Of-The–Year Index for Delaware Bay (Source: Helser, and Kahn. 2001)

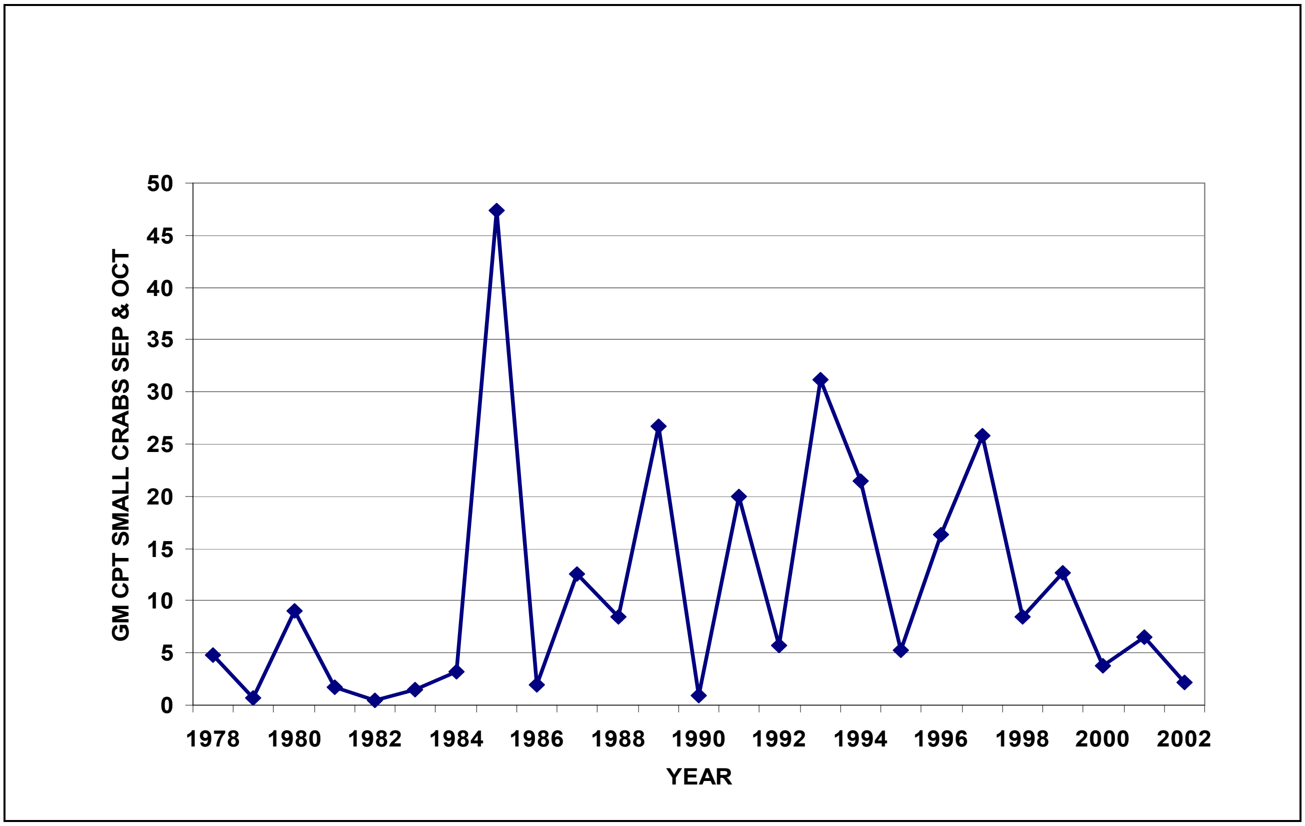


Figure 5.3-4 Blue Crab Index of Spawning Stock Biomass (Source: Helser, and Kahn. 2001)

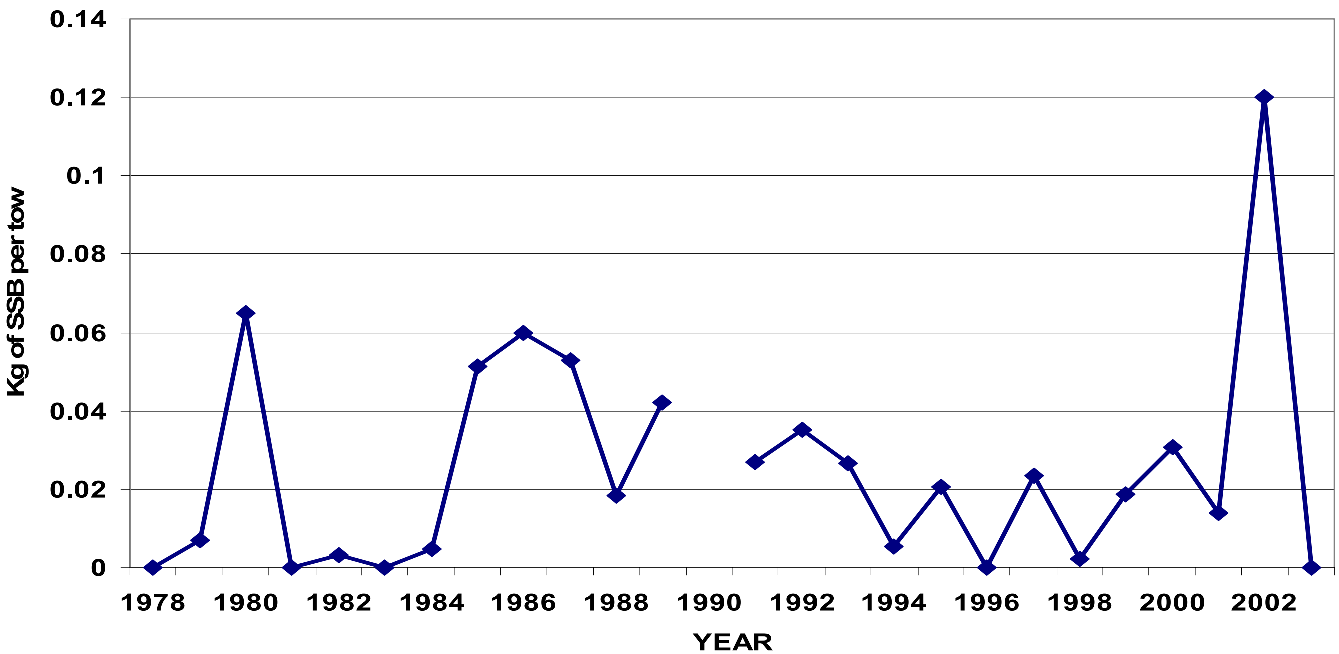


Figure 5.3-5 Blue Crab Catch Data 1979-2002

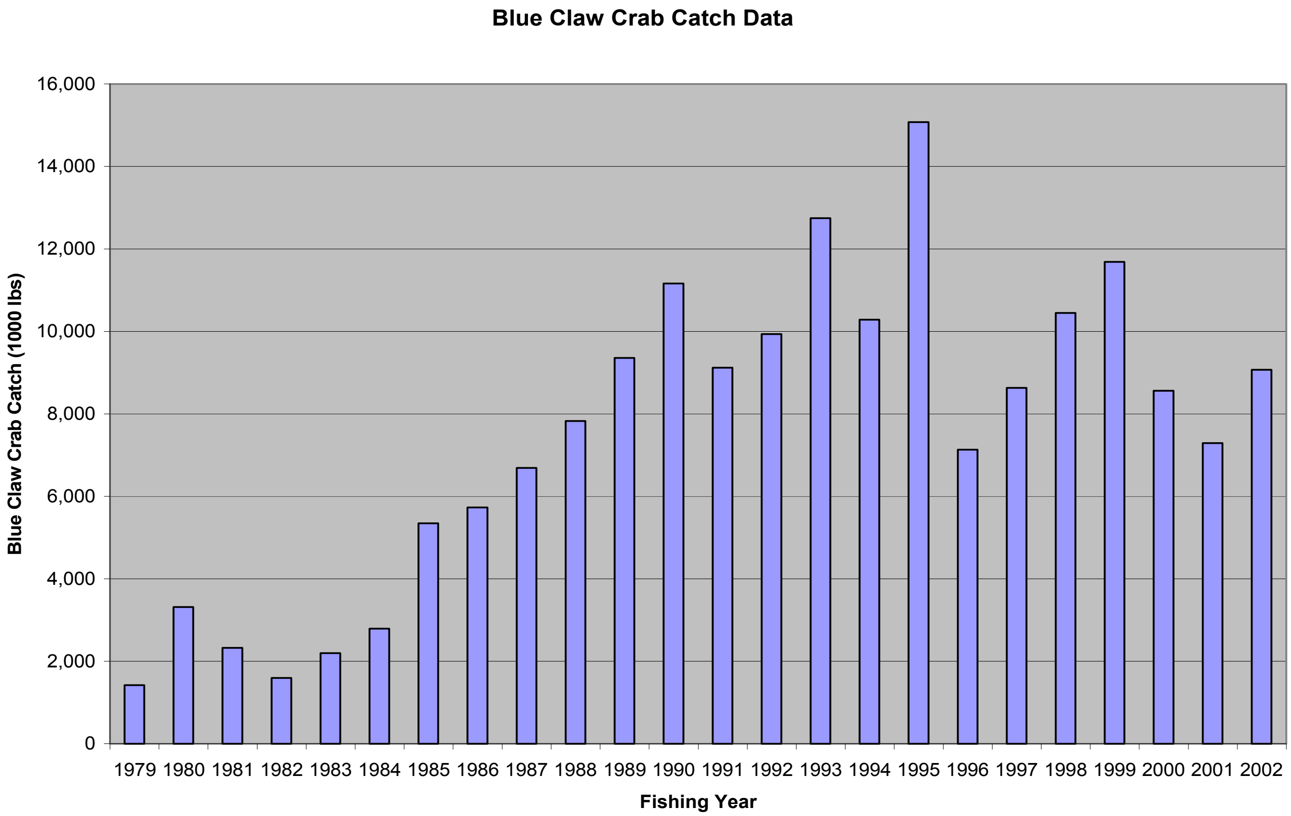


Figure 5.4-1 American Shad Population Estimate

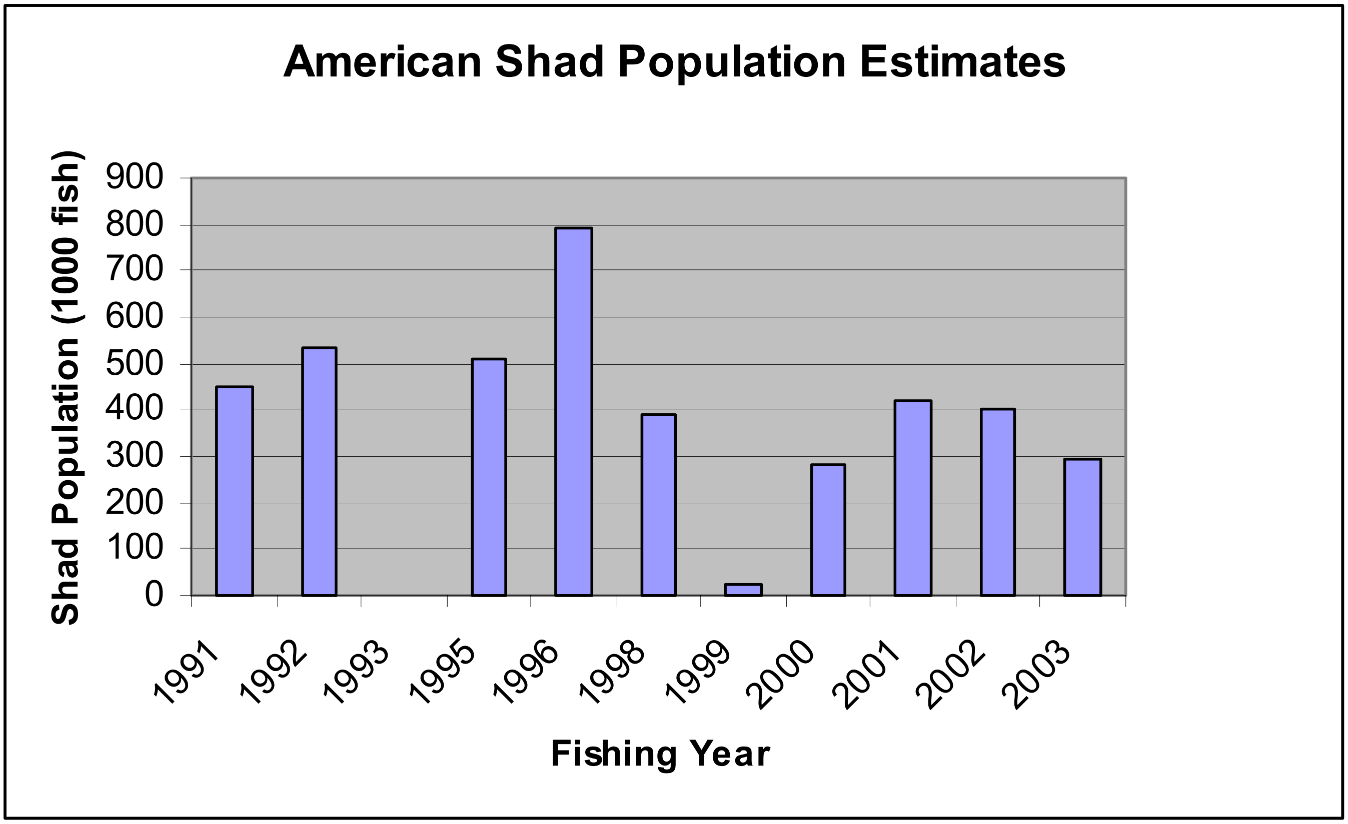
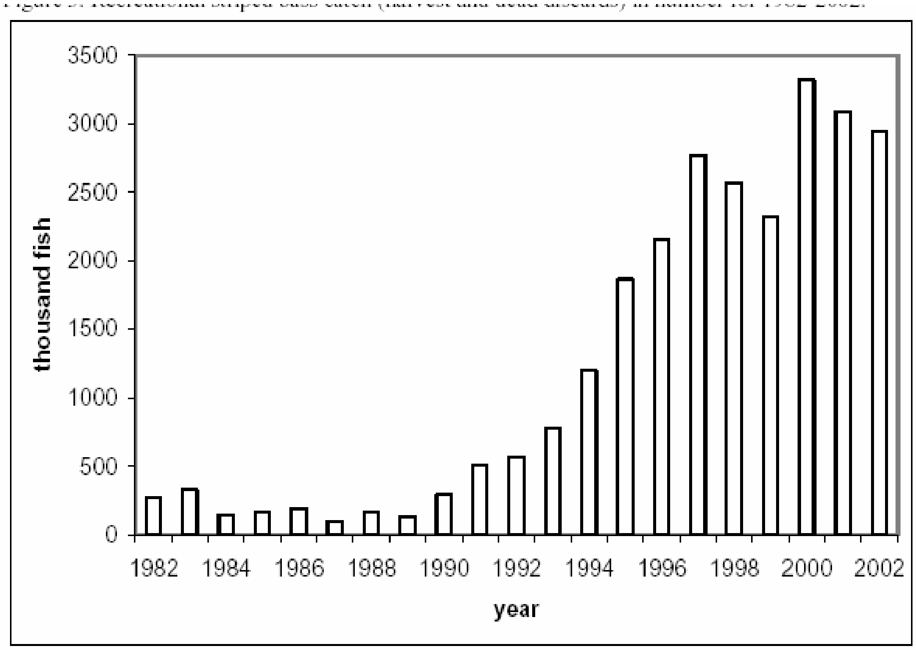


Figure 5.5-1 a, b Recreational Striped Bass Harvest



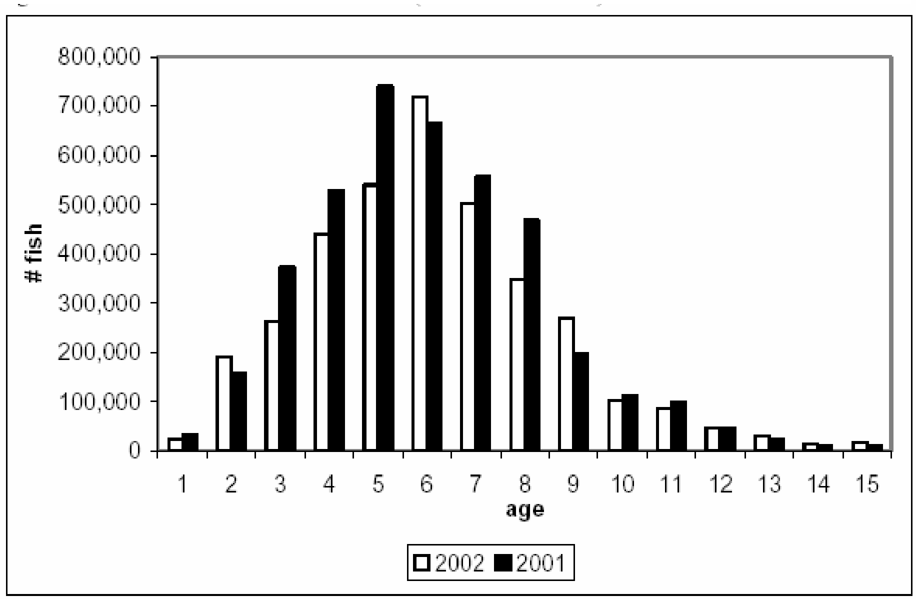


Figure 5.5-2 a, b Striped Bass Juvenile Indices for New York and New Jersey

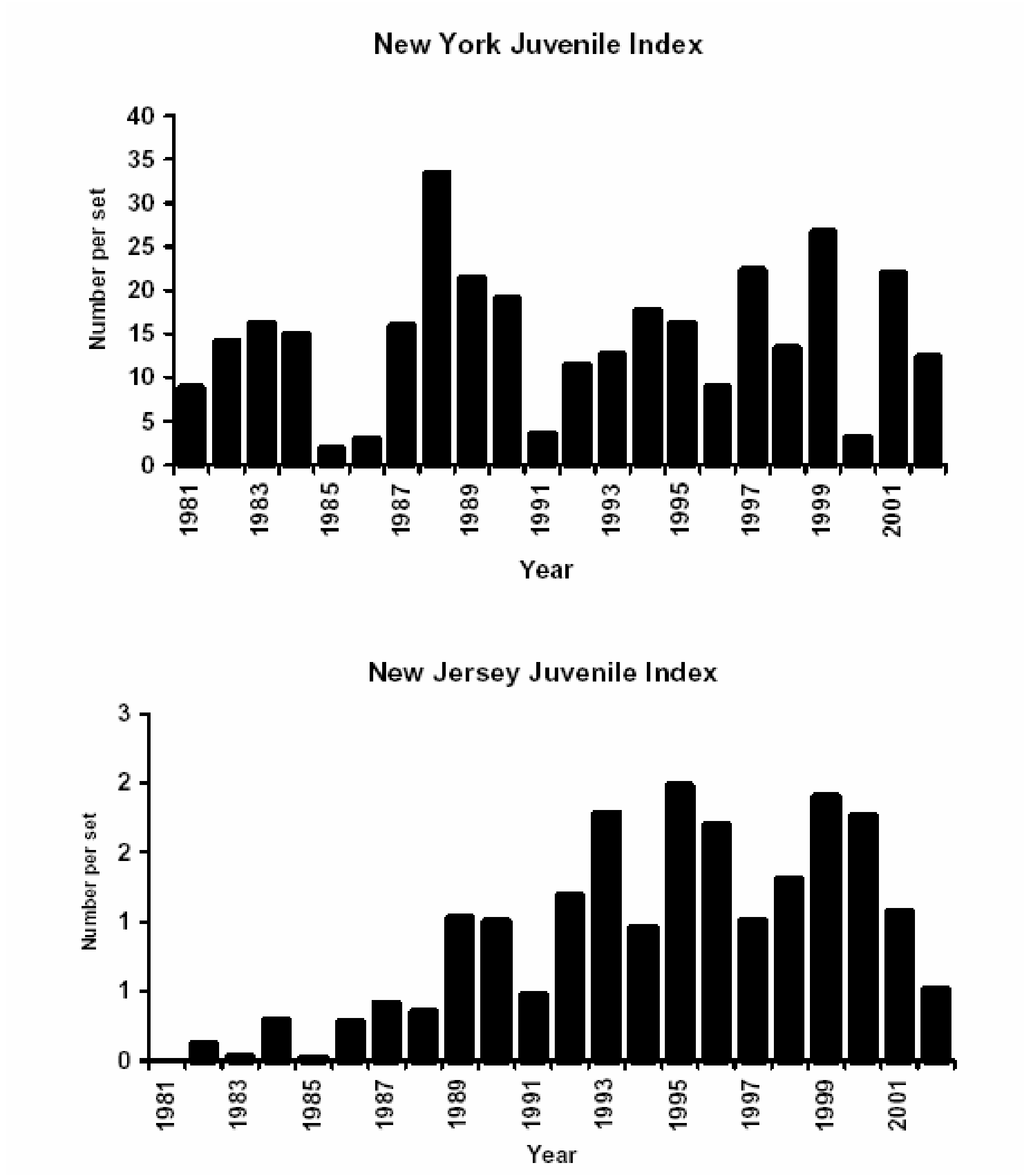


Figure 5.5-3 Striped Bass Young of the Year Indices 1990-2002

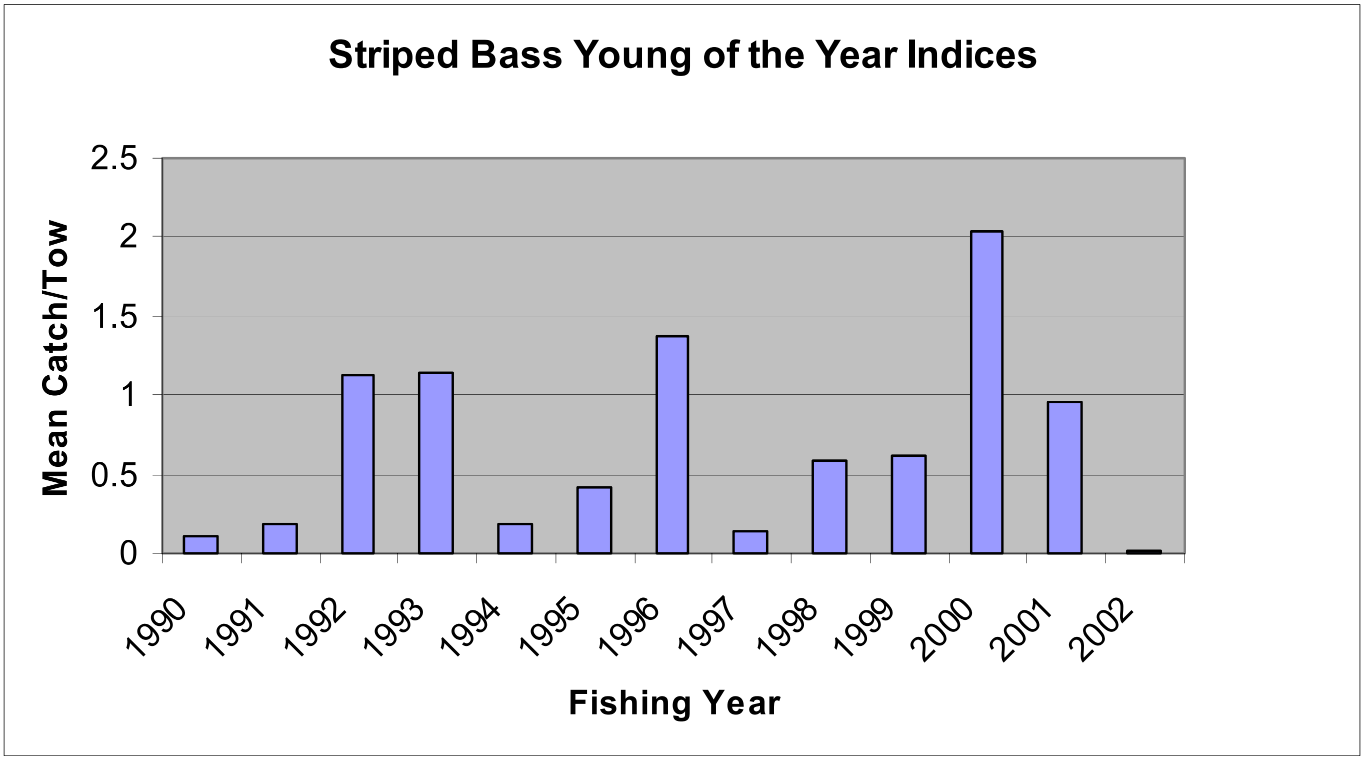


Figure 5.5-4 Striped Bass Relative Abundance 1966-2002

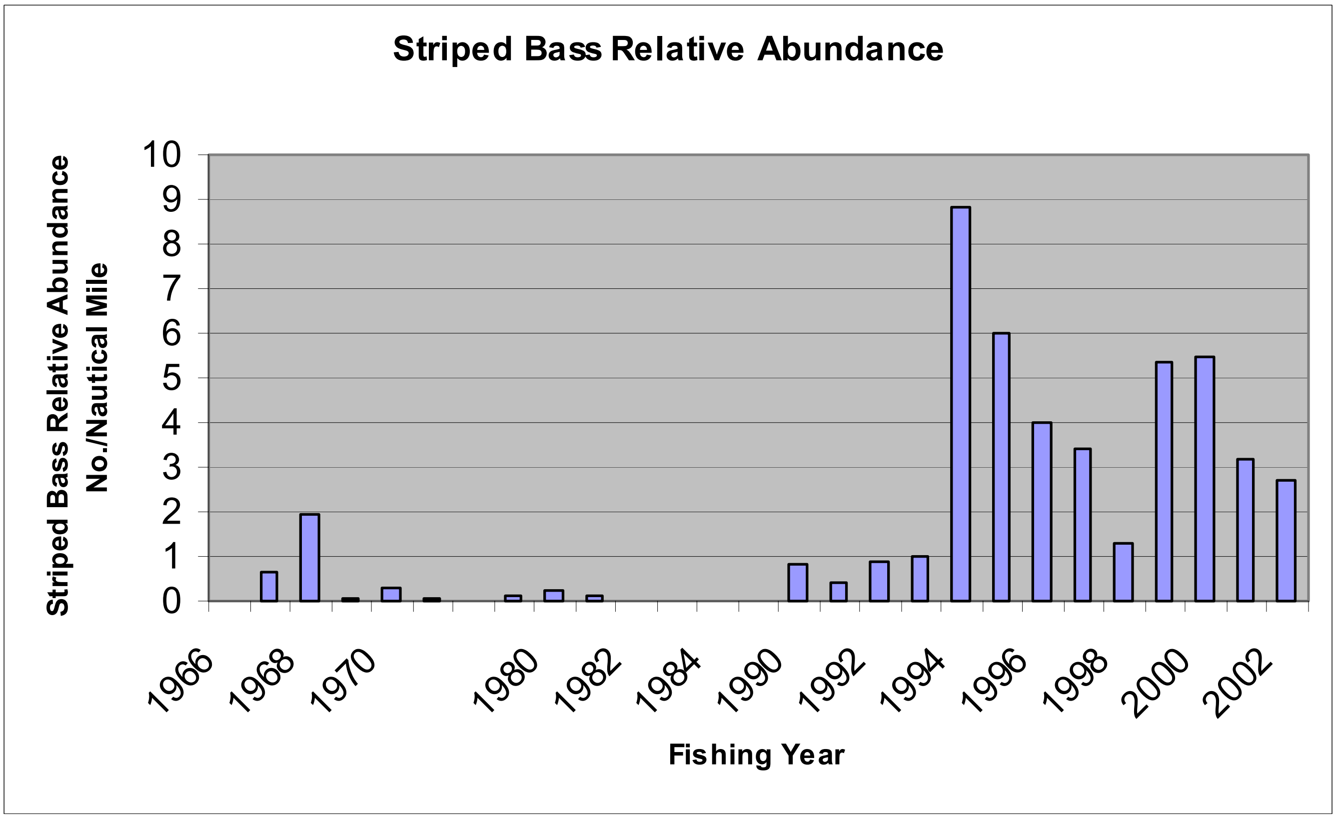


Figure 5.6-1 Weakfish Relative Abundance 1966-2003

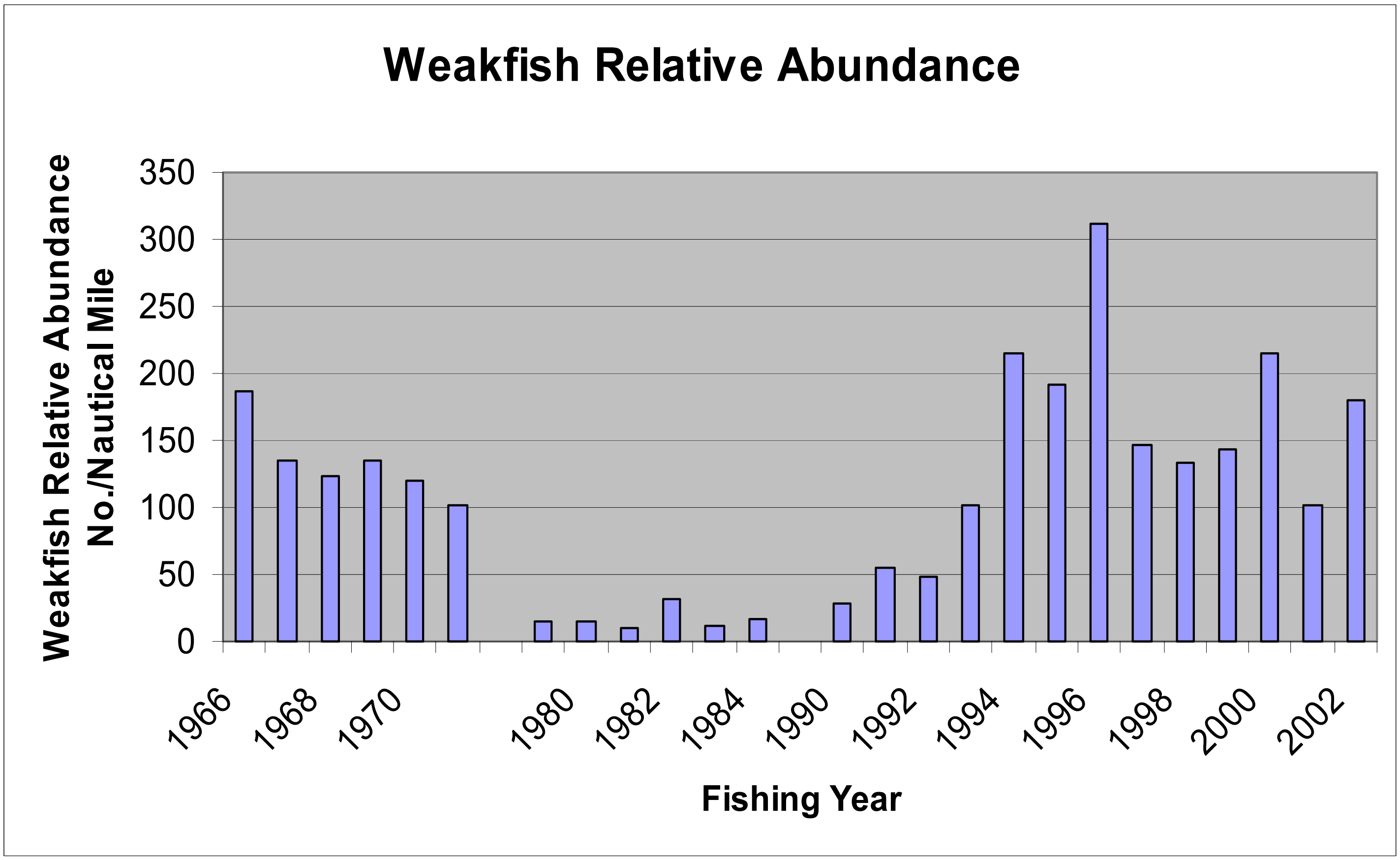


Figure 5.6-2 Weakfish Young of the Year Indices 1980-2002

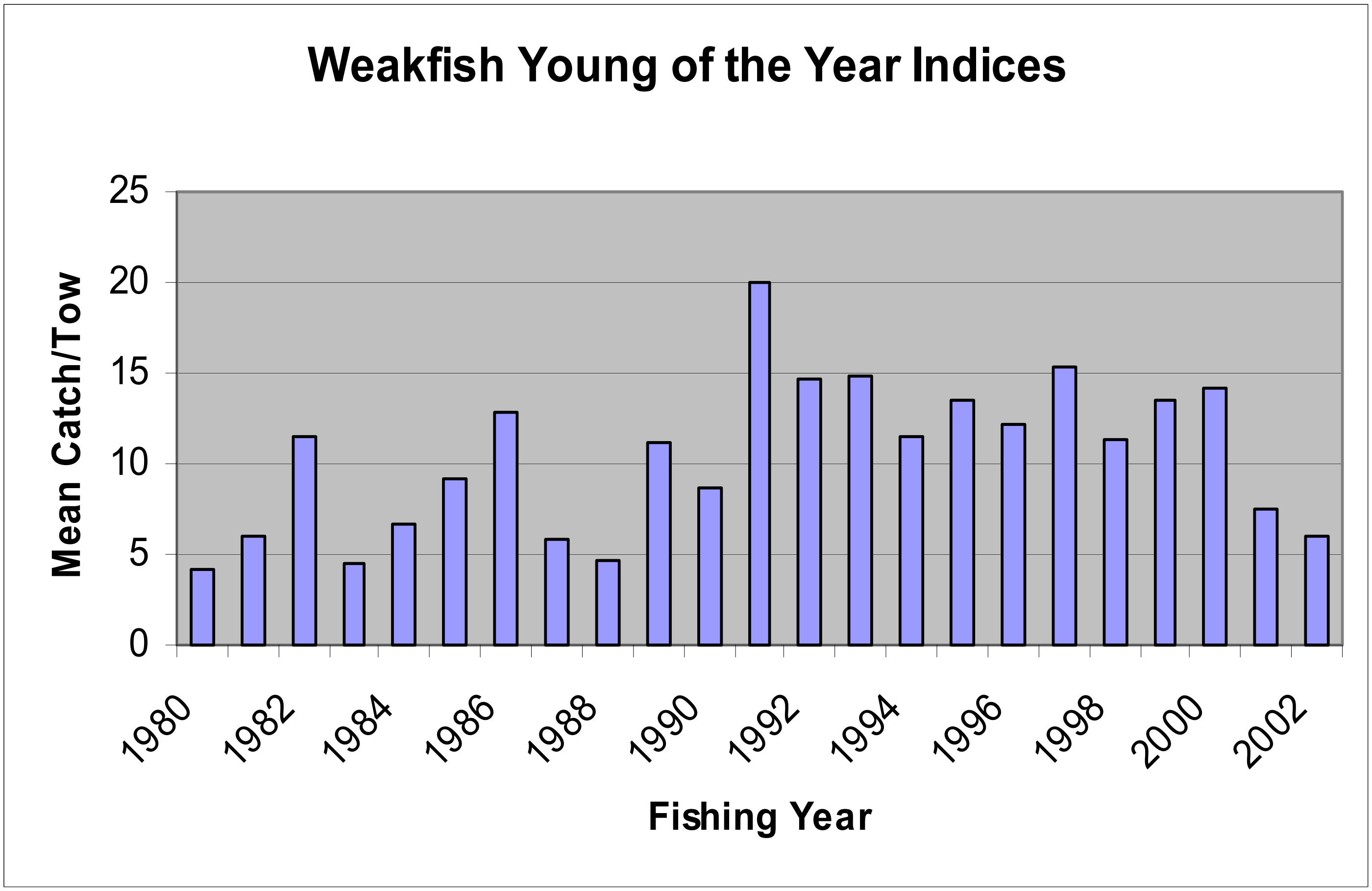


Figure 5.7-1 Annual Catch Rates of Atlantic Sturgeon in the Delaware River

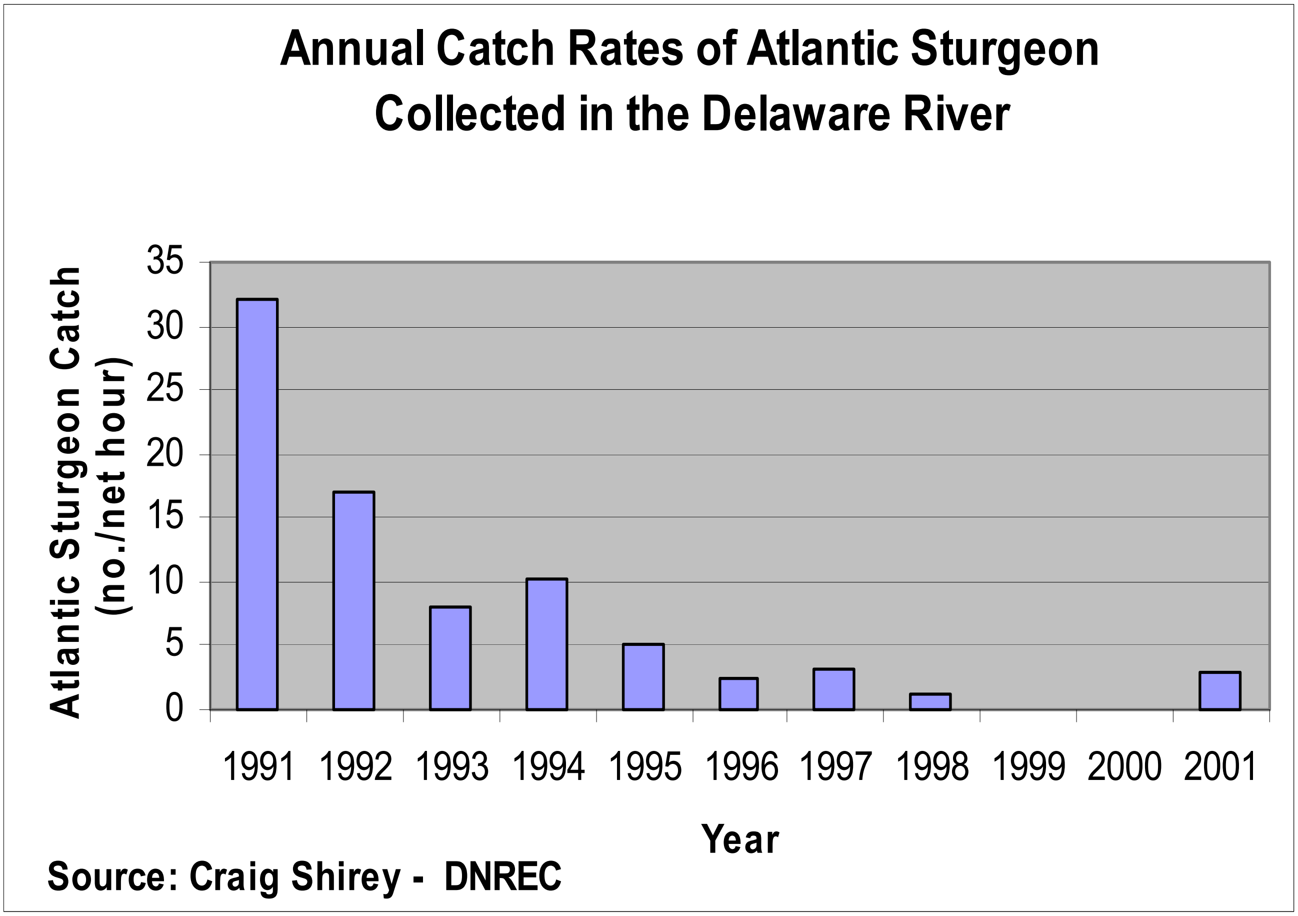
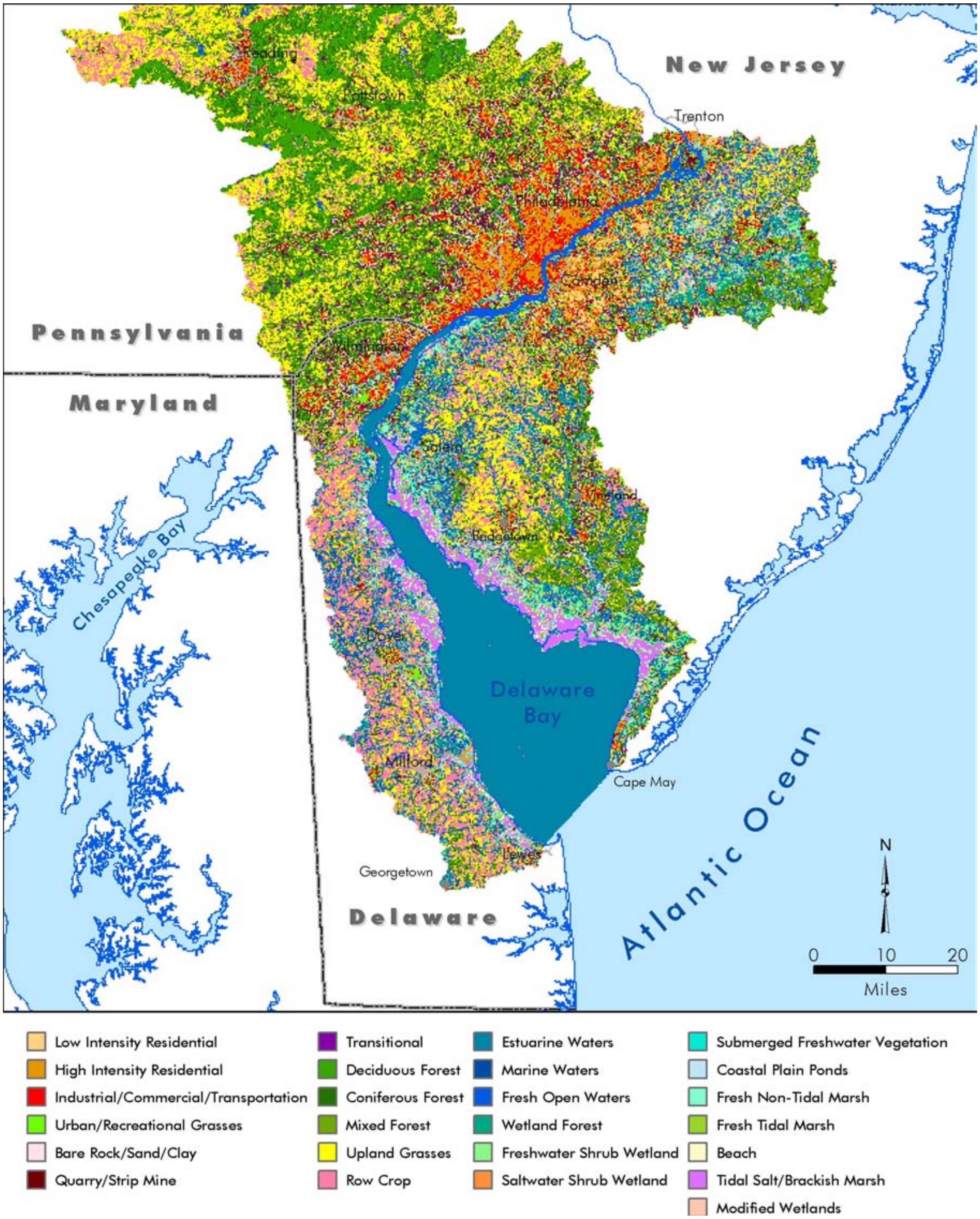


Figure 6.1-1 Habitat Types in the Delaware Estuary



11.0 TABLES

TABLE 2.1-1 METHODS OF ANALYSIS FOR BOAT RUN PARAMETERS

CATEGORY OF PARAMETERS	PARAMETER	METHOD REFERENCE	MDL[1]	LOQ[2]
ROUTINE	ALKALINITY	EPA 310.1	0.6 mg/L	1.0 mg/L
	CHLORIDE	EPA 325.2	1 mg/L	3 mg/L
	DISSOLVED OXYGEN	EPA 360.2	N/A	0.1 mg/L
	DO SATURATION, %	YSI	N/A	1%
	HARDNESS	EPA 130.2	1.0 mg/L	1.0 mg/L
	pH	EPA 150.1	N/A	0.1 unit
	ORTHOPHOSPHATE, DISSOVED	EPA 365.1	0.002 mg/L	0.010 mg/L
	PHOSPHOROUS, TOTAL	EPA 365.4	0.005 mg/L	0.040 mg/L
	SALINITY	STDMTD 2520	N/A	0.1ppt
	SECCHI DISK	ELS	N/A	N/A
	SODIUM	EPA 200.7	207 ug/L	5000 ug/L
	SPECIFIC CONDUCTANCE	EPA 120.1	N/A	2.0 uS/cm
	TEMPERATURE, AIR/WATER	EPA 170.1	N/A	N/A
	SUSPENDED SOLIDS, TOTAL (TSS)	EPA 160.2	N/A	5.0 mg/L
	DISSOLVED SOLIDS, TOTAL (TDS)	EPA 160.1	N/A	2.0 mg/L
	TURBIDITY	EPA 180.1	N/A	1.0 NTU
	NH_3 - N	EPA 350.1	0.004 mg/L	0.020 mg/L
	NO_2 - N	EPA 354.1	0.003 mg/L	0.008 mg/L
	NO_3 - N	EPA 353.2, 354.1	0.005 mg/L	0.010 mg/L
	NO_3 – N & NO_2 - N	EPA 353.2	0.005 mg/L	0.010 mg/L
BACTERIAL	E. COLI	STMTD 18th ed. 9225-C	N/A	1 cfu/100mL
	ENTEROCOCCUS	STMTD 18th ed. 9230-C	N/A	1 cfu/100mL
	COLIFORM, FECAL (MTEC)	EPA 1103.1	N/A	1 cfu/100mL
ALGAL	CHLOROPHYLL A[3]	STDMTD 18th ed. 10200H	0.6 ug/L	1.0 ug/L
	PHEOPHYTIN A	STDMTD 18th ed. 10200H	N/A	2.0 ug/L
	SILICA	EPA 370.1	0.3 mg/L	1.0 mg/L
	PRODUCTIVITY, CARBON 14 METHOD	Procedure developed by University of Delaware College of Marine Studies	N/A	N/A
	LIGHT TRANSMISSION[4]	LI-COR	N/A	0.0015 $umol/s/m^2$
HEAVY METALS	COPPER, DISSOLVED	EPA 200.7	0.9 ug/L	5.0 ug/L
	COPPER, TOTAL	EPA 200.7	0.9 ug/L	5.0 ug/L
	CHROMIUM, HEXAVALENT	STDMTD 13th ed. 117A	1.4 ug/L	5.0 ug/L
	ZINC, DISSOLVED	EPA 200.7	0.2 ug/L	10.0 ug/L
	ZINC, TOTALl	EPA 200.7	0.2 ug/L	10.0 ug/L
VOLATILE ORGANICS		EPA 524.2	0.01 ug/l	0.1 ug/l

[1]Method Detection Limit, as defined in the Federal Register 40 CFR Part 136 Appendix B.
[2]Limit of Quantitation. LOQ represents the lowest standard in the calibration curve or, in instances where a standard curve is not specified by the procedure, LOQ represents the limitations of the method.
[3]For Chlorophyll A, one split sample, for analysis at another laboratory selected by DNREC, shall be conducted.
[4]Light transmission to be conducted as practical to obtain correlation with Secchi disk readings.

Table 2.2-2 Fishes Collected during the National Coastal Assessment Program in Delaware Bay and Tributaries 2000 – 2002

COMMON NAME	SCIENTIFIC NAME
ACADIAN REDFISH	SEBASTES FASCIATUS
ALEWIFE	ALOSA PSEUDOHARENGUS
AMERICAN EEL	ANGUILLA ROSTRATA
AMERICAN LOBSTER	HOMARUS AMERICANUS
AMERICAN PLAICE	HIPPOGLOSSOIDES PLATESSOIDES
AMERICAN SHAD	ALOSA SAPIDISSIMA
ANCHOVY	ENGRAULIDAE SP
ATLANTIC COD	GADUS MORHUA
ATLANTIC CROAKER	MICROPOGONIAS UNDULATUS
ATLANTIC HERRING	CLUPEA HARENGUS
ATLANTIC MENHADEN	BREVOORTIA TYRANNUS
ATLANTIC MOONFISH	SELENE SETAPINNIS
ATLANTIC SILVERSIDE	MENIDIA MENIDIA
ATLANTIC TOMCOD	MICROGADUS TOMCOD
BANDED KILLIFISH	FUNDULUS DIAPHANUS
BAY ANCHOVY	ANCHOA MITCHILLI
BLACK CRAPPIE	POMOXIS NIGROMACULATUS
BLACK DRUM	POGONIAS CROMIS
BLACK SEA BASS	CENTROPRISTIS STRIATA
BLUE CRAB	CALLINECTES SAPIDUS
BLUEBACK HERRING	ALOSA AESTIVALIS
BLUEFISH	POMATOMUS SALTATRIX
BLUESPOTTED CORNETFISH	FISTULARIA TABACARIA
BROWN BULLHEAD	AMEIURUS NEBULOSUS
BUTTERFISH	PEPRILUS TRIACANTHUS
CARP	CYPRINUS
CHANNEL CATFISH	ICTALURUS PUNCTATUS
CLEARNOSE SKATE	RAJA EGLANTERIA
COWNOSE RAY	RHINOPTERA BONASUS
CUNNER	TAUTOGOLABRUS ADSPERSUS
FAWN CUSK-EEL	LEPOPHIDIUM PROFUNDORUM
FLOUNDER	PSEUDOPLEURONECTES AMERICANUS
FLUKE	PARALICHTHYS DENTATUS
FOURBEARD ROCKLING	ENCHELYOPUS CIMBRIUS
FOURSPINE STICKLEBACK	APELTES QUADRACUS
FOURSPOT FLOUNDER	PARALICHTHYS OBLONGUS
GIZZARD SHAD	DOROSOMA CEPEDIANUM
GLASSEYE SNAPPER	PRIACANTHUS CRUENTATUS
GOLDEN SHINER	NOTEMIGONUS CRYSOLEUCAS
GOOSEFISH	LOPHIUS AMERICANUS
GRUBBY SCULPIN	MYOXOCEPHALUS AENAEUS
HERRING	CLUPEIDAE SP
HERRING SMELT	ARGENTINA SILUS
HICKORY SHAD	ALOSA MEDIOCRIS
HOGCHOKER	TRINECTES MACULATUS
HORSESHOE CRAB	MEROSTOMATA
INSHORE LIZARDFISH	SYNODUS FOETENS
LINED SEAHORSE	HIPPOCAMPUS ERECTUS

LITTLE SKATE	RAJA ERINACEA
LONG-FINNED SQUID	ILEX SPs
LONGHORN SCULPIN	MYOXOCEPHALUS OCTODECEMSPINOSU
LOOKDOWN	SELENE VOMER
MOONFISH	SELENE OERSTEDII
MULLET	MUGIL Sps.
MUMMICHOG	FUNDULUS HETEROCLITUS
NAKED GOBY	GOBIOSOMA BOSC
NINESPINE STICKLEBACK	PUNGITIUS PUNGITIUS
NORTHERN KINGFISH	MENTICIRRHUS SAXATILIS
NORTHERN PIPEFISH	SYNGNATHUS FUSCUS
NORTHERN PUFFER	SPHOEROIDES MACULATUS
NORTHERN SEAROBIN	PRIONOTUS CAROLINUS
NORTHERN SENNET	SPHYRAENA BOREALIS
NORTHERN STARGAZER	ASTROSCOPUS GUTTATUS
OCEAN POUT	MACROZOARCES AMERICANUS
OYSTER TOADFISH	OPSANUS TAU
PINFISH	LAGODON RHOMBOIDES
PIPEFISH	SYNGNATHIDAE
PLANEHEAD FILEFISH	MONACANTHUS HISPIDUS
POLLOCK	POLLACHIUS VIRENS
PORGY	SPARIDAE SP
PUMPKINSEED	LEPOMIS GIBBOSUS
RED DRUM	SCIAENOPS OCELLATUS
RED HAKE	UROPHYCIS CHUSS
ROCK GUNNEL	PHOLIS GUNNELLUS
ROUND SCAD	DECAPTERUS PUNCTATUS
SCUP	STENOTOMUS CHRYSOPS
SEA RAVEN	HEMITRIPTERUS AMERICANUS
SHAD	ALOSA SPs.
SHEEPSHEAD MINNOW	CYPRINODON VARIEGATUS
SHINER	NOTROPIS SP
SILVER HAKE	MERLUCCIUS BILINEARIS
SILVER PERCH	BAIRDIELLA CHRYSOURA
SKATE	RAJIDAE SP
SMALLMOUTH FLOUNDER	ETROPUS MICROSTOMUS
SMOOTH DOGFISH	MUSTELUS CANIS
SMOOTH FLOUNDER	PLEURONECTES PUTNAMI
SNAKE BLENNY	LUMPENUS LUMPRETAEFORMIS
SPINY DOGFISH	SQUALUS ACANTHIAS
SPOT	LEIOSTOMUS XANTHURUS
SPOTTAIL SHINER	NOTROPIS HUDSONIUS
SPOTTED HAKE	UROPHYCIS REGIA
STRIPED ANCHOVY	ANCHOA HEPSETUS
STRIPED BASS	MORONE SAXATILIS
STRIPED BLENNY	CHASMODES BOSQUIANUS
STRIPED CUSK-EEL	OPHIDION MARGINATUM
STRIPED SEAROBIN	PRIONOTUS EVOLANS
SUMMER FLOUNDER	PARALICHTHYS DENTATUS
SWAMP DARTER	ETHEOSTOMA FUSIFORME
TAUTOG	TAUTOGA ONITIS
THORNY SKATE	AMBLYRAJA RADIATA

WEAKFISH	CYNOSCION REGALIS
WHITE CATFISH	AMEIURUS CATUS
WHITE HAKE	UROPHYCIS TENUIS
WHITE PERCH	MORONE AMERICANA
WHITE SUCKER	CATOSTOMUS COMMERSONI
WINDOWPANE	SCOPHTHALMUS AQUOSUS
WINTER FLOUNDER	PLEURONECTES AMERICANUS
WINTER SKATE	RAJA OCELLATA
YELLOW JACK	CARANX BARTHOLOMAEI
YELLOWTAIL FLOUNDER	PLEURONECTES FERRUGINEUS

TABLE 2.2-3 Samples Collected During the National Coastal Assessment Program

	Portion Analyzed	No. of Fish in Sample	Mean Length [(1)] (cm)	Minimum Length [(1)] (cm)	Maximum Length [(1)] (cm)
Blue Crab	whole body	8	13.5	12.0	16.0
Blue Crab	whole body	5	13.1	12.0	15.1
Blue Crab	whole body	8	14.5	12.7	15.7
Blue Crab	whole body	6	13.3	12.0	15.4
Blue Crab	whole body	6		12.0	15.5
Blue Crab	whole body	5	14.0	11.7	15.7
Blue Crab	whole body	8		12.2	15.5
Blue Crab	whole body	6	15.0	14.0	17.2
Blue Crab	whole body	7	13.7	12.4	15.2
White Perch	fillet, w/skin	6	19.4	17.1	23.7
White Perch	fillet, skin on	6	17.7	16.2	20.4
White Perch	fillet, skin on	8	16.6	15.3	18.1
White Perch	fillet, skin on	9	15.4	10.1	17.1
Channel Catfish	fillet, skin on	9	22.9	20.4	26.0
White Perch	fillet, skin on	5	15.1	12.3	16.4
White Perch	fillet, skin on	7		14.5	17.5
Weakfish	fillet, skin on	5	30.2	27.5	32.0
Weakfish	fillet, skin on	8		13.7	19.9
White Perch	fillet, skin on	4		28.5	32.0
Weakfish	fillet, skin on	9		24.9	36.6

Channel Catfish	fillet, skin on	6	23.1	21.2	25.1
White Perch	fillet, skin on	9	16.4	25.1	15.1
Channel Catfish	fillet, skin on	9	23.3	20.9	26.3
White Perch	fillet, skin on	9	16.8	15.0	18.5
Channel Catfish	fillet, skin on	5	28.8	24.9	32.5
White Perch	fillet, skin on	9	16.7	15.3	18.2
Channel Catfish	fillet, skin on	9	17.0	15.5	20.1

Table 5.3-1 Model Inputs and results from catch-survey model applied to Delaware Bay blue crab (1979-2002)						
Model Inputs						
	Survey Indices (#/tow)		Survey Avg. Wt. (kg)		Landings	
Fishing Year	Recruits	Fully-Recruited	Recruits	Fully-Recruited	Number, Mil.	1,000 Pounds
1979	2.04	0.32	0.03	0.16	4.38	1,423
1980	1.28	0.82	0.03	0.15	9.96	3,318
1981	5.64	0.47	0.01	0.17	7.10	2,329
1982	2.02	1.48	0.01	0.15	4.67	1,595
1983	0.54	0.47	0.03	0.16	6.49	2,198
1984	0.83	0.55	0.02	0.18	8.35	2,794
1985	3.36	0.96	0.02	0.17	16.04	5,350
1986	7.76	0.62	0.03	0.17	17.74	5,731
1987	1.53	0.85	0.03	0.14	20.52	6,690
1988	3.11	0.74	0.03	0.15	24.89	7,829
1989	4.02	1.59	0.02	0.13	28.84	9,358
1990	10.49	1.16	0.01	0.13	34.53	11,163
1991	0.74	1.06	0.03	0.16	26.96	9,120
1992	4.75	1.31	0.02	0.18	32.01	9,936
1993	3.76	2.47	0.03	0.14	38.81	12,748
1994	8.12	1.46	0.03	0.16	32.50	10,285
1995	11.22	1.39	0.01	0.14	48.53	15,080
1996	2.62	1.46	0.03	0.14	22.29	7,132
1997	4.01	1.26	0.03	0.13	26.62	8,633
1998	12.98	1.61	0.02	0.14	32.90	10,445
1999	5.32	1.59	0.03	0.14	35.65	11,690
2000	9.41	1.55	0.01	0.14	25.52	8,561

2001	8.35	1.42	0.01	0.13	21.40	7,295
2002	3.54	1.03	0.03	0.15	27.19	9,074
2003	2.556	0.72	0.01	0.15		

Table 6.1-1 Data Sources Used to Create PHU Base Map and Perform Habitat Analysis

Database	Data Source	Use
National Land Cover Dataset (NLCD)	USGS webserver	Land cover base data
NWI wetland polygons	USFWS/NWI webserver	Supplemental wetland information
Delaware State Wetland Mapping Project (SWMP) data	DNREC CD	Supplemental wetland information
New Jersey State Wetlands	NJDEP webserver	Supplemental wetland information
Pennsylvania Small Watersheds	Pennsylvania Spatial Data Access (PASDA) webserver	Watershed boundaries
New Jersey HUC 11 Watersheds	NJDEP webserver	Watershed boundaries
Delaware Watersheds	DNREC email	Watershed boundaries
EPA Reach file 3	EPA webserver	Stream lines
National Elevation Dataset	USGS webserver	Elevation
Mid-Atlantic GAP data	CD	Vegetative communities
New Jersey LULC 1997	NJDEP webserver	Vegetative communities
FEMA Q3 Floodplain data	FEMA online dealer	Floodplains
Horseshoe crab areas	USFWS	Areas important to horseshoe crabs

Table 6.1-2 Classification Scheme and Relative Size of Primary Habitat Units (2002)

Basemap Primary Habitat Unit	Total Acreage (in acres)	Percentage of Total Study Area
I. Forests and Woodlands		
A. Upland Deciduous Forest	866,886	20.14
B. Coniferous Forest	105,018	2.44
C. Mixed Forest	260,969	6.06
D. Wetland Forest	253,491	5.89
E. Transitional (Early Successional Forest)	14,578	0.34
II. Shrublands		
A. Freshwater Shrub Wetlands	58,372	1.36
B. Saltwater Shrub Wetlands	3517	0.08
III. Herbaceous Vegetation		
A. Upland Grasses (Pasture-Hay)	858,548	19.95
B. Urban Recreational Grasses	42,810	0.99
C. Freshwater Herbaceous Vegetation of Coastal Plain Ponds	582	0.01
D. Freshwater Non-tidal Marsh	30,976	0.72
E. Freshwater Tidal Marsh	12,581	0.29
F. Submerged Freshwater Vegetation	428	0.01
G. Tidal Salt/Brackish Marsh	165,367	3.84
H. Beach (Sparsely Vegetated)	1340	0.03
I. Row Crops	396,622	9.21
J. Modified Wetlands	54,347	1.26
IV. Un-vegetated Aquatic Systems		
A. Marine Waters	125	0.00
B. Estuarine Waters	486,527	11.30
C. Fresh Open Waters	68,809	1.60
V. Unvegetated Terrestrial Systems		
A. Bare Rock/Sand/Clay	785	0.02
B. Quarry/Strip Mine	24,063	0.56
VI. Developed Land		
A. High Intensity Residential	85,226	1.98
B. Low Intensity Residential	388,794	9.03
C. Industrial/Commercial/Transportation	123,538	2.87
Total	**4,304,301**	**100.00**

Table 6.2-1 **Private Protected Open Space (Acres)**

Year 2002 Private Protected Open Space (acres)				
County	***Preserved Farmland***	***Land Trust Owned and Eased Lands***	***Total Private Protected Open Space***	***Private Protected Open Space as Percent of Total Area***[2]
Berks	29,553	6,252	35,805	6.51%
Bucks	5,835	7,523	13,358	3.44%
Chester	16,348	30,660	47,008	9.72%
Dauphin[1]	7,229	n/a	7,229	n/a
Delaware	208	2,289	2,497	2.12%
Lancaster[1]	50,795	106	50,901	8.38%
Lebanon[1]	6,898	n/a	6,898	2.98%
Lehigh	12,155	577	12,732	5.74%
Montgomery	5,551	3,443	8,994	2.91%
Northampton	4,336	746	5,082	2.12%
Philadelphia	0	531	531	0.61%
PA TOTAL	***138,908***	***52,127***	***191,035***	***5.35%***
New Castle	15,434	3,815	19,249	7.06%
DE TOTAL	***15,434***	***3,815***	***19,249***	***7.06%***
Atlantic	259	1,003	1,262	0.35%
Burlington	16,170	4,108	20,278	3.94%
Camden	47	9	56	0.04%
Cape May	2,246	3,291	5,537	3.39%
Cumberland	10,559	21,872	32,431	10.36%
Gloucester	7,376	823	8,199	3.95%
Hunterdon	13,384	2,480	15,864	5.77%
Mercer	3,535	3,252	6,787	4.69%
Ocean	2,443	11,876	14,319	3.52%
Salem	14,227	4,744	18,971	8.77%
Warren	8,279	2,684	10,963	4.79%
NJ TOTAL	***78,525***	***56,142***	***134,667***	***4.53%***
REGION TOTAL	***232,867***	***112,084***	***344,951***	***4.90%***

Source: All data was acquired from the respective county planning commissions with the exception of the following: Land Trust Owned and Eased Lands data for Bucks, Chester, Delaware, Montgomery and Philadelphia counties was provided by the GreenSpace Alliance of Southeastern Pennsylvania; preserved farmland data for Lebanon County was acquired from the Lebanon County GIS department; Land Trust Owned and Eased Lands data for Atlantic, Cape May, Cumberland, Hunterdon, Mercer, Ocean and Salem counties was obtained from Green Acres, NJDEP.

Votes:

The Conservation Fund is currently collecting comprehensive land trust owned and eased lands data for Lebanon, Dauphin and Lancaster County. This data set will become available in 2004.

This calculation is based on county land area only (water area is not included). Source: U.S. Census Bureau

Table 6.2-2 Public Protected Open Space (Acres)

ar 2002 Public Protected Open Space by Ownership (acres)

County	Federal	State	County	Municipal	Total Public Park Area	Percent of Total Area[4]	Park Acreage Per 1,000 Population[5]
Berks	7,612	29,307	1,147	15,774	53,840	9.79%	144.1
Bucks	0	12,752	8,322	7,612	28,686	7.38%	48.0
Chester	1,290	6,747	4,945	6,529	19,511	4.03%	45.0
Dauphin[1]	1	54,081	510	n/a	54,592	16.24%	216.8
Delaware	726	2,683	844	3,519	7,772	6.59%	14.1
Lancaster	0	9,769	1,984	2,744	14,497	2.39%	30.8
Lebanon[2]	0	27,171	n/a	n/a	27,171	11.73%	225.8
Lehigh	92	6,481	3,064	3,116	12,753	5.75%	40.9
Montgomery[3]	2,166	4,389	5,770	10,335	22,660	7.33%	30.2
Northampton	1,602	6,293	795	2,642	11,332	4.74%	42.4
Philadelphia	365	282	8,126	1,360	10,133	11.72%	6.7
PA TOTAL	***13,854***	***159,955***	***35,507***	***53,631***	***262,947***	***7.36%***	***46.6***
New Castle	5,845	19,799	5,626	1,491	32,761	12.01%	65.5
DE TOTAL	***5,845***	***19,799***	***5,626***	***1,491***	***32,761***	***12.01%***	***65.5***
Atlantic	20,660	59,995	5,628	2,430	88,713	24.71%	351.3
Burlington	4,001	128,856	1,966	10,343	145,166	28.19%	342.9
Camden	0	18,536	2,087	3,461	24,084	16.93%	47.3
Cape May	5,401	40,985	2,181	4,173	52,740	32.29%	515.4
Cumberland	0	74,140	169	1,323	75,632	24.15%	516.5
Gloucester	0	5,108	1,687	6,034	12,829	6.17%	50.4
Hunterdon	0	9,607	5,901	3,790	19,298	7.01%	158.2
Mercer	0	3,464	7,763	6,520	17,747	12.28%	50.6
Ocean	17,091	97,625	5,363	8,217	128,296	31.51%	251.1
Salem	2,409	15,993	15	823	19,240	8.90%	299.3
Warren	9,072	20,211	1,344	1,650	32,277	14.09%	315.1
NJ TOTAL	***58,634***	***474,520***	***34,104***	***48,764***	***616,022***	***20.72%***	***217.0***
REGION TOTALS	***78,333***	***654,274***	***75,237***	***103,886***	***911,730***	***13.37%***	***101.5***

Source: All data was acquired from the respective county planning commissions with the exception of the following: all data for Dauphin County was obtained from the Dauphin County Dept. of Parks and Recreation; Bucks County county parkland data was obtained from the Bucks County Dept. of Parks and Recreation; the Fairmount Parks Commission provided county parkland data for Philadelphia; county and municipal parkland data for Cape May, Cumberland, Hunterdon, and Salem Counties and municipal parkland data for Gloucester County was obtained from Green Acres, NJDEP; and partial state and federal lands data was collected from NJDEP . Table assembled in August 2003.

Notes:

[1]County lands in Dauphin County are included in the table above but the associated spatial data is not currently available in digital GIS form. Municipal parkland data for Dauphin County is not currently available in GIS form.

[2]Current federal, county and municipal parkland data for Lebanon County is not available in GIS form.

[3]Additions to Montgomery County's county and municipal park systems through 2002 are included in the above table, but the associated shape files have not yet been created by the Montgomery County Planning Commission and are not represented on the Regional Protected Open Space Map. Approximately 500 acres of county parkland and 600 acres of municipal parkland are not shown on the map.

[4]This calculation is based on county land area only (water area is not included). Source: U.S. Census Bureau

[5]This calculation uses actual population figures from the 2000 U.S. Census. Source: U.S. Census Bureau

Table 6.2-3 2000-2003 Protected Open Space by Ownership

County	Year	Federal	State	County	Municipal	Total Protected Public Open Space	Protected Open Space as Percent of Total Area[4]	Protected Open Space Per 1,000 Population[3]	Preserved Farmland	Land Trust or Privately Protected	Open Space as Percent of Total Area[4]	Open Space as Percent of Total Area[4]	Total Protected Open Space	Open Space as Percent of Total Area[4]	Open Space Per 1,000 Population[3]
2000-2003 Protected Open Space by Ownership (acres)															
Bucks[1,2]	2000	0	12,752	7,567	7,267	27,586	7.10%	46.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2002	0	12,752	8,322	7,612	28,686	7.38%	48.0	5,835	7,523	1.94%	0.00%	28,686	7.38%	48.0
	2003	0	12,880	8,322	10,363	31,565	8.12%	52.8	10,020	7,617	1.96%	0.00%	31,565	8.12%	52.8
Chester	2000	1,290	6,747	4,945	5,722	18,704	n/a	n/a	10,932	n/a	n/a	n/a	n/a	n/a	n/a
	2002	1,290	6,747	4,945	6,529	19,511	4.03%	45.0	16,348	30,660	6.34%	0.00%	19,511	4.03%	45.0
	2003	1,290	7,102	5,407	6,951	20,750	4.29%	47.9	20,072	30,660	6.34%	0.00%	20,750	4.29%	47.9
Delaware	2000	726	2,683	844	3,334	7,587	n/a	n/a	208	n/a	n/a	n/a	n/a	n/a	n/a
	2002	726	2,683	844	3,519	7,772	6.59%	14.1	208	2,289	1.94%	0.00%	7,772	6.59%	14.1
	2003	726	2,683	844	5,197	9,450	8.02%	17.2	208	2,289	1.94%	0.00%	9,866	8.37%	17.9
Montgomery[5]	2000	2,166	4,349	5,564	9,454	21,533	n/a	n/a	4,207	n/a	n/a	n/a	n/a	n/a	n/a
	2002	2,166	4,389	5,770	10,335	22,660	7.33%	30.2	5,551	3,443	1.11%	0.00%	22,660	7.33%	30.2
	2003	2,166	4,349	5,920	10,981	23,416	7.57%	31.2	6,012	3,443	1.11%	0.00%	23,416	7.57%	31.2
Philadelphia	2000	365	282	8,126	1,360	10,133	11.72%	6.7	0	531	0.61%	0.00%	10,133	11.72%	6.7
	2002	365	282	8,126	1,360	10,133	11.72%	6.7	0	531	0.61%	0.00%	10,133	11.72%	6.7
	2003	365	282	8,126	1,360	10,133	11.72%	6.7	0	531	0.61%	0.00%	10,133	11.72%	6.7
PA TOTAL	**2000**	**4,547**	**26,813**	**27,046**	**27,137**	**85,545**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	2002	**4,547**	**26,853**	**28,007**	**29,355**	**88,762**	**6.40%**	**23.1**	**27,942**	**44,446**	**3.21%**	**0.00%**	**88,762**	**6.40%**	**23.1**
	2003	**4,547**	**27,296**	**28,619**	**34,852**	**95,314**	**6.88%**	**24.8**	**36,312**	**44,540**	**3.21%**	**0.00%**	**95,314**	**6.88%**	**24.8**
Burlington	2000	4,001	127,565	1,211	5,486	138,263	26.85%	326.6	13,430	2,411	0.47%	0.00%	138,263	26.85%	326.6
	2002	4,001	128,856	1,966	10,343	145,166	28.19%	342.9	16,170	4,108	0.80%	0.00%	145,166	28.19%	342.9
	2003	4,001	129,570	2,029	10,731	146,331	28.42%	345.6	17,877	5,847	1.14%	0.00%	146,331	28.42%	345.6
Camden	2000	0	18,536	1,964	3,276	23,776	16.71%	46.7	47	9	0.01%	0.00%	23,776	16.71%	46.7
	2002	0	18,536	2,087	3,461	24,084	16.93%	47.3	47	9	0.01%	0.00%	24,084	16.93%	47.3
	2003	0	18,842	2,599	4,198	25,639	18.02%	50.4	47	9	0.01%	0.00%	25,639	18.02%	50.4
Gloucester	2000	0	5,108	1,687	3,599	10,394	5.00%	40.8	5,437	468	0.22%	0.00%	10,394	5.00%	40.8
	2002	0	5,108	1,687	6,034	12,829	6.17%	50.4	7,376	823	0.40%	0.00%	12,829	6.17%	50.4
	2003	0	5,108	1,687	6,034	12,829	6.17%	50.4	7,376	823	0.40%	0.00%	12,829	6.17%	50.4
Mercer	2000	0	3,464	7,292	5,282	16,038	11.10%	45.7	2,843	2,781	1.92%	0.00%	16,038	11.10%	45.7
	2002	0	3,464	7,763	6,520	17,747	12.28%	50.6	3,535	3,252	2.25%	0.00%	17,747	12.28%	50.6
	2003	0	3,642	7,982	7,567	19,191	13.28%	54.7	3,656	3,463	2.40%	0.00%	19,191	13.28%	54.7
NJ TOTAL	**2000**	**4,001**	**154,673**	**12,154**	**17,643**	**188,471**	**16.67%**	**122.6**	**21,757**	**5,669**	**0.56%**	**0.00%**	**188,471**	**16.67%**	**122.6**
	2002	**4,001**	**155,964**	**13,503**	**26,358**	**199,826**	**19.79%**	**129.9**	**27,128**	**8,192**	**0.81%**	**0.00%**	**199,826**	**19.79%**	**129.9**
	2003	**4,001**	**157,162**	**14,297**	**28,530**	**203,990**	**20.20%**	**132.7**	**28,956**	**10,142**	**1.00%**	**0.00%**	**203,990**	**20.20%**	**132.7**
REGION TOTAL	**2000**	**8,548**	**181,486**	**39,200**	**44,780**	**274,014**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	2002	**8,548**	**182,817**	**41,510**	**55,713**	**288,588**	**12.05%**	**53.6**	**55,070**	**52,638**	**2.20%**	**0.00%**	**288,588**	**12.05%**	**53.6**
	2003	**8,548**	**184,458**	**42,916**	**63,382**	**299,304**	**12.49%**	**55.6**	**65,147**	**54,682**	**2.28%**	**0.00%**	**299,304**	**12.49%**	**55.6**

Source: Data was acquired from the respective county planning commissions; the Bucks County Dept. of Parks and Recreation; the Bucks County Open Space Program; the Heritage Conservancy; the Fairmount Parks Commission; the GreenSpace Alliance and NJDEP. Select from the respect following page for more detailed information on data collection. This table was assembled in December 2003.

12.0 APPENDICES

12.1 MONITORING MATRIX

Field1	Project Name	Collected By	Frequency	Period	RM From	To	Data Span	Ending	Sample Matrix	Parameters	Contact	"Notes"	Data Access	Availability	Time Frame Access
1	DRBC Daily Hydrologic Summary Report	USGS/DRBC, NYCDEP, Kimberly Clark Inc.	Daily/Hourly	Present	90	330	1985	Present	Daily flow, NYC storage, Estuary chloride & location	Flow WaterLevels Chloride Levels	Richard Fromuth (609) 883-9500 Ext.232.	Montague,Trenton, Lehigh River at Bethel & Easton, Schuylkill in Phila and Potts. Also long term data on NYC Delaware storage flows and % capacity at the Pepacton, Cannonsville, Neversink & Rondout, Delaware River Basin Reservoirs.	Hard Copy and Computer file	?	Daily
2	USGS Surface Water Quality Stations	USGS/NJDOH	4x/yr		30	330	1967	Present	Water	Dissolved nutrients, fecal coliform, enterococcus, metals, pesticides, PCBs, nitrogen, phosphorus and TOC	Bob Reiser (609) 771-3980	Stations in the Delaware Basin are listed in Appendix G2A - F. Analyzed by NJDOH. Macro nutrients analyzed 4x/yr, selected metals 2x/yr.	Hard Copy	Hard drive	1 week
3	USGS Groundwater Monitoring Network	USGS	Monthly		60	300		Present	Water levels	Ground water level measurements	Kirk White (610) 647-9008	USGS routinely monitors GW levels in at least 8 upland monitoring wells contributing to the recharge zone of the river.	Hard Copy	Hard drive	2-4 weeks
4	Oyster Spat Survey	DNREC	Seasonal	May-Sept	0	48	1974	Present	Abundance Indices	Abundance of Oyster Spat	Richard Cole (302) 739-4782	Delaware estuary and Bay relative abundance estimates.	Computer File	?	?
5	Shorebird migration survey	NJDEP/DNREC	Yearly	May-June	0	20	1986	Present	Counts	Aerial survey of abundancedm, species	Kathleen Clark (609) 628-2103	Weekly aerial survey of beaches, in May, Cape May to Cehansey (NJ) and Woodland Beach, DE to Cape Henlopen, DE	Computer file-Lotus	?	summary data available, raw data not given out
6	Apex Predators Survey	NOAA/NMFS NEFC	2 - 3x/yr	May-Oct	6	30	1995	Present	Tagging Study	Tagging study, Relative Abundance and dissection of selected sharks	Nancy Kohler (401) 782-3200	Gill netting & tagging in lower bay near sandbar shark nursing grounds, utilizing long lines and gill nets. (750' by 10' by 4" stretch mesh) May - Oct sampling at 12 stations in the Bay (See Appendix N1 & N2)	computer file	Disk	6 months
7	Beach Seine Survey/Striped Bass young of the year	NJDEP	2-3x/mo and 3x/yr	Aug-Oct	54	133	1980	Present	Census	Counts, Relative Abundance estimates	Tom Baum (609)748-2020	Juvenile fish survey from Artificial Island to Trenton at 16 fixed stations 2x/mo and at random stations 3x/yr. Primarily Str.bass yoy index & Amer.Shad yoy index in tidal waters.	Computer file	disk	annually
8	Burrows Run Preserve - Bird census	Del. Nature Society	Ongoing	Jul-Nov	58	133	1991	Present	Census data	Visul sitings, Relative abundance	Jim White (302) 239-2334 ext. 104	See Appendix G3 for station locations. Stations sampled mid-July - mid-November.	?	disk	?
9	Trawl Survey	NJDEP	5x/yr	May-Sept	4	58	1991	Present	Census	Abundance estimates, Young of the year	Jeffrey Normant (609)742-2040	Delaware Bay - Cape May to Salem, NJ. Sampling at 11 sites in NJ, Delaware Bay & Estuary with 16foot otter trawl.	Computer file; Excell	Hard Drive	3 months
10	Juvenile Fish Survey	DNREC	Monthly 7x/yr	Apr-Oct.	12	72	1980	Present	Census	Abundance estimates, young of the year survey	Stewart Michels (302) 739-4782	16' Bottom trawl C&D canal south in Delaware waters 1989 - present sampling from Reedy Island up to Wilmington area.	Computer file	Internet	present
11	Fisheries Landing Data	NOAA, NMFS, DNREC, NJDEP	Monthly	Jan-Dec	4	72	1880	Present	Catch Data	Landing Data	William Whitemore (312) 653-2887	Cape May, Lambertville, Port Norris, Wilmington landing data, selected records date back to 1880 (American Shad)	computer file; ASCII	Hard Drive	present; continuous
12	Water Use Inventory	DRBC	Annual		0	330	1987	1995	Water Useage	Identification Consumptive Use	David Sayers (609) 883-9500 Ext. 236	Update Inventory of several thousand locks and intakes within the Delaware River Basin			
13	Delaware Estuary Boat Run	DNREC/DRBC	March-Nov. 12/yr	Mar - Nov	31	128	1967	1997	Water	Fecal coliforms, conventionals, nutrients, metals, VOC's, radiological algae	Ed Santoro (609)883-9500 Ext. 268	Samples collected at 22 mid-channel stations, at low water slack. Radioactivity is tested annually. Subsurface samples collected from Trenton, NJ to mouth of Delaware Bay.	Computer file	STORET	2-3 months
14	Toxics Program	DRBC	Yearly		60	117	1993	Present	Tissue	79 PCB congeners, metals, pesticides	Dr.Thomas Fikslin (609) 883-9500	Five stations surveyed in the Delaware Estuary. Three stations within the non tidal river. One additional station is anticipated to be added during 2004.	Computer file	Disk	1 year
15	NAWQA	USGS	Monthly/Fixed Sites		133	330		1999	Water Sediment Tissue Biota	Inorganic,organic, biological, ecological	Jeffrey M. Fisher (609) 771-3953	Fixed sites sampled over 3 years and resampled every 6-7 years. Study area Delaware River & Coastal Plain to head of tide.See Appendix B1-B4 major ions are listed in B5.	Computer file;	Storet	3 months
16	Status & Trends	NOAA	Biennial		0	48	Present	Present	Tissue	Mussels & Oysters, tissue analysis, sediment grain size.	Gunnar Lauenstein (301) 713-3028 ext. 152	Up to eight locations in Delaware Bay on alternate years. See Appendix B-6.			
17	Market Fish Survey	FDA	Annual	1989	0	160	Present?	Present	Tissue	Fish Tissue		Tissue sampling of marketed fish and shellfish for heavy metals, Organophosphate and Organo chlorine Pesticides, Chlorophenyl Herbicides PAHs , PCBs and Dioxin/furans. This information is used to set action levels and criteria for injestion.			
18	Bottom Trawl Fisheries Survey	DNREC	Monthly	Mar -Nov	0	60	1966 and 1989	Present	Tissue	Fish Tissue	Stewart Michels (302) 739-4782	DNREC 33' bottom trawling since 1989.	Computer file; ASCII	disk	present
19	Raptor Study	NJDEP	Regular	Mar-Jul	0	60	1988	Present	Tissue	Productivity; contaminants in eggs, blood	Kathy Clark (609) 628-2436	Contaminants in Bald Eagles, Ospreys, Peregrine Falcons. Also limited sampling (1992-93) from DE Eagles on Estuary.	?	?	?
20	Mid-Atlantic Integrated Assessment (MAIA)	NOAA	Annually	Sept	0	133	1997	1998	Water Benthic Bioassay Tissue	Sediment toxicity and contaminant levels, Benthic biological studies and water quality studies	Dr. Javed Hameedi (301) 713-3034	92 stations in Estuary and Salem and Schuylkill Rivers and small estuaries; Cohansey, Blackbird Creek, St. Jones. (See Appendix H). Fish tissue will be collected during the 1998 survey.	Hard copy	Internet website	week to week
21	Nat'l Estuarine Reserve Sites (NERRS)				22	38						2 sites Cohansey Estuary, 2 sites St. Jones			
22	AMNET	NJDEP	1/5 yrs.	Jan-Dec	10	100	1995	Present	Census	Biological impairment ratings and biological studies	Alfred Korndoerfer (609)292-0427	Sample collection in 20 watershed management areas around the state. Delaware is sorted into 7 watershed areas and 307 sampling stations (See Appendix 1A - D). All stations above head of tide.	Computer file; Word Perfect, GIS	Hard Drive	Present
23	Atl. Coastal Fisheries Coop. Mgmt. progarm	NJDEP			20	160	1995	Present	Commercial catch, tagging	Catch record at port and age studies	Peter J. Himchak (609) 748-2020	Catch data/length frequency data on landings, tagging of selected species. Refer to Appendix J for info. Key species studied include: Amer. shad, River Herring, Atl. Sturgeon,Tautog, Amer.eel, and striped bass,	Hard Copy	disk	?
24	Modelling Calibration Studies	USGS/DRBC			170	200	1989	Present	Water	See notes	Ken Najjar (609) 883-9500 x256	Survey in upper river, modeling covers the area from Hancock, NY to Delaware Water Gap. Studies have included time of travel, nutrients and BOD, plant biomass and others.	Hard Copy		
25	Significant habitat mapping	USFWS, DELEP., DNREC	?	?	0	60	1994	Present	Mapping	Land use and cover types	Fish & Wildlife (609)646-9310	Mapping of significant habitats of priority species in the estuary. Matching funds provided by USEPA, USFWS, States			
26	Nat'l GAP Project	USFWS/BRD/EPA	?	?	0	60	1992	1993	Mapping	Land use and cover types	Fish & Wildlife (609)646-9310	Land use and cover type mapping focusing on plant commmunities and habitat			
27	GIS Mapping	NJDEP	Ongoing		0	330	1986	2002	Mapping	Land use and cover types	Lawrence L. Thornton (609) 984-2243	Land cover mapping of the entire state, sampling location maps.			
28	DVRPC Mapping	DVRPC	Ongoing		0	90			Mapping	Land use and cover types	Barry Seymour (215)592-1800 ext.2831	Land use mapping from low level aerial flights			
30	Int'l Shorebird Survey	Center for Conservation Sciences	Annually	Apr-Oct	0	30			Aerial survey	Annual counts	Brian Harrington (508)224-6521	Periodic surveys at limited, designated sites.	Computer file	disk	present
31	Tributary Studies	PADEP/DRBC	6x/Yr	Quarterly at minimum	80	100	1967	Present	Water	Conventionals, nutrients, metals, volatile organic compounds	Steve O'Niell (610) 832-6068 Ed Santoro (609) 883-9500 ext.268	Sample 3X June-Oct. 1X each in Fall, Winter, Spring in Pennsylvania tributaries to Delaware Riverj above the head of tide. (See Appendix C1 - C2)	Computer file	STORET	present

Field1	Project Name	Collected By	Frequency	Period	RM From	To	Data Span	Ending	Sample Matrix	Parameters	Contact	"Notes"	Data Access	Availability	Time Frame Access
32	Upper River Study	NJDEP/DRBC	7x/Yr	Apr - Oct	133	253			Water	Conventionals, nutrients, metals, volatile organic compounds, pesticides, and PCBs.	Tom Vernam (609) 292-0427	See Appendix D for parameter list. Sampling along mainstem and tributaries.			
33	Benthic Assemblages and habitat studies	PADEP, DNREC	5 year	1X/5yr	10	130	1997	Present	Benthic assemblages	Benthic assemblages	Gary Walters (610) 832-6099	See Appendix F	Computer file; hard copy	Microsoft Access	present
34	Bridge Scour Survey	USGS/PennDOT	Annual	Yearly	68	330	1987	Present	Bridge Scour	Assessment of sediment removal around fixed structures	Pamela Telis (717)730-6914	Tributary monitor sites. 13 USGS sites and 5 reservoir release sites.	hard copy	customized data base	?
35	WQ Studies in Delaware	USGS	Every 15 min.	Daily	54	100	?	Present	WQ Flow	Conventional parameters and water flow	Hugh Darling/Dan Goode (610) 647-9008 X-215	4 stations on Delaware mainstem, Ben Franklin Bridge, Fort Mifflin, Chester, Reedy Island Jetty, also monitor in Schuylkill near Vincent Dam.	Computer file; ASCII	Hard Drive	present; continuous
36	Scenic Rivers Monitoring Program	DRBC/NPS	Monthly		210	330	1984	Present	Water	Water chemistry, flow, ecological	Bob Limbeck (609) 883-9500 X230	Upper basin monitoring from Hancock, NY to the Delaware Water Gap.			
37	Specific Conductance Monitoring	USGS	1 per hour	Jan-Dec	55	90	1965	Present	Water	Chloride levels in the Estuary	Dave Galeone (610) 647-9008 X-215	Specific conductance data is converted by DRBC to chlorides and location of 7-day average 250 ml/l isochlor is determined on a daily basis stations at Ben Franklin Br., Ft. Mifflin, Chester, Kimberly Clark and Reedy Island.	Computer file; ASCII	Hard Drive	present; continuous
38	USACOE Feasibility Study	USACOE			210	330					Christine Bethke	Sampling in upper Delaware River, Riparian Evaluation System and Flood loss reduction			
39	Delaware Bay Reef Program	DNREC	1 or 2x/mo		6	30	1995	Present	Benthic Assemblages	Epifaunal community survey/Use Survey	Jeff Tinsman (302)739-4782	Periodic collections at artificial reef sites in Delaware Bay. 8 permitted sites from Collins Beach to Lewes, DE	Hard Copy	only available on Hard Copy	4 months
40	DE Fisheries Spawning Study	DNREC	4X/mo		68	104			Spawning Study	Abundance	Craig Shirey (302) 739-4431	Electro Fishing survey from Del.Mem.Bridge to Big Timber Creek, NJ - 20 stations	Computer file	Disk	?
41	DE Fisheries Sturgeon Study	DNREC	4x/mo (Jun-Dec)	June-Oct	58	62		Present	Tagging Study - DNA, Age and growth	Abundance,Census, Tagging Study	Craig Shirey (302) 739-4431	Drift and Gill netting, sonic & streamer tagging, DNA samples, ageing study fish collections from Pea Patch Isl. South to Salem .Experimental net 4" - 10" SQ mesh - 1,200' long.	Computer file; D-base	disk	present
43	DE Trawl Survey	DNREC	3x/mo	Mar-Dec	60	110		Present	Census	Census abundance, morphometrics and meristics	Stewart Michels (302)739-4782	Bay wide survey, adult fishes collected with 20' trawl.	Computer file; ASCII	disk	present
44	DE Sturgeon Study	DNREC	4x/mo	Jun - Oct	54	61		Present	Census Tagging	Tagging, DNA, Age & Growth	Craig Shirey (302) 739-4431	Drift gill netting, sonic and streamer tagging, DNA sampling, age and growth collections from Pea Patch Island to Salem.	Computer file; D-base	disk	present
45	DE Striped Bass Study	DNREC	4x/mo	Mar-Dec	68	110				Census, Spawning	Craig Shirey (302) 739-4431	Electro fishing sampling from Philadelphia Navy Yard to Delaware Memorial Bridge (20 stations)	Computer file; D-base	disk	9 months
46	Marine Water Quality Survey	NJDEP	Varies monthly to quarterly		4	48			Bacteriological sampling	Total & fecal coliforms	Robert Connell (609)738-2000	Presently 246 stations sampled in Delaware Bay. Frequency of collection varies to a minimum of 5x/yr. (See Appendix L1 & L2 for additional information)			
47	Callicoon Creek Watershed Study	NY Audubon Soc., NPS,WQCC, NRCS, SCSWSD	Weekly	Jul-Aug	303	304	35612	Ended	Nutrients, aquatic vegitation, Coliforms, Macro-invertibrate collection	Nutrients, conventuional pollutants, total & fecal coliforms, visual census	Lori Danuff McKeon (914)557-8025	Numerous stations in the Callicoon watershed sampled weekly. (See Attachment M for work plan)			
48	Marine Water Monitoring	NJDEP	Quarterly	Jan - Dec	0	48	1989	Present	Water Biota	Conventional nutrients, Biota, Bacteriological sampling - Entero-coccus and total coliform	Robert Connell (609)748-2000	19 sites sampled in Bay.			
49	WWTP Monitoring	PADEP, DRBC	Monthly,Bi-monthly, Quarterly	Jan-Dec	54	133	1967	Present	Oxygen, nitrogen series, metals, selected others	Conventionals, Nutrients, Metals, Selected Organics, TSS, BOD, P, pH	Ed Santoro (609)883-9500 X268 Steve O'Niell (610)832-6068	See Appendix O1 AND 02 for information. A list of facilities within the study area is presented on Appendix 02.	Hard copy and Computer file	STORET	present
50	Water Snapshot	Over 70 groups coordinated by DRBC	Annual	April	40	330	1996	Present	Water quality	Temperature, pH, Nitrogen, Phosphorus	Clarke Rupert (609)883-9500 ext.260	Volunteer groups take water samples	Computer file; Excel Hard Copy	DRBC website	2-4 weeks
51	Shellfish/ Recreational Survey	DNREC	4-5x/mo,	May-Sept	0	78	1989	Present	Water	Bacteriological sampling - Entero-coccus and total coliform	Jack Pingree (302)739-4590	Seven stations in Bay/Ocean. Since 1992 DNREC switched to systematic random sampling design. Del.River/Bay sampled since 1994. All major tribs into Del.Bay are sampled.	Computer file; Lotus spreadsheets	Disk	present
52	NJDEP ambient biomonitoring program	NJDEP, USEPA, USGS	5 year cycle		60	330	1975 1991	1988 Present	Sediment	Macro invertebrate survey. Coarse particulate organic matter	Alfred Korndoerfer (609)292-0427	At a minimum one station in each 2nd order stream along the NJ side of Delaware. (See Appendix A for map of stations)			
53	Univ. of Delaware Research Cruises	Univ. of Del.	Periodic 1 - 15x/yr	Jan-Dec	0	130	1978	Present	Water	Conventionals, nutrients, trace elements, dissolved and particulate trace metals and organic compounds microbia bio-mass and production	Dr. Jonathan Sharp (302)645-4259	Stations located every 5 - 10 km along main axis to the mouth of the Bay. Station 10 is the only station located in a tributary (Schuylkill River) Many stations coincident to the Delaware Estuary Boat Run (ID#14)(See Appendix R for map of stations).			
54	Estuary Enhancement Program	PSE&G	Trawls 1x/mo Beach Seine 2x/mo	April May-Oct	0	96	1994	Present	Biota, mapping, habitat enhancement, detrital sampling	Impingement, entrainment abundance, trawl survey, fish ladder monitoring, pesticide monitoring in marsh restoration areas	Ken Straight (856) 878-6929	Trawl surveys for fish abundance. See Appendix SA.. Fish ladder program for 5 tribs to Del.Estuary. are presented in Appendix SB. A site location map showing wetland restoration and reference marsh sites are presented in Appendix SC.			
55	Juvenile Survey	DNREC	7x/mo	Apr-Oct	0	60		Present	Census	Census, Spawning	Stewart Michels (302)739-4782	Young of the year and invertebrate collections using a 16' trawl.			
56	Pennsylvania Water Quality Network (WQN)	PADEP	Monthly	Jan-Dec	80	305	1931	Present	Water/Tissue	Conventionals, Nutrients, TDS, TSS, TOC, Metals, Fish Tissue and VOC's, Radiologicals,Coliforms,Flow, Biota,Plankton,Chl A, Macroinvertebrates	Tammy Schreffler (717)772-4048	9 stations (including WQN lakes) within the Delaware Estuary, fish tissue analyses 1 every 5 years. Macroinvertebrate samples 10x/yr, 14 stns lower Delaware Basin, above the head of tide, 6 stns central Delaware Basin, 10 stns upper Delaware Basin.			
57	USGS Surface Water Flow Monitoring	USGS	Every 15 mins.	Year Round	0	330	Variable, some stations early 1900	Present	Flow	Stage and Discharge	Randy Durlin USGS District Offices , PA	Real time data available on internet for NJ, NY, PA. Archived data available from internet and USGS District Office. Latitude & longitude locations for all stations.Non-tidal river & most tributaries			
58	National Weather Service Flood Forecasting Network	National Weather Service, USCS	As Required	Year Round	0	330			Forecast River Stages	River Stage	NWS Office in Mt. Holly, NJ & Binghampton, NY	During flood events, NWS uses precipitation forecasts and USGS stream flow data to forecast flood stages at USGS gauging stations eq. with satellite telemetry. Forecasts are placed on NOAA weather radio, media and internet.Lat/Lon Locations for stations.			
59	National Weather Service Precipitation	National Weather Service	Hourly	Year Round	0	330	Variable - some stations since 1900		Precipitation	Daily & hourly precipitation	Nat'l Climatic Data Ctr., Ashville, NC Internet	Data is reported to weather service offices in Mt.Holly,NJ or Binghampton,NY via satellite, radio reporting rain gages or volunteer observers. Station locations are by lat. & long.About 100 stations throughout Basin			

Field1	Project Name	Collected By	Frequency	Period	RM From	To	Data Span	Ending	Sample Matrix	Parameters	Contact	"Notes"	Data Access	Availability	Time Frame Access
60	Snow Survey	NWS, NYCDEP, Cornell U., Corps of Eng.	Bi-weekly, Daily	Nov - April	130	330			Snow Water Equivalent		Cornell U., NWS Mid-Atl River Forecast Ctr.,	Daily map snowing water equivalent is displayed on web page for NWS mid-atlantic river forecast center,. Site locations by lat & long. Additional contact, Corps of Engineers, NYCDEP. Reservoir Headwater			
61	Riverkeeper Citizens Water Quality Monitoring Prog	Volunteers for Riverkeeper	2x/mo	Jan-Dec	130	174	1991	Present	Water	Conventionals, nutrients, sediment and macroinvertebrates	Faith Zerbe (215) 369-1188	Volunteer network monitors 80 sites in the Delaware River and tributaries.			
62	Christmas Bird Count	National Audubon Society	Annual	Dec-Jan	0	90	1900	Present	Census	Relative Abundance	Vince Elia (609)861-0700	Bird recorded over a three week period Dec - Jan			
63	Delaware Observation Well Network	DNREC	Daily	Jan-Dec	30	60	1950	Present	Water Level	Water Level		5 observation wells monitored daily.			
64	Benthic Infauna	Normandeau Assoc.			100	133	1981	Present	Biota, Census	Abundance	George Potera (610) 948 1700				
65	Macro Invertebrate Survey	DNREC			0	60	1974	Present	Biota, Census	Species richness and diversity	Division of Water Resources DE (302)739-4590	189 stations in Delaware collected above head of tide.	Computer file; Quattro Pro, Excel, Access	Spreadsheet on disk	present
67	Macro Invertebrate Survey	Del. Nat. Society	3x/yr		0	60	1986	Present	Biota, Census	abundance	Ginger North (302) 239-2334 ext. 112	20 - 30 sites monitored at 3 times per year.			
68	Ambient Water Quality Survey	DNREC	Annual - Bi annual		7	48	1965	Present	Water	Conventionals, nutrients, metals	Dave McQuaide (302) 739-4771	15 sub-tributary basins and Delaware Bay investigated.	Hard Copy	Storet	Monthly
69	Striped Bass Tagging Program	NJDEP	2-3x/wk	Feb/Mar /Apr	30	130	1989	Present	Tagging Study	Fishing Mortality estimate - Age/Ln Key	Tom Baum (609)748-2020	NJ contribution to coastwide striped bass tagging program administered by USFWS; Age/Ln contribution to virtual population analysis.	computer file	?	?
70	PA Ground Water Network (GWN)	PADEP	Bi-annual	Jan-Dec			1986	Present	Water	Conventionals, Nutrients, Metals	Stuart Reese (717)772-4018 Tammy Schreffler (717)772-4048	235 ambient and 345 fixed station network monitoring points.			
71	Chester County Observation Well Network	USGS	12x/yr	Jan-Dec			1973	Present	Water levels	Ground water levels	Kirk White (610)647-9008	Wells are aerially distributed throughout Chester County, PA. Data stored in USGS GWIS Data Base and used for rough forecasting and monitoring.			
72	Shellfish Program	DNREC	6x/yr	Apr/Nov	0	70	1970	Present	Water	Total Coliforms	Jack Pingree (302) 739-4590	24 Near-shore and 30 mid-channel stations	Computer file; Lotus spreadsheets	disk; hard drive	present
73	Small Mouth Bass Survey	DNREC	3-4x/mo	May/Sept		72	1997	Present	Census	Length, weight, age, stock density	Mike Stangell (302) 739-4782	Electroshocking in 16 sections of the Brandywine River (Freshwater area)			
74	So. New Castle Co. Groundwater Monitoring Network	DGS WRANCC	4x/yr	Apr/Sept	0	0	1994	Present	Groundwater Quality	Nutrients, Metals, TDS, Chlorides, Radon, Bacteria and pesticides	Stephanie Baxter 302-831-8258	Groundwater Monitoring Network of 60 water table and confined aquifer wells in Coastal Plain of Southern New Castle County, DE. Purpose of program is to monitor the quality of groundwater which is sole source of drinking water.			
75	Christina River Basin Stowmwater Monitoring Progra	USGS DNREC	6x/yr	Monthly	0	0	1997	Present	Stormwater Quality	Full list of EPA pollutants	Lisa Senior (610)739-4590 ext.209.	Characterize quality of stormwater runoff for representative land uses at 11 sites for later use in a TMDL model of the Christina Basin in DE, PA and MD			
76	WRPA Recharge Monitoring Program (NCC)	WRANCC	4x/yr	Apr/Sept	0	0	1989	Present	Groundwater Quality	Levels, TDS, TOC, Nitrates, pH, Conductivity, total phosphorue and chlorides	Gerald Kauffman (302) 831-4929	Monitoring program at groundwater recharge facilities required by New Castle CO. Water Resource Protection Area Program			
77	Christina Basin Water Quality Management Strategy	WRANCC	n/a	n/a	0	0	1995	Present	GIS Mapping/Data	geology,soils,outfalls,discharges,land use,zoning,floodplains,wetlands,aquifers,Superfund sites	Gerald Kauffman 302-831-4925	15-map GIS Series prepared for Christina Basin Water Quality Management Strategy in DE, PA, and MD.			
78	New Castle Co. Water Supply/Demand Data	WRANCC	monthly/anually	n/a			1983	Present	Water use	Water Supply/Demand Data	Gerald Kauffman 302-831-4925	Regional water supply and demand data for New Castle County, DE			
79	New Castle Co. Stream Flow Survey	DGS WRANCC	daily	n/a			1960	Present	Stream flow, Reservoir storage	Flow, Water levels	Gerald Kauffman 302-831-4925	Daily stream flow measurements at 4 water supply intakes along the Brandywine Creek, Red Clay Creek, and White Clay Creek in New Castle County, DE			
80	U Delaware GIS Mapping	WRANCC	daily	n/a			1975	Present	GIS Data	Roads, streams, land use, soils, etc.	Vern Svatos 302-831-4932	WRANCC operates on ARC/INFO GIS for water supply and water quality planning and management purposes in New Castle County, DE.			
87	Horseshoe Crab spawning census	LiMuli Labs, Inc.	Annual	May-June	0		1990	Present	Counts	Ground counts, samples at many NJ and DE beaches	Benjie Swan Limulus Labs	Baywide sampling locations, conducted at full moons in May and June.			
88	Lower River Monitoring Program	DRBC	Bi-weekly	May-Sept.	134	210	1999	Present	Water	Conventionals, Nutrients, Bacteria	Geoff Smith (609) 883-9500 ext. 234		Excel	STORET	
89	Lower River Biomonitoring Program	DRBC	Annual	Aug-Sept	330	210	2001	Present	Benthic Macroinvertebrates and Habitat	Benthic Metrics, RSP Habitat, partice size, depth and flow velocity	Geoff Smith (609) 883-9500 ext. 234		Excel	EDAS /STORET	
90	River Tracker Network	Delaware Riverkeeper Network	Monthly	Jan-December	0		1991	Present	Water	Nitrate-Nitrogen, Ortho-Phosphate, pH, dissolved oxygen, water temperature, air temp	Faith Zerbe (610) 469-6005 or (215) 369-1188	Developed as a first line of defense to develop trends over time. Data collected by trained volunteer monitors adhering to QA/QC standards. Sampling stations throughout the Delaware Watershed and mostly on tributary streams. Majority of sites located			
91	Adopt-A-Buffer Initiative	Delaware Riverkeeper Network	Twice a year	June and August	0		2002	Present	Habitat, stream restoration projects; riparian buffers	quality of stream buffers (all projects); cross sections; macroinvertebrates, wildlife survey (selected projects)	Faith Zerbe (610) 469-6005 or (215) 369-1188	Developed to alert project partners if projects need follow-up maintenance to function and to track the long-term growth and status of restoration projects.			
92	Bug Madness	Delaware Riverkeeper Network	Annual	March-April	0		2001	Present	Benthic Macroinvertebrates and Habitat	Benthic metrics, consolidation, dominant substrate types, surrounding landuse	Faith Zerbe (610) 469-6005 or (215) 369-1188	Trained volunteer monitors and DRN staff monitor 30 restoration projects in the Watershed (mostly New Jersey and Pennsylvania). DRN recruiting new volunteers to adopt other restoration projects.			
93	Pollution Monitoring Studies	Delaware Riverkeeper Network	Dependent on Project Needs		0		2003	Present	Benthic macroinvertebrates; Water	Benthic metrics, nutrients, bacteria, dissolved oxygen, habitat	Faith Zerbe (610) 469-6005 or (215) 369-1188	Project based monitoring; parameters dependent on monitoring study design for suspected pollution problem. High level of rigor.			

12-2 List of Benthic Infauna Collected in the Delaware Estuary from the National Coastal Assessment Program 2000 Survey

CLASS	ORDER	FAMILY	GENUS	SPECIES	LATIN_NAME
Polychaeta	Phyllodocida	Nephtyidae	Aglaophamus	circinata	Aglaophamus circinata
Polychaeta	Terebellida	Ampharetidae	Ampharete	acutifrons	Ampharete acutifrons
Polychaeta	Terebellida	Ampharetidae			Ampharetidae
Polychaeta	Terebellida	Ampharetidae	Amphicteis	gunnery	Amphicteis gunnery
Polychaeta	Phyllodocida	Pilargiidae	Ancistrosyllis	groenlandica	Ancistrosyllis groenlandica
Polychaeta	Phyllodocida	Pilargiidae	Ancistrosyllis	hartmanae	Ancistrosyllis hartmanae
Polychaeta	Spionida	Cirratulidae	Aphelochaeta		Aphelochaeta spp.
Polychaeta	Spionida	Apistobranchidae	Apistobranchus	tullbergi	Apistobranchus tullbergi
Polychaeta	Spionida	Spionidae	Apoprionospio	pygmaea	Apoprionospio pygmaea
Polychaeta	Eunicida	Oenonidae	Arabella	iricolor	Arabella iricolor
Polychaeta	Eunicida	Oenonidae	Arabella	mutans	Arabella mutans
Polychaeta	Orbiniida	Paraonidae	Aricidea	catherinae	Aricidea catherinae
Polychaeta	Orbiniida	Paraonidae	Aricidea	cerrutii	Aricidea cerrutii
Polychaeta	Orbiniida	Paraonidae	Aricidea	quadrilobata	Aricidea quadrilobata
Polychaeta	Orbiniida	Paraonidae	Aricidea		Aricidea spp.
Polychaeta	Orbiniida	Paraonidae	Aricidea	suecica	Aricidea suecica
Polychaeta	Orbiniida	Paraonidae	Aricidea	wassi	Aricidea wassi
Polychaeta	Terebellida	Ampharetidae	Asabellides	oculata	Asabellides oculata
Polychaeta	Phyllodocida	Syllidae	Autolytus		Autolytus spp.
Polychaeta	Capitellida	Maldanidae	Axiothella	mucosa	Axiothella mucosa
Polychaeta	Phyllodocida	Syllidae	Brania	wellfleetensis	Brania wellfleetensis
Polychaeta	Phyllodocida	Pilargiidae	Cabira	incerta	Cabira incerta
Polychaeta	Capitellida	Capitellidae	Capitella	capitata	Capitella capitata
Polychaeta	Capitellida	Capitellidae	Capitella	jonesi	Capitella jonesi
Polychaeta	Capitellida	Capitellidae			Capitellidae
Polychaeta	Spionida	Spionidae	Carazziella	hobsonae	Carazziella hobsonae
Polychaeta	Spionida	Cirratulidae	Caulleriella	sp. J	Caulleriella sp. J
Polychaeta	Spionida	Cirratulidae	Chaetozone	setosa	Chaetozone setosa
Polychaeta	Sabellida	Sabellidae	Chone		Chone spp.
Polychaeta	Spionida	Cirratulidae			Cirratulidae
Polychaeta	Spionida	Cirratulidae	Cirriformia	grandis	Cirriformia grandis
Polychaeta	Orbiniida	Paraonidae	Cirrophorus	armatus	Cirrophorus armatus
Polychaeta	Orbiniida	Paraonidae	Cirrophorus	brevicirratus	Cirrophorus brevicirratus
Polychaeta	Orbiniida	Paraonidae	Cirrophorus	lyra	Cirrophorus lyra
Polychaeta	Orbiniida	Paraonidae	Cirrophorus		Cirrophorus spp.
Polychaeta	Capitellida	Maldanidae	Clymenella	torquata	Clymenella torquata
Polychaeta	Cossurida	Cossuridae	Cossura	soyeri	Cossura soyeri
Polychaeta	Cossurida	Cossuridae	Cossura		Cossura spp.
Polychaeta	Cossurida	Cossuridae	Cossurella		Cossurella spp.
Polychaeta	Cossurida	Cossuridae			Cossuridae
Polychaeta	Sabellida	Sabellidae	Demonax	microphthalmus	Demonax microphthalmus
Polychaeta	Sabellida	Sabellidae	Demonax		Demonax spp.
Polychaeta	Eunicida	Onuphidae	Diopatra	cuprea	Diopatra cuprea
Polychaeta	Flabelligerida	Flabelligeridae	Diplocirrus	hirsutus	Diplocirrus hirsutus
Polychaeta	Spionida	Spionidae	Dipolydora	caulleryi	Dipolydora caulleryi
Polychaeta	Spionida	Spionidae	Dipolydora	quadrilobata	Dipolydora quadrilobata
Polychaeta	Spionida	Spionidae	Dipolydora	socialis	Dipolydora socialis
Polychaeta	Spionida	Spionidae	Dispio	uncinata	Dispio uncinata

Polychaeta	Eunicida	Lumbrineridae			Dorvilleidae
Polychaeta	Eunicida	Oenonidae	Drilonereis	longa	Drilonereis longa
Oligochaeta	Tubificida	Enchytraeidae			Enchytraeidae
Polychaeta	Phyllodocida	Sphaerodoridae	Ephesiella	minuta	Ephesiella minuta
Polychaeta	Phyllodocida	Phyllodocidae	Eteone	longa	Eteone longa
Polychaeta	Sabellida	Sabellidae	Euchone	incolor	Euchone incolor
Polychaeta	Phyllodocida	Phyllodocidae	Eumida	sanguinea	Eumida sanguinea
Polychaeta	Terebellida	Terebellidae	Eupolymnia	nebulosa	Eupolymnia nebulosa
Polychaeta	Terebellida	Terebellidae	Eupolymnia		Eupolymnia spp.
Polychaeta	Phyllodocida	Syllidae	Exogone	dispar	Exogone dispar
Polychaeta	Phyllodocida	Syllidae	Exogone	hebes	Exogone hebes
Polychaeta	Phyllodocida	Syllidae	Exogone	longicirris	Exogone longicirris
Polychaeta	Phyllodocida	Syllidae	Exogone	rolani	Exogone rolani
Polychaeta	Phyllodocida	Syllidae	Exogone		Exogone spp.
Polychaeta	Phyllodocida	Syllidae	Exogone	verugera	Exogone verugera
Polychaeta	Phyllodocida	Sigalionidae	Fimbriosthenelais	minor	Fimbriosthenelais minor
Polychaeta	Oweniida	Oweniidae	Galathowenia	oculata	Galathowenia oculata
Polychaeta	Phyllodocida	Polynoidae	Gattyana	cirrosa	Gattyana cirrosa
Polychaeta	Phyllodocida	Glyceridae	Glycera	americana	Glycera americana
Polychaeta	Phyllodocida	Glyceridae	Glycera	capitata	Glycera capitata
Polychaeta	Phyllodocida	Glyceridae	Glycera	dibranchiata	Glycera dibranchiata
Polychaeta	Phyllodocida	Glyceridae	Glycera		Glycera spp.
Polychaeta	Phyllodocida	Glyceridae			Glyceridae
Polychaeta	Phyllodocida	Goniadidae	Glycinde	solitaria	Glycinde solitaria
Polychaeta	Phyllodocida	Goniadidae	Goniada	maculata	Goniada maculata
Polychaeta	Phyllodocida	Goniadidae	Goniadella	gracilis	Goniadella gracilis
Polychaeta	Phyllodocida	Goniadidae			Goniadidae
Polychaeta	Phyllodocida	Syllidae	Grubeosyllis	clavata	Grubeosyllis clavata
Polychaeta	Phyllodocida	Polynoidae	Harmothoe	extenuata	Harmothoe extenuata
Polychaeta	Phyllodocida	Polynoidae	Harmothoe	imbricata	Harmothoe imbricata
Polychaeta	Phyllodocida	Polynoidae	Harmothoe		Harmothoe spp.
Polychaeta	Phyllodocida	Hesionidae			Hesionidae
Polychaeta	Capitellida	Capitellidae	Heteromastus	filiformis	Heteromastus filiformis
Polychaeta	Capitellida	Capitellidae	Heteromastus		Heteromastus spp.
Polychaeta	Sabellida	Serpulidae	Hydroides	dianthus	Hydroides dianthus
Polychaeta	Sabellida	Serpulidae	Hydroides		Hydroides spp.
Polychaeta	Terebellida	Ampharetidae	Hypaniola		Hypaniola spp.
Polychaeta	Phyllodocida	Phyllodocidae	Hypereteone	fauchaldi	Hypereteone fauchaldi
Polychaeta	Phyllodocida	Phyllodocidae	Hypereteone	heteropoda	Hypereteone heteropoda
Polychaeta	Phyllodocida	Nereidae	Laeonereis	culveri	Laeonereis culveri
Polychaeta	Orbiniida	Orbiniidae	Leitoscoloplos	fragilis	Leitoscoloplos fragilis
Polychaeta	Orbiniida	Orbiniidae	Leitoscoloplos	robustus	Leitoscoloplos robustus
Polychaeta	Orbiniida	Orbiniidae	Leitoscoloplos		Leitoscoloplos spp.
Polychaeta	Phyllodocida	Polynoidae	Lepidonotus	squamatus	Lepidonotus squamatus
Polychaeta	Phyllodocida	Polynoidae	Lepidonotus	sublevis	Lepidonotus sublevis
Polychaeta	Orbiniida	Paraonidae	Levinsenia	gracilis	Levinsenia gracilis
Oligochaeta	Tubificida	Tubificidae	Limnodrilus	hoffmeisteri	Limnodrilus hoffmeisteri
Polychaeta	Terebellida	Terebellidae	Loimia	medusa	Loimia medusa
Polychaeta	Terebellida	Terebellidae	Loimia	sp. A	Loimia sp. A
Polychaeta	Eunicida	Lumbrineridae			Lumbrineridae
Polychaeta	Eunicida	Lumbrineridae	Lumbrinerides	acuta	Lumbrinerides acuta

Polychaeta	Spionida	Magelonidae	Magelona	papillicornis	Magelona papillicornis
Polychaeta	Spionida	Magelonidae	Magelona	rosea	Magelona rosea
Polychaeta	Spionida	Magelonidae	Magelona		Magelona spp.
Polychaeta	Capitellida	Maldanidae			Maldanidae
Polychaeta	Sabellida	Sabellidae	Manayunkia	speciosa	Manayunkia speciosa
Polychaeta	Spionida	Spionidae	Marenzellaria	jonesi	Marenzellaria jonesi
Polychaeta	Spionida	Spionidae	Marenzellaria	viridis	Marenzellaria viridis
Polychaeta	Capitellida	Capitellidae	Mediomastus	ambiseta	Mediomastus ambiseta
Polychaeta	Capitellida	Capitellidae	Mediomastus	californiensis	Mediomastus californiensis
Polychaeta	Capitellida	Capitellidae	Mediomastus		Mediomastus spp.
Polychaeta	Sabellida	Sabellidae	Megalomma		Megalomma spp.
Polychaeta	Terebellida	Ampharetidae	Melinna	cristata	Melinna cristata
Polychaeta	Terebellida	Ampharetidae	Melinna	maculata	Melinna maculata
Polychaeta	Phyllodocida	Hesionidae	Microphthalmus	aberrans	Microphthalmus aberrans
Polychaeta	Phyllodocida	Hesionidae	Microphthalmus	hartmanae	Microphthalmus hartmanae
Polychaeta	Phyllodocida	Hesionidae	Microphthalmus	sczelkowii	Microphthalmus sczelkowii
Polychaeta	Phyllodocida	Hesionidae	Microphthalmus		Microphthalmus spp.
Polychaeta	Spionida	Cirratulidae	Monticellina	dorsobranchialis	Monticellina dorsobranchialis
Polychaeta	Eunicida	Eunicidae	Nematonereis	hebes	Nematonereis hebes
Polychaeta	Terebellida	Terebellidae	Neoamphitrite	johnstoni	Neoamphitrite johnstoni
Polychaeta	Terebellida	Terebellidae	Neoamphitrite	ornata	Neoamphitrite ornata
Polychaeta	Phyllodocida	Nephtyidae			Nephtyidae
Polychaeta	Phyllodocida	Nephtyidae	Nephtys	bucera	Nephtys bucera
Polychaeta	Phyllodocida	Nephtyidae	Nephtys	caeca	Nephtys caeca
Polychaeta	Phyllodocida	Nephtyidae	Nephtys	incisa	Nephtys incisa
Polychaeta	Phyllodocida	Nephtyidae	Nephtys	picta	Nephtys picta
Polychaeta	Phyllodocida	Nephtyidae	Nephtys		Nephtys spp.
Polychaeta	Phyllodocida	Nephtyidae	Nephtys	squamosa	Nephtys squamosa
Polychaeta	Phyllodocida	Nereidae			Nereididae
Polychaeta	Phyllodocida	Nereidae			Nereididae spp.
Polychaeta	Phyllodocida	Nereidae	Nereis	acuminata	Nereis acuminata
Polychaeta	Phyllodocida	Nereidae	Nereis	diversicolor	Nereis diversicolor
Polychaeta	Phyllodocida	Nereidae	Nereis	grayi	Nereis grayi
Polychaeta	Phyllodocida	Nereidae	Nereis	pelagica	Nereis pelagica
Polychaeta	Phyllodocida	Nereidae	Nereis	sp. F	Nereis sp. F
Polychaeta	Phyllodocida	Nereidae	Nereis		Nereis spp.
Polychaeta	Phyllodocida	Nereidae	Nereis	succinea	Nereis succinea
Polychaeta	Phyllodocida	Nereidae	Nereis	virens	Nereis virens
Polychaeta	Eunicida	Lumbrineridae	Ninoe	nigripes	Ninoe nigripes
Polychaeta	Capitellida	Capitellidae	Notomastus	hemipodus	Notomastus hemipodus
Polychaeta	Capitellida	Capitellidae	Notomastus	latericeus	Notomastus latericeus
Polychaeta	Capitellida	Capitellidae	Notomastus		Notomastus spp.
Polychaeta	Orbiniida	Questidae	Novaquesta	trifurcata	Novaquesta trifurcata
Polychaeta	Phyllodocida	Syllidae	Odontosyllis	fulgurans	Odontosyllis fulgurans
Polychaeta	Eunicida	Onuphidae			Onuphidae
Polychaeta	Eunicida	Onuphidae	Onuphis	eremita	Onuphis eremita
Polychaeta	Opheliida	Opheliidae	Ophelina	acuminata	Ophelina acuminata
Polychaeta	Eunicida	Dorvilleidae	Ophryotrocha		Ophryotrocha spp.
Polychaeta	Oweniida	Oweniidae	Owenia	fusiformis	Owenia fusiformis
Polychaeta	Oweniida	Oweniidae			Oweniidae
Polychaeta	Phyllodocida	Phyllodocidae	Paranaitis	speciosa	Paranaitis speciosa

Polychaeta	Orbiniida	Paraonidae	Paraonis	fulgens	Paraonis fulgens
Polychaeta	Orbiniida	Paraonidae	Paraonis		Paraonis spp.
Polychaeta	Phyllodocida	Syllidae	Parapionosyllis	longicirrata	Parapionosyllis longicirrata
Polychaeta	Spionida	Spionidae	Paraprionospio	pinnata	Paraprionospio pinnata
Polychaeta	Eunicida	Dorvilleidae	Parougia	caeca	Parougia caeca
Polychaeta	Terebellida	Pectinariidae	Pectinaria	gouldii	Pectinaria gouldii
Polychaeta	Terebellida	Pectinariidae	Pectinaria	granulata	Pectinaria granulata
Polychaeta	Terebellida	Pectinariidae			Pectinariidae
Polychaeta	Capitellida	Maldanidae	Petaloproctus	tenuis	Petaloproctus tenuis
Polychaeta	Eunicida	Dorvilleidae	Pettiboneia	duofurca	Pettiboneia duofurca
Polychaeta	Flabelligerida	Flabelligeridae	Pherusa	affinis	Pherusa affinis
Polychaeta	Flabelligerida	Flabelligeridae	Pherusa	plumosa	Pherusa plumosa
Polychaeta	Phyllodocida	Pholoidae	Pholoe	minuta	Pholoe minuta
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce	arenae	Phyllodoce arenae
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce	groenlandica	Phyllodoce groenlandica
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce	maculata	Phyllodoce maculata
Polychaeta	Phyllodocida	Phyllodocidae	Phyllodoce		Phyllodoce spp.
Polychaeta	Phyllodocida	Phyllodocidae			Phyllodocidae
Polychaeta	Phyllodocida	Nereidae	Platynereis	dumerilli	Platynereis dumerilli
Polychaeta	Phyllodocida	Hesionidae	Podarke	obscura	Podarke obscura
Polychaeta	Phyllodocida	Hesionidae	Podarkeopsis	levifuscina	Podarkeopsis levifuscina
Polychaeta					Polychaeta
Polychaeta	Terebellida	Terebellidae	Polycirrus	sp. G	Polycirrus sp. G
Polychaeta	Terebellida	Terebellidae	Polycirrus		Polycirrus spp.
Polychaeta	Spionida	Spionidae	Polydora	cornuta	Polydora cornuta
Polychaeta	Archiannelida	Polygordiidae	Polygordius		Polygordius spp.
Polychaeta	Phyllodocida	Polynoidae			Polynoidae
Polychaeta	Sabellida	Sabellidae	Potamilla	neglecta	Potamilla neglecta
Polychaeta	Capitellida	Maldanidae	Praxillella	gracilis	Praxillella gracilis
Polychaeta	Spionida	Spionidae	Prionospio	heterobranchia	Prionospio heterobranchia
Polychaeta	Spionida	Spionidae	Prionospio	perkinsi	Prionospio perkinsi
Polychaeta	Spionida	Spionidae	Prionospio		Prionospio spp.
Polychaeta	Spionida	Spionidae	Prionospio	steenstrupi	Prionospio steenstrupi
Polychaeta	Spionida	Spionidae	Pseudopolydora	diopatra	Pseudopolydora diopatra
Polychaeta	Spionida	Spionidae	Pseudopolydora		Pseudopolydora spp.
Polychaeta	Sabellida	Sabellidae	Pseudopotamilla	sp. A	Pseudopotamilla sp. A
Polychaeta	Spionida	Spionidae	Pygospio	elegans	Pygospio elegans
Polychaeta	Capitellida	Maldanidae	Rhodine	loveni	Rhodine loveni
Polychaeta	Capitellida	Maldanidae	Sabaco	americanus	Sabaco americanus
Polychaeta	Terebellida	Sabellariidae	Sabellaria	vulgaris	Sabellaria vulgaris
Polychaeta	Sabellida	Sabellidae			Sabellidae
Polychaeta	Opheliida	Scalibregmatidae	Scalibregma	inflatum	Scalibregma inflatum
Polychaeta	Eunicida	Dorvilleidae	Schistomeringos	rudolphi	Schistomeringos rudolphi
Polychaeta	Spionida	Spionidae	Scolelepis		Scolelepis spp.
Polychaeta	Spionida	Spionidae	Scolelepis	squamata	Scolelepis squamata
Polychaeta	Spionida	Spionidae	Scolelepis	texana	Scolelepis texana
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	acicularum	Scoletoma acicularum
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	ernesti	Scoletoma ernesti
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	fragilis	Scoletoma fragilis
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	hebes	Scoletoma hebes
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	impatiens	Scoletoma impatiens

Polychaeta	Eunicida	Lumbrineridae	Scoletoma		Scoletoma spp.
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	tenuis	Scoletoma tenuis
Polychaeta	Eunicida	Lumbrineridae	Scoletoma	verrilli	Scoletoma verrilli
Polychaeta	Orbiniida	Orbiniidae	Scoloplos	armiger	Scoloplos armiger
Polychaeta	Orbiniida	Orbiniidae	Scoloplos	rubra	Scoloplos rubra
Polychaeta	Sabellida	Serpulidae			Serpulidae
Polychaeta	Phyllodocida	Sigalionidae	Sigalion	arenicola	Sigalion arenicola
Polychaeta	Phyllodocida	Pilargiidae	Sigambra	tentaculata	Sigambra tentaculata
Polychaeta	Phyllodocida	Syllidae	Sphaerosyllis	perkinsi	Sphaerosyllis perkinsi
Polychaeta	Phyllodocida	Syllidae	Sphaerosyllis	taylori	Sphaerosyllis taylori
Polychaeta	Spionida	Spionidae	Spio	filicornis	Spio filicornis
Polychaeta	Spionida	Spionidae	Spio	goniocephala	Spio goniocephala
Polychaeta	Spionida	Spionidae	Spio	setosa	Spio setosa
Polychaeta	Spionida	Spionidae	Spio	sp. A	Spio sp. A
Polychaeta	Spionida	Spionidae	Spio		Spio spp.
Polychaeta	Spionida	Chaetopteridae	Spiochaetopterus	oculatus	Spiochaetopterus oculatus
Polychaeta	Spionida	Spionidae			Spionidae
Polychaeta	Spionida	Spionidae	Spiophanes	bombyx	Spiophanes bombyx
Polychaeta	Spionida	Spionidae	Spiophanes	wigleyi	Spiophanes wigleyi
Polychaeta	Sternaspida	Sternaspidae	Sternaspis	scutata	Sternaspis scutata
Polychaeta	Phyllodocida	Sigalionidae	Sthenelais	boa	Sthenelais boa
Polychaeta	Phyllodocida	Sigalionidae	Sthenelais	limicola	Sthenelais limicola
Polychaeta	Spionida	Spionidae	Streblospio	benedicti	Streblospio benedicti
Polychaeta	Phyllodocida	Syllidae	Streptosyllis	arenae	Streptosyllis arenae
Polychaeta	Phyllodocida	Syllidae	Streptosyllis	varians	Streptosyllis varians
Polychaeta	Phyllodocida	Syllidae			Syllidae
Polychaeta	Phyllodocida	Syllidae			Syllidae spp.
Polychaeta	Phyllodocida	Syllidae	Syllides	longocirrata	Syllides longocirrata
Polychaeta	Phyllodocida	Syllidae	Syllides	setosa	Syllides setosa
Polychaeta	Phyllodocida	Syllidae	Syllis	cornuta	Syllis cornuta
Polychaeta	Phyllodocida	Syllidae	Syllis		Syllis spp.
Polychaeta	Terebellida	Terebellidae			Terebellidae
Polychaeta	Terebellida	Trichobranchidae	Terebellides	stroemi	Terebellides stroemi
Polychaeta	Spionida	Cirratulidae	Tharyx	acutus	Tharyx acutus
Polychaeta	Spionida	Cirratulidae	Tharyx	kirkegaardi	Tharyx kirkegaardi
Polychaeta	Opheliida	Opheliidae	Travisia	carnea	Travisia carnea
Oligochaeta	Tubificida	Tubificidae			Tubificidae
Malacostraca	Amphipoda	Haustoriidae	Acanthohaustorius	intermedius	Acanthohaustorius intermedius
Malacostraca	Amphipoda	Haustoriidae	Acanthohaustorius	millsi	Acanthohaustorius millsi
Malacostraca	Amphipoda	Aoridae	Acuminodeutopus	naglei	Acuminodeutopus naglei
Malacostraca	Amphipoda	Aeginellidae			Aeginellidae
Malacostraca	Amphipoda	Aeginellidae	Aeginina	longicornis	Aeginina longicornis
Malacostraca	Cumacea	Nannastacidae	Almyracuma	proximoculi	Almyracuma proximoculi
Malacostraca	Mysidacea	Mysidae	Americamysis	bigelowi	Americamysis bigelowi
Malacostraca	Amphipoda	Oedicerotidae	Americhelidium	americanum	Americhelidium americanum
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca		Ampelisca
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca		Ampelisca spp.
Malacostraca	Amphipoda	Ampeliscidae	Ampelisca	verrilli	Ampelisca verrilli
Malacostraca	Amphipoda	Ampeliscidae			Ampeliscidae
Malacostraca	Amphipoda				Amphipoda
Malacostraca	Amphipoda	Ampithoidae			Ampithoidae

Malacostraca	Isopoda	Sphaeromatidae	Ancinus	depressus	Ancinus depressus
Malacostraca	Amphipoda	Lysianassidae	Anonyx	liljeborgii	Anonyx liljeborgii
Malacostraca	Amphipoda	Aoridae			Aoridae
Malacostraca	Amphipoda	Corophiidae	Apocorophium	lacustre	Apocorophium lacustre
Malacostraca	Amphipoda	Arigissidae	Argissa	hamatipes	Argissa hamatipes
Arachnida	Acari	Arrenuridae	Arrenurus		Arrenurus spp.
Malacostraca	Amphipoda	Bateidae	Batea	catharinensis	Batea catharinensis
Malacostraca	Amphipoda	Bateidae	Batea		Batea spp.
Malacostraca	Amphipoda	Haustoriidae	Bathyporeia	quoddyensis	Bathyporeia quoddyensis
Malacostraca	Amphipoda	Ampeliscidae	Byblis		Byblis spp.
Malacostraca	Decapoda	Callianassidae	Callianassa	setimanus	Callianassa setimanus
Malacostraca	Decapoda	Callianassidae	Callianassa		Callianassa spp.
Malacostraca	Cumacea	Nannastacidae	Campylaspis	affinis	Campylaspis affinis
Malacostraca	Decapoda	Cancridae	Cancer	borealis	Cancer borealis
Malacostraca	Decapoda	Cancridae	Cancer	irroratus	Cancer irroratus
Malacostraca	Amphipoda	Caprellidae	Caprella	penantis	Caprella penantis
Malacostraca	Amphipoda	Caprellidae	Caprella		Caprella spp.
Malacostraca	Amphipoda	Melitidae	Casco	bigelowi	Casco bigelowi
Malacostraca	Amphipoda	Ischyroceridae	Cerapus	tubularis	Cerapus tubularis
Insecta	Diptera	Ceratopogonidae			Ceratopogonidae
Malacostraca	Isopoda	Idoteidae	Chiridotea	caeca	Chiridotea caeca
Malacostraca	Isopoda	Idoteidae	Chiridotea	tuftsi	Chiridotea tuftsi
Insecta	Diptera	Chironomidae			Chironomidae
Insecta	Diptera	Chironomidae	Chironomus		Chironomus spp.
Malacostraca	Amphipoda	Corophiidae			Corophiidae
Malacostraca	Amphipoda	Corophiidae	Corophium		Corophium spp.
Malacostraca	Amphipoda	Corophiidae	Corophium	volutator	Corophium volutator
Malacostraca	Decapoda	Crangonidae	Crangon	septemspinosa	Crangon septemspinosa
Malacostraca	Decapoda	Crangonidae			Crangonidae
Malacostraca	Amphipoda	Corophiidae	Crassicorophium	crassicorne	Crassicorophium crassicorne
Insecta	Diptera	Chironomidae	Cricotopus		Cricotopus spp.
Insecta	Diptera	Chironomidae	Cryptochironomus		Cryptochironomus spp.
Malacostraca	Cumacea				Cumacea
Malacostraca	Isopoda	Anthuridae	Cyathura	polita	Cyathura polita
Malacostraca	Cumacea	Bodotriidae	Cyclaspis	pustulata	Cyclaspis pustulata
Malacostraca	Cumacea	Bodotriidae	Cyclaspis	varians	Cyclaspis varians
Ostracoda	Myodocopina	Cylindroleberididae			Cylindroleberididae
Malacostraca	Amphipoda	Ampithoidae	Cymadusa	compta	Cymadusa compta
Malacostraca	Decapoda				Decapoda
Malacostraca	Amphipoda	Oedicerotidae	Deflexilodes	intermedius	Deflexilodes intermedius
Malacostraca	Amphipoda	Dexaminidae	Dexamine	thea	Dexamine thea
Malacostraca	Cumacea	Diastylidae			Diastylidae
Malacostraca	Cumacea	Diastylidae	Diastylis	abbreviata	Diastylis abbreviata
Malacostraca	Cumacea	Diastylidae	Diastylis	polita	Diastylis polita
Malacostraca	Cumacea	Diastylidae	Diastylis	sculpta	Diastylis sculpta
Malacostraca	Cumacea	Diastylidae	Diastylis	sp. J	Diastylis sp. J
Malacostraca	Cumacea	Diastylidae	Diastylis		Diastylis spp.
Malacostraca	Decapoda	Pinnotheridae	Dissodactylus	mellitae	Dissodactylus mellitae
Malacostraca	Amphipoda	Podoceridae	Dulichia	porrecta	Dulichia porrecta
Malacostraca	Amphipoda	Melitidae	Dulichiella	appendiculata	Dulichiella appendiculata
Malacostraca	Amphipoda	Melitidae	Dulichiella		Dulichiella spp.

Malacostraca	Isopoda	Idoteidae	Edotia	triloba	Edotia triloba
Malacostraca	Amphipoda	Melitidae	Elasmopus	levis	Elasmopus levis
Malacostraca	Amphipoda	Melitidae	Elasmopus		Elasmopus spp.
Malacostraca	Amphipoda	Phoxocephalidae	Eobrolgus	spinosus	Eobrolgus spinosus
Malacostraca	Isopoda	Idoteidae	Erichsonella	attenuata	Erichsonella attenuata
Malacostraca	Isopoda	Idoteidae	Erichsonella	filiformis	Erichsonella filiformis
Malacostraca	Isopoda	Idoteidae	Erichsonella		Erichsonella spp.
Malacostraca	Amphipoda	Ischyroceridae	Erichthonius	brasiliensis	Erichthonius brasiliensis
Malacostraca	Amphipoda	Ischyroceridae	Erichthonius	rubricornis	Erichthonius rubricornis
Malacostraca	Amphipoda	Ischyroceridae	Erichthonius		Erichthonius spp.
Malacostraca	Cumacea	Leuconidae	Eudorella	pusilla	Eudorella pusilla
Malacostraca	Cumacea	Leuconidae	Eudorella		Eudorella spp.
Ostracoda	Myodocopina	Sarsiellidae	Eusarsiella	ozotothrix	Eusarsiella ozotothrix
Ostracoda	Myodocopina	Sarsiellidae	Eusarsiella	spinosa	Eusarsiella spinosa
Ostracoda	Myodocopina	Sarsiellidae	Eusarsiella		Eusarsiella spp.
Ostracoda	Myodocopina	Sarsiellidae	Eusarsiella	texana	Eusarsiella texana
Ostracoda	Myodocopina	Sarsiellidae	Eusarsiella	zostericola	Eusarsiella zostericola
Malacostraca	Amphipoda	Gammaridae			Gammaridae
Malacostraca	Amphipoda	Gammaridae	Gammarus	annulatus	Gammarus annulatus
Malacostraca	Amphipoda	Gammaridae	Gammarus	mucronatus	Gammarus mucronatus
Malacostraca	Amphipoda	Gammaridae	Gammarus	palustris	Gammarus palustris
Malacostraca	Amphipoda	Gammaridae	Gammarus		Gammarus spp.
Malacostraca	Amphipoda	Aoridae	Globosolembos	smithi	Globolembos smithi
Arachnida	Acari	Halacaridae			Halacaridae
Ostracoda	Podocopida	Cytherideidae	Haplocytheridea	setipunctata	Haplocytheridea setipunctata
Ostracoda	Podocopida	Cytherideidae	Haplocytheridea	sp. B	Haplocytheridea sp. B
Malacostraca	Tanaidacea	Paratanaidae	Hargeria	rapax	Hargeria rapax
Insecta	Diptera	Chironomidae	Harnischia		Harnischia spp.
Malacostraca	Amphipoda	Phoxocephalidae	Harpinia	propinqua	Harpinia propinqua
Malacostraca	Amphipoda	Oedicerotidae	Hartmanodes		Hartmanodes spp.
Malacostraca	Amphipoda	Haustoriidae			Haustoriidae
Malacostraca	Mysidacea	Mysidae	Heteromysis	formosa	Heteromysis formosa
Cephalocarida		Hutchinsoniellidae	Hutchinsonella	macrocantha	Hutchinsonella macrocantha
Arachnida	Acari	Eremaeidae	Hydrozetes		Hydrozetes spp.
Malacostraca	Isopoda	Idoteidae	Idotea	balthica	Idotea balthica
Malacostraca	Isopoda	Idoteidae	Idotea	metallica	Idotea metallica
Malacostraca	Isopoda	Idoteidae	Idotea	phosphorea	Idotea phosphorea
Branchiopoda	Anomopoda	Macrothricidae	Ilyocryptus		Ilyocryptus spp.
Malacostraca	Amphipoda	Isaeidae			Isaeidae
Malacostraca	Amphipoda	Ischyroceridae			Ischyroceridae
Malacostraca	Amphipoda	Ischyroceridae	Ischyrocerus	anguipes	Ischyrocerus anguipes
Malacostraca	Amphipoda	Ischyroceridae	Jassa	falcata	Jassa falcata
Malacostraca	Cumacea	Lampropidae	Lamprops	quadriplicata	Lamprops quadriplicata
Malacostraca	Amphipoda	Aoridae	Lembos	websteri	Lembos websteri
Malacostraca	Amphipoda	Aoridae	Leptocheirus	pinguis	Leptocheirus pinguis
Malacostraca	Amphipoda	Aoridae	Leptocheirus	plumulosus	Leptocheirus plumulosus
Malacostraca	Amphipoda	Aoridae	Leptocheirus		Leptocheirus spp.
Malacostraca	Tanaidacea	Leptochelidae	Leptochelia	savignyi	Leptochelia savignyi
Malacostraca	Tanaidacea	Paratanaidae	Leptochelia		Leptochelia spp.
Malacostraca	Cumacea	Diastylidae	Leptostylis	longimana	Leptostylis longimana
Malacostraca	Cumacea	Leuconidae	Leucon	americanus	Leucon americanus

Malacostraca	Decapoda	Majidae	Libinia	dubia	Libinia dubia
Arachnida	Acari	Limnesiidae	Limnesia		Limnesia spp.
Merostomata	Xiphosura	Limulidae	Limulus	polyphemus	Limulus polyphemus
Malacostraca	Amphipoda	Liljeborgiidae	Listriella	barnardi	Listriella barnardi
Malacostraca	Amphipoda	Liljeborgiidae	Listriella		Listriella spp.
Malacostraca	Amphipoda	Lysianassidae			Lysianassidae
Malacostraca	Amphipoda	Lysianassidae	Lysianopsis	alba	Lysianopsis alba
Malacostraca	Decapoda	Majidae			Majidae
Malacostraca	Amphipoda	Protellidae	Mayerella	limicola	Mayerella limicola
Malacostraca	Amphipoda	Melitidae	Melita	nitida	Melita nitida
Malacostraca	Amphipoda	Melitidae			Melitidae
Malacostraca	Amphipoda	Stenothoidae	Metopella	angusta	Metopella angusta
Malacostraca	Amphipoda	Aoridae	Microdeutopus	anomalus	Microdeutopus anomalus
Malacostraca	Amphipoda	Aoridae	Microdeutopus	gryllotalpa	Microdeutopus gryllotalpa
Malacostraca	Amphipoda	Aoridae	Microdeutopus		Microdeutopus spp.
Malacostraca	Amphipoda	Isaeidae	Microprotopus	raneyi	Microprotopus raneyi
Malacostraca	Amphipoda	Isaeidae	Microprotopus	sp. E	Microprotopus sp. E
Arachnida	Acari	Mideopsidae	Mideopsis		Mideopsis spp.
Malacostraca	Amphipoda	Corophiidae	Monocorophium	acherusicum	Monocorophium acherusicum
Malacostraca	Amphipoda	Corophiidae	Monocorophium	insidiosum	Monocorophium insidiosum
Malacostraca	Amphipoda	Corophiidae	Monocorophium	tuberculatum	Monocorophium tuberculatum
Malacostraca	Amphipoda	Oedicerotidae	Monoculodes		Monoculodes spp.
Malacostraca	Isopoda	Munnidae	Munna	fabricii	Munna fabricii
Malacostraca	Mysidacea				Mysidacea
Malacostraca	Mysidacea	Mysidae			Mysidae
Malacostraca	Mysidacea	Mysidae	Neomysis	americana	Neomysis americana
Malacostraca	Decapoda	Xanthidae	Neopanope	sayi	Neopanope sayi
Arachnida	Acari	Unionicolidae	Neumania		Neumania spp.
Malacostraca	Amphipoda	Oedicerotidae			Oedicerotidae
Malacostraca	Decapoda	Ogyrididae	Ogyrides	alphaerostris	Ogyrides alphaerostris
Malacostraca	Amphipoda	Lysianassidae	Orchomenella	minuta	Orchomenella minuta
Ostracoda					Ostracoda
Ostracoda	Podocopida	Family P			Ostracodea Family P
Malacostraca	Decapoda	Portunidae	Ovalipes	ocellatus	Ovalipes ocellatus
Arachnida	Acari	Oxidae	Oxus		Oxus spp.
Malacostraca	Cumacea	Diastylidae	Oxyurostylis	smithi	Oxyurostylis smithi
Malacostraca	Decapoda	Paguridae			Paguridae
Malacostraca	Decapoda	Paguridae	Pagurus	longicarpus	Pagurus longicarpus
Malacostraca	Decapoda	Paguridae	Pagurus	politus	Pagurus politus
Malacostraca	Decapoda	Paguridae	Pagurus		Pagurus spp.
Malacostraca	Decapoda	Palaemonidae	Palaemonetes	vulgaris	Palaemonetes vulgaris
Malacostraca	Decapoda	Palaemonidae			Palaemonidae
Malacostraca	Decapoda	Xanthidae	Panopeus	herbstii	Panopeus herbstii
Malacostraca	Amphipoda	Aeginellidae	Paracaprella	tenuis	Paracaprella tenuis
Malacostraca	Amphipoda	Haustoriidae	Parahaustorius	longimerus	Parahaustorius longimerus
Ostracoda	Myodocopina	Cylindroleberididae	Parasterope	pollex	Parasterope pollex
Ostracoda	Podocopida	Paradoxostomatidae	Pellucistoma		Pellucistoma spp.
Malacostraca	Decapoda	Penaeidae	Penaeus	aztecus	Penaeus aztecus
Malacostraca	Amphipoda	Isaeidae	Photis	macrocoxa	Photis macrocoxa
Malacostraca	Amphipoda	Isaeidae	Photis		Photis spp.
Malacostraca	Amphipoda	Phoxocephalidae			Phoxocephalidae

Malacostraca	Amphipoda	Phoxocephalidae	Phoxocephalus	holbolli	Phoxocephalus holbolli
Malacostraca	Decapoda	Pinnotheridae	Pinnixa	chaetopterana	Pinnixa chaetopterana
Malacostraca	Decapoda	Pinnotheridae	Pinnixa	sayana	Pinnixa sayana
Malacostraca	Decapoda	Pinnotheridae	Pinnixa		Pinnixa spp.
Malacostraca	Decapoda	Pinnotheridae	Pinnotheres	ostreum	Pinnotheres ostreum
Malacostraca	Decapoda	Pinnotheridae			Pinnotheridae
Malacostraca	Isopoda	Paramunnidae	Pleurogonium	spinosissimum	Pleurogonium spinosissimum
Malacostraca	Isopoda	Paramunnidae	Pleurogonium		Pleurogonium spp.
Ostracoda	Podocopida				Podocopida
Ostracoda	Podocopida	Family C			Podocopida Family C
Malacostraca	Isopoda	Cirolanidae	Politolana	polita	Politolana polita
Insecta	Diptera	Chironomidae	Polypedilum	illinoense	Polypedilum illinoense group
Insecta	Diptera	Chironomidae	Polypedilum	scalaenum	Polypedilum scalaenum group
Insecta	Diptera	Chironomidae	Polypedilum	simulans	Polypedilum simulans group
Insecta	Diptera	Chironomidae	Polypedilum		Polypedilum spp.
Malacostraca	Amphipoda	Pontogeneiidae	Pontogeneia	inermis	Pontogeneia inermis
Malacostraca	Decapoda	Portunidae			Portunidae
Insecta	Diptera	Chironomidae	Procladius		Procladius spp.
Malacostraca	Amphipoda	Haustoriidae	Protohaustorius		Protohaustorius spp.
Malacostraca	Amphipoda	Haustoriidae	Protohaustorius	wigleyi	Protohaustorius wigleyi
Ostracoda	Podocopida	Brachycytheridae	Pterygocythereis	sp. A	Pterygocythereis sp. A
Malacostraca	Isopoda	Anthuridae	Ptilanthura	tenuis	Ptilanthura tenuis
Malacostraca	Amphipoda	Phoxocephalidae	Rhepoxynius	hudsoni	Rhepoxynius hudsoni
Malacostraca	Decapoda	Xanthidae	Rhithropanopeus	harrisii	Rhithropanopeus harrisii
Branchiopoda	Ctenopoda	Sididae	Sida	crystallina	Sida crystallina
Arachnida	Acari	Sperchontidae	Sperchon		Sperchon spp.
Malacostraca	Amphipoda	Pleustidae	Stenopleustes	gracilis	Stenopleustes gracilis
Malacostraca	Amphipoda	Pleustidae	Stenopleustes	inermis	Stenopleustes inermis
Insecta	Diptera	Chironomidae	Stictochironomus		Stictochironomus spp.
Malacostraca	Isopoda	Idoteidae	Synidotea	sp. F	Synidotea sp. F
Malacostraca	Tanaidacea	Nototanaidae	Tanaissus	liljeborgi	Tanaissus liljeborgi
Malacostraca	Tanaidacea	Nototanaidae	Tanaissus	psammophilus	Tanaissus psammophilus
Malacostraca	Tanaidacea	Nototanaidae	Tanaissus		Tanaissus spp.
Insecta	Diptera	Chironomidae	Tanytarsus		Tanytarsus spp.
Malacostraca	Amphipoda	Synopiidae	Tiron	spiniferus	Tiron spiniferus
Malacostraca	Amphipoda	Talitridae	Uhlorchestia	uhleri	Uhlorchestia uhleri
Malacostraca	Amphipoda	Aoridae	Unciola	irrorata	Unciola irrorata
Malacostraca	Amphipoda	Aoridae	Unciola	serrata	Unciola serrata
Malacostraca	Amphipoda	Aoridae	Unciola		Unciola spp.
Malacostraca	Decapoda	Upogebiidae	Upogebia	affinis	Upogebia affinis
Malacostraca	Decapoda	Xanthidae			Xanthidae
					Bryozoa
Ascidiacea					Ascidiacea
Leptocardia	Amphioxi	Branchiostomidae	Branchiostoma		Branchiostoma spp.
Ascidiacea	Pleurogona	Styelidae	Dendrodoa	carnea	Dendrodoa carnea
Ascidiacea	Pleurogona	Styelidae	Styela	clava	Styela clava
Anthozoa	Actiniaria				Actiniaria
Hydrozoa	Athecata	Clavidae	Clava	multicornis	Clava multicornis
Hydrozoa					Hydrozoa
Ophiuroidea	Ophiurida	Amphiuridae	Amphioplus	abditus	Amphioplus abditus
Ophiuroidea	Ophiurida	Amphiuridae	Amphipholis	squamata	Amphipholis squamata

Ophiuroidea	Ophiurida	Amphiuridae			Amphiuridae
Asteroidea	Forcipulatida	Asteriidae	Asterias	forbesi	Asterias forbesi
Asteroidea					Asteroidea
Echinoidea	Clypeasteroida	Echinarachnidae	Echinarachnius	parma	Echinarachnius parma
					Echinodermata
Echinoidea					Echinoidea
Holothuroidea					Holothuroidea
Holothuroidea	Apodida	Synaptidae	Leptosynapta	tenuis	Leptosynapta tenuis
Ophiuroidea	Ophiurida	Ophiuridae	Ophiura	sarsi	Ophiura sarsi
Ophiuroidea					Ophiuroidea
Holothuroidea	Dendrochirotida	Sclerodactylidae	Sclerodactyla	briareus	Sclerodactyla briareus
Bivalvia	Veneroida	Semelidae	Abra	lioica	Abra lioica
Gastropoda	Cephalaspidea	Scaphandridae	Acteocina	canaliculata	Acteocina canaliculata
Gastropoda	Mesogastropoda	Rissoidae	Alvania	pelagica	Alvania pelagica
Gastropoda	Neogastropoda	Buccinidae	Amphissa	haliaeeti	Amphissa haliaeeti
Bivalvia	Mytiloida	Mytilidae	Amygdalum	papyria	Amygdalum papyria
Gastropoda	Neogastropoda	Columbellidae	Anachis	lafresnayi	Anachis lafresnayi
Bivalvia	Arcoida	Arcidae	Anadara	transversa	Anadara transversa
Bivalvia	Ostreoida	Anomiidae	Anomia	simplex	Anomia simplex
Aplacophora					Aplacophora
Bivalvia	Ostreoida	Pectinidae	Argopecten	irradians concentricus	Argopecten irradians concentri
Bivalvia	Veneroida	Astartidae	Astarte	borealis	Astarte borealis
Bivalvia	Veneroida	Astartidae	Astarte	castanea	Astarte castanea
Bivalvia	Veneroida	Astartidae	Astarte		Astarte spp.
Bivalvia	Veneroida	Astartidae	Astarte	undata	Astarte undata
Gastropoda	Mesogastropoda	Cerithiidae	Bittium	alternatum	Bittium alternatum
Bivalvia					Bivalvia
Gastropoda	Mesogastropoda	Caecidae	Caecum	pulchellum	Caecum pulchellum
Gastropoda	Mesogastropoda	Caecidae	Caecum		Caecum spp.
Gastropoda	Mesogastropoda	Calyptraeidae			Calyptraeidae
Bivalvia	Veneroida	Cardiidae	Cerastoderma	pinnulatum	Cerastoderma pinnulatum
Gastropoda	Mesogastropoda	Cerithiidae			Cerithiidae
Gastropoda	Mesogastropoda	Vitrinellidae	Circulus	multistriatus	Circulus multistriatus
Bivalvia	Veneroida	Corbiculidae	Corbicula	fluminea	Corbicula fluminea
Bivalvia	Myoida	Corbulidae	Corbula	contracta	Corbula contracta
Bivalvia	Veneroida	Crassatellidae	Crassinella	lunulata	Crassinella lunulata
Bivalvia	Ostreoida	Ostreidae	Crassostrea	virginica	Crassostrea virginica
Bivalvia	Mytiloida	Mytilidae	Crenella	decussata	Crenella decussata
Gastropoda	Mesogastropoda	Calyptraeidae	Crepidula	convexa	Crepidula convexa
Gastropoda	Mesogastropoda	Calyptraeidae	Crepidula	fornicata	Crepidula fornicata
Gastropoda	Mesogastropoda	Calyptraeidae	Crepidula	plana	Crepidula plana
Gastropoda	Mesogastropoda	Calyptraeidae	Crepidula		Crepidula spp.
Bivalvia	Veneroida	Carditidae	Cyclocardia	borealis	Cyclocardia borealis
Gastropoda	Cephalaspidea	Scaphandridae	Cylichna	gouldi	Cylichna gouldi
Gastropoda	Cephalaspidea	Scaphandridae	Cylichnella	oryza	Cylichnella oryza
Gastropoda	Nudibranchia	Corambidae	Doridella	obscura	Doridella obscura
Bivalvia	Veneroida	Solenidae	Ensis	directus	Ensis directus
Bivalvia	Veneroida	Solenidae	Ensis		Ensis spp.
Gastropoda	Neogastropoda	Muricidae	Eupleura	caudata	Eupleura caudata
Gastropoda	Mesogastropoda	Naticidae	Euspira	heros	Euspira heros
Gastropoda					Gastropoda

Bivalvia	Veneroida	Veneridae	Gemma	gemma	Gemma gemma
Bivalvia	Mytiloida	Mytilidae	Geukensia	demissa	Geukensia demissa
Gastropoda	Cephalaspidea	Hamineidae	Haminoea	solitaria	Haminoea solitaria
Bivalvia	Myoida	Hiatellidae	Hiatella	arctica	Hiatella arctica
Gastropoda	Mesogastropoda	Hydrobiidae	Hydrobia	totteni	Hydrobia totteni
Gastropoda	Mesogastropoda	Hydrobiidae			Hydrobiidae
Gastropoda	Neogastropoda	Nassariidae	Ilyanassa	obsoleta	Ilyanassa obsoleta
Gastropoda	Neogastropoda	Nassariidae	Ilyanassa	trivittata	Ilyanassa trivittata
Gastropoda	Neogastropoda	Turridae	Kurtziella	cerina	Kurtziella cerina
Gastropoda	Mesogastropoda	Littorinidae	Lacuna	vincta	Lacuna vincta
Bivalvia	Veneroida	Cardiidae	Laevicardium	mortoni	Laevicardium mortoni
Gastropoda	Mesogastropoda	Littorinidae	Littorina	irrorata	Littorina irrorata
Gastropoda	Mesogastropoda	Littorinidae	Littorina	littorea	Littorina littorea
Bivalvia	Veneroida	Lucinidae			Lucinidae
Bivalvia	Pholadomyoida	Lyonsiidae	Lyonsia	hyalina	Lyonsia hyalina
Bivalvia	Veneroida	Tellinidae	Macoma	balthica	Macoma balthica
Bivalvia	Veneroida	Tellinidae	Macoma		Macoma spp.
Bivalvia	Veneroida	Tellinidae	Macoma	tenta	Macoma tenta
Bivalvia	Veneroida	Mactridae			Mactridae
Bivalvia	Veneroida	Veneridae	Mercenaria	mercenaria	Mercenaria mercenaria
Gastropoda	Neogastropoda	Columbellidae	Mitrella	lunata	Mitrella lunata
Gastropoda	Neogastropoda	Columbellidae	Mitrella		Mitrella spp.
Bivalvia	Veneroida	Montacutidae			Montacutidae
Bivalvia	Veneroida	Mactridae	Mulinia	lateralis	Mulinia lateralis
Gastropoda	Neogastropoda	Muricidae			Muricidae
Bivalvia	Myoida	Myidae	Mya	arenaria	Mya arenaria
Bivalvia	Myoida	Myidae	Mya		Mya spp.
Bivalvia	Myoida	Myidae			Myidae
Bivalvia	Veneroida	Montacutidae	Mysella	planulata	Mysella planulata
Bivalvia	Mytiloida	Mytilidae			Mytilidae
Bivalvia	Mytiloida	Mytilidae	Mytilus	edulis	Mytilus edulis
Gastropoda	Neogastropoda	Nassariidae			Nassariidae
Gastropoda	Neogastropoda	Nassariidae	Nassarius	vibex	Nassarius vibex
Gastropoda	Mesogastropoda	Naticidae			Naticidae
Gastropoda	Mesogastropoda	Naticidae	Neverita	duplicata	Neverita duplicata
Bivalvia	Nuculoida	Nuculidae	Nucula	proxima	Nucula proxima
Bivalvia	Nuculoida	Nuculidae	Nucula		Nucula spp.
Bivalvia	Nuculoida	Nuculidae	Nucula	tenuis	Nucula tenuis
Bivalvia	Nuculoida	Nuculanidae	Nuculana	pernula	Nuculana pernula
Bivalvia	Nuculoida	Nuculanidae			Nuculanidae
Bivalvia	Nuculoida	Nuculidae			Nuculidae
Gastropoda	Nudibranchia				Nudibranchia
Gastropoda	Pyramidelloida	Pyramidellidae	Odostomia	bisuturalis	Odostomia bisuturalis
Gastropoda	Pyramidelloida	Pyramidellidae	Odostomia		Odostomia spp.
Gastropoda	Pyramidelloida	Pyramidellidae	Odostomia	trifida	Odostomia trifida
Gastropoda	Pyramidelloida	Pyramidellidae	Odostomia	weberi	Odostomia weberi
Gastropoda	Nudibranchia	Onchidorididae	Onchidoris	muricata	Onchidoris muricata
Bivalvia	Pholadomyoida	Pandoridae	Pandora	gouldiana	Pandora gouldiana
Bivalvia	Pholadomyoida	Pandoridae	Pandora		Pandora spp.
Bivalvia	Pholadomyoida	Periplomatidae	Periploma	papyratium	Periploma papyratium
Bivalvia	Pholadomyoida	Periplomatidae	Periploma		Periploma spp.

Bivalvia	Veneroida	Petricolidae	Petricola	pholadiformis	Petricola pholadiformis
Gastropoda	Opisthobranchia	Philinidae	Philine	lima	Philine lima
Bivalvia	Veneroida	Veneridae	Pitar	morrhuanus	Pitar morrhuanus
Gastropoda	Basommatophora	Planorbidae			Planorbidae
Polyplacophora					Polyplacophora
Gastropoda	Pyramidelloida	Pyramidellidae			Pyramidellidae
Bivalvia	Veneroida	Montacutidae	Pythinella	cuneata	Pythinella cuneata
Gastropoda	Cephalaspidea	Retusidae	Retusa	obtusa	Retusa obtusa
Gastropoda	Cephalaspidea	Acteonidae	Rictaxis	punctostriatus	Rictaxis punctostriatus
Gastropoda	Cephalaspidea	Scaphandridae			Scaphandridae
Scaphopoda					Scaphopoda
Bivalvia	Veneroida	Semelidae			Semelidae
Bivalvia	Solemyoida	Solemyidae	Solemya		Solemya spp.
Bivalvia	Solemyoida	Solemyidae	Solemya	velum	Solemya velum
Bivalvia	Veneroida	Solenidae	Solen	viridis	Solen viridis
Bivalvia	Veneroida	Solenidae			Solenidae
Bivalvia	Veneroida	Sphaeriidae			Sphaeriidae
Bivalvia	Veneroida	Mactridae	Spisula	solidissima	Spisula solidissima
Bivalvia	Veneroida	Psammobiidae	Tagelus	plebeius	Tagelus plebeius
Gastropoda	Mesogastropoda	Naticidae	Tectonatica	pusilla	Tectonatica pusilla
Bivalvia	Veneroida	Tellinidae	Tellina	agilis	Tellina agilis
Bivalvia	Veneroida	Tellinidae	Tellina		Tellina spp.
Bivalvia	Veneroida	Tellinidae			Tellinidae
Bivalvia	Veneroida	Thyasiridae	Thyasira	trisinuata	Thyasira trisinuata
Gastropoda	Pyramidelloida	Pyramidellidae	Turbonilla	interrupta	Turbonilla interrupta
Gastropoda	Pyramidelloida	Pyramidellidae	Turbonilla		Turbonilla spp.
Bivalvia	Veneroida	Veneridae			Veneridae
Gastropoda	Mesogastropoda	Vitrinellidae	Vitrinella		Vitrinella spp.
Bivalvia	Nuculoida	Nuculanidae	Yoldia	limatula	Yoldia limatula
Bivalvia	Nuculoida	Nuculanidae	Yoldia	sapotilla	Yoldia sapotilla
Bivalvia	Nuculoida	Nuculanidae	Yoldia		Yoldia spp.
					Nematoda
		Phoronidae	Phoronis		Phoronis spp.
Turbellaria					Turbellaria
					Porifera
					Priapulida
Anopla	Heteronemertea	Lineidae			Lineidae
					Rhynchocoela
Anopla	Paleonemertea	Tubulanidae	Tubulanus		Tubulanus spp.
		Golfingiidae	Phascolion	strombi	Phascolion strombi

12-3 Shad Hydroaccoustic Estimate Discussion

Numbers of American Shad ascending the Delaware River has been estimated since 1975 using the Peterson capture-recapture method, Schaefer capture-recapture method, single beam hydroacoustic method, or some combination of these three techniques. Single beam hydroacoustic methods are currently employed. All methodologies, capture-recapture and hydroacoustic have been implemented with underlying assumptions. Although it was possible to account for violation of some assumptions, funding and logistical constraints prevented full exploration of assumptions inherent in capture-recapture methods used on the Delaware River. Handling and tagging sensitivity of American shad was always a concern. These concerns coupled with manpower constraints led to the adoption of more efficient and less invasive hydroacoustic methods in the 1990's by the NJFWS, with cooperation from the Academy of Natural Sciences in Philadelphia. However, hydroacoustic methods depend upon their own set of assumptions. When initially deployed on the Delaware River, estimating numbers of shad ascending the Delaware River between bridge piers on the Route 202 toll Bridge near Lambertville New Jersey was a large scale-cutting edge application of the method. The NJFWS historically spearheaded efforts to measure run size using capture-recapture methods and secured independent review of hydroacoustic methods following their initial application (Lorantas et. al. 2003). Although the hydroacoustic method appeared acceptable compared to capture-recapture methods, some improvements were suggested and made. These included:

- Extending the study until May 31 to encompass all components of the run.
- Determining the actual bottom profile of each wetted span which served to adjust the computational formula used to estimate shad within bridge span cross-sectional areas.
- Measuring American shad apparent swimming velocity on site [measured as approximately 1 meter/sec].
- Initiating count procedures earlier in the year, mid-March, in anticipation of a possible early spawning run.
- Adding an "alternative" estimator which calculated and extrapolated shad densities in more conservative fashion (1ft. – 6ft. off the bottom) as opposed to the standard calculation method (extrapolation 1ft off bottom to surface [even during high flows]).

Lorantas, et al. (2003) suggested that the hydroacoustic contractor made as accurate and precise an estimator as was possible within existing budget.

Hydroacoustic run size estimates were initially funded by the NJFWS. Subsequent collection of biological data and harvest data associated with the Delaware River run was mandated by ASMFC; consequently, the value of the work funded by the NJFWS became apparent and cooperative states shared in funding the initiative. Ultimately, biological data, harvest data, and run size data were used to assess the Delaware River stock of shad and guide future management.

As the time for stock assessment approached (2003) and levels of precision necessary to make use of data became apparent, run size estimation methodologies were reviewed in greater detail by the Cooperative. Following those reviews, needs for improved precision in the current method/technique were identified and alternative estimation methods examined. The synopsis below has been prepared by the Technical Committee to guide decision makers in selecting techniques for run size estimation useful for stock assessments. Essentially two approaches were examined. The first attempted to validate or served to correct assumptions

defined as critical in the hydroacoustic method. The second looked at a promising capture-recapture method that made use of tetracycline marked American shad in the Delaware River whose origin was from hatchery reared shad derived from restoration activities being implemented by the Pennsylvania Fish and Boat Commission on the Lehigh River and Schuylkill River.

With respect to the current hydroacoustic method, it is hoped that validation of critical assumptions or adjustments in the estimation process, associated with the validation effort, will yield an estimate with sufficient reliability to be useful in the stock assessment process. Assumptions inherent in the current hydroacoustic method were examined and those expected to have the most influence on run size (in no particular order) are:

(1) Counted fish school signals are comprised of all American shad.
(2) Swim speed of American shad is a constant 1m/s.
(3) Location of American shad in the water column was is 1 foot from bottom to 6 ft from bottom, fish densities from two transducers within this region were extrapolated to the entire region.
(4) Direction of travel is 100% upstream (no double counting).

In addition to these assumptions, specific issues associated with the time of deployment of sampling gear, potential of gear to repel American shad, pulsed movement of large schools (partially related to measurements methods) and the influence of background noise and gear threshold settings to exclude background noise were examined. In the Technical Committees judgment, with current level of understanding, these issues were not determined to have as significant an affect on the estimate as other assumptions or characteristics of the estimation process, although some influence might be expected. Validation of the above 4 items was approached with a short term focus (2 week) to limit costs. In light of the short-term approach chosen, it was obvious that real time knowledge of passage would enhance the efficiency of any validation activity. Upon review of validation methods it was determined by Lorantas et al. (2003) that the hydroacoustic camera (Didson Camera) was a device that could address most assumptions, however its availability was too limited and cost too great to consider it as near term (2003) validation method, although it reigned as the preferred validation method. Two, direct sampling methods were considered, electrofishing and gill netting. However, limited success in past attempts at gill netting and known difficulty associated with electrofishing and collecting American shad from deep water gave these techniques limited appeal in light of assumptions that could be addressed. Similarly, cost and number of assumptions validated limited appeal of the radio-tag approach. Two video camera techniques were considered and may have promise depending upon depth of field, and field of view, which would likely be dependent upon river turbidity. Although costs are reasonable, and the number of assumptions that can be addressed high, the ability to quantitatively assess and reliably assess key assumptions in consistent fashion may be limited. Log book diaries derived from fisherman whose record catch location will be used to provide a general indication that very large shad schools move past the Route 202 Bridge. Such log data is available and anglers have expressed willingness to share data to aid in characterizing the shad run. In light of the limitations and opportunities available for cost effective validation, it was made known that the USFWS-Alaska may have split beam hydroacoustic gear that could be operated concurrently with the single beam gear typically deployed in the Delaware River. The split beam gear would address some but not all assumptions of concern and likely be of less cost that the Didson Camera. Additionally, the

single beam contractor agreed to truncate the duration of the survey period by two weeks and credit the NJFWS for that period. (Lorantas et al., 2003)

Lorantas et al, 2003 noted that the contractor has endeavored to validate any concerns (assumptions and issues) the NJFWS has identified, through: (1) literature review, (2) on site-experiments and (3) observations on site within the limits of budget and equipment. However limited direct validation of the assumptions and issues identified as critical through the course of the shad run have never been completely elucidated.

Given the cost and complexity of the hydroacoustic validation approach a promising alternative capture-recapture technique was explored (Change in Ratio Method). This method made use of otolith marked American shad ascending the Delaware River following stocking in the Lehigh River as marked fry. The method examined the proportion of otolith tagged American shad in the Delaware River below the Lehigh River mouth and the proportion of otolith tagged American shad above the Lehigh River mouth. This information coupled with an exact count of American shad ascending the Lehigh River would yield an estimate of the Delaware River Run size from the vicinity of the Lehigh upriver. Unfortunately the proportion of marked American shad in the Delaware River would have to be greater than 0.05 below the Lehigh River mouth to yield a statistically reliable estimate. As noted by Lorantas et al. (2003), under current stocking levels of marked Juveniles (tetracycline mark) in the Lehigh River, the proportion of marked adult American shad returning and collected in the Delaware in assessment operations are insufficient to yield reliable results.

As reported by Lorantas et al., (2003) the short term recommendations include:
(1) Use split beam hydroacoustic techniques in conjunction with current single beam methods during shad passage times to compare resulting estimates. It is acceptable for the single beam and split beam gear to operate concurrently within a bridge pier.

(2) Fund the split beam validation technique by truncating the single beam survey such that savings can fund a short term 1 or 2 week validation effort.

(3) Step down Alternative Validation (should split beam equipment not be available)
- (a) Downrigger mounted video camera.
- (b) Mobile video camera (R.O.V.)
- (c) Electrofishing
- (d) Bottom gill net

As reported by Lorantas et al., (2003) the long term recommendations include:
(1) Do not commit to funding current single beam hydroacoustic methods until after validation activities in 2003 are complete.
(2) The Didson hydroacoustic camera was the only validation methodology that would provide definitive quantifiable answers to assumptions and issues associated with use of current hydroacoustic techniques. Deployment of the hydroacoustic camera is expensive. This technology should be explored further.
(3) Change in Ratio estimation methods was explored and application under existing stocking levels of marked American Shad will not yield reliable estimates.
(4) Explore other capture-recapture techniques.

12-4 Striped Bass Tagging Program Analysis

This monitoring report summarizes results from analyses of tagging data from the USFWS Cooperative Striped Bass Tagging Program. The results include estimates of instantaneous fishing mortality (F) and survival (S) rates. Estimates of F and S are provided with and without correction for live release bias. Also included are estimates used for model selection and model averaging, length, structure of tag releases, age structure of recaptures, geographic distributions of recaptures by month, and estimates of catch and exploitation rates by program.

Description of Tagging Programs

Nine tagging programs provided information for this report, and have been in progress for at least 10 years. Most producer area and coastal programs tag striped bass (mostly >= 18 inches total length) during routine state monitoring programs. Producer area tagging programs operate mainly during spring spawning, and use many capture gears, such as pound nets, gill nets, seines and electroshocking. Producer area programs are as follows: 1. Delaware and Pennsylvania (DE-PA) with fish tagged primarily in April and May; 2. Hudson River (HUDSON) with fish tagged in May; 3. Maryland (MDDNR) with fish tagged primarily in April and May, and 4. Virginia spawning stock program (VARAP) with fish tagged in the Rappahannock River during April and May.

Coastal Programs tag striped bass from mixed stocks during fall, winter, or early spring and use several gears including hook & line, seine, gill net, and otter trawl. The coastal tagging programs are as follows: 1. Massachusetts (MADFW) with fish tagged during fall months; 2. North Carolina winter trawl survey (NCCOOP) with fish tagged primarily in January; 3. New Jersey Delaware Bay (NJDEL) with fish tagged in March and April; and 4. New York ocean haul survey (NYOHS) with fish tagged during fall months. Striped bass (including those < 18 inches) are tagged during the Western Long Island Survey (NYDEC-WLI) from May through October in bays along the western end of Long Island, New York. Tag release and recapture data are exchanged between the U.S. Fish and Wildlife Service (USFWS) office in Annapolis, MD, and the cooperating tagging agencies. The USFWS maintains the tag release/recovery database and provides rewards to fishermen who report the recapture of tagged fish. Through July of 2003, a total of 403,747 striped bass have been tagged and released, with 73,663 recaptures reported and recorded in the USFWS database (Tina McCrobie, personal comm.).

Data Analysis

The Striped Bass Tagging Committee's analysis protocol is based on assumptions described in Brownie et al. (1985). The tag recovery data is analyzed in program MARK (White, 1999). Important assumptions of the tagging programs (as reported in Brownie 1985) are as follows:

1. The sample is representative of the target population.
2. There is no tag loss.
3. Survival rates are not affected by the tagging itself.
4. The year of tag recoveries is correctly tabulated.
5. The fate of each tagged fish is independent of the fate of other tagged fish.
6. The fate of a given tagged fish is a multinomial random variable.
7. All tagged individuals of an identifiable class (age, sex) in the sample have the same annual survival and recovery rates.

The analysis protocol follows an information-theoretic approach based on Kullback-Leibler Information Theory and Akaike's information criterion (Burnham and Anderson 2003), and involves the following steps. A set of biologically-reasonable candidate models are identified prior to analysis. Various patterns of survival and recovery are used to parameterize the candidate models. These models allow parameters to be constant, time specific, or allow time to be modeled as a continuous variable. Other models allow time periods to coincide with changes in regulatory regimes.

Estimates of survival

The tagging committee calculated the maximum likelihood estimates of the multinomial parameters of survival and recovery based on an observed matrix of recaptures (using Program MARK). Candidate models are fit to the tag recovery data and arranged in order of fit by the second-order adjustment to Akaike's information criterion (AICc) (Akaike, 1973; Burnham and Anderson, 1992). Annual survival rates are estimated for two size groups (fish >= 18 inches TL and fish >= 28 inches TL). Annual survival is calculated as a weighted average across all models, where weight is a function of model fit (Buckland et al. 1997). Model averaging eliminates the need to select the single "best" model, allowing the uncertainty of model selection to be incorporated into the variance of parameter estimates (Burnham and Anderson 2003). Survival is inestimable for the terminal year in the fully time saturated {S(t)r(t)} model, so the time saturated model is excluded from the model averaged survival estimate for the terminal year only. A weighted average of unconditional variances (conditional on the set of models) is estimated for the model-averaged estimates of survival (Buckland et al. 1997).

Estimation of Fishing Mortality

For each tagging program, instantaneous fishing mortality (F) is estimated by converting the adjusted survival (S) to total mortality (Z) and subtracting a constant value (M = 0.15) for natural mortality, where F= - LN(S) - 0.15. Using this technique, natural mortality is held fixed, and any change in total mortality (Z) results in an equal change in fishing mortality (F). Uncertainty in the estimates of F (at the 95% confidence interval) is calculated from model-averaged unconditional variances of the adjusted survival estimates. We estimate an average F for coastal programs, and a weighted average of F for producer area programs. Weights for producer area averages (based on the estimated proportion of fish contributed to the coast-wide stock, G. Shepherd, pers. comm. and D. Kahn, pers. comm.) are as follows: Hudson (0.13); Delaware (0.09); and Chesapeake Bay (0.78), with MD (0.67) and VA (0.33).

Estimation of Encounter and Exploitation Rates

In addition to estimates of S and F, we estimated annual catch rates and annual exploitation rates for three length groups (>= 18 inch, 18-28 inch, and >= 28 inch) with tag recoveries of striped bass released by seven agencies (1987 - 2002) of the Cooperative Striped Bass Tagging Program.

Each time series of annual catch rates and annual exploitation rates reflects trends in fishing effort and exploitation, respectively, but do not include any assumptions about natural mortality or depend on estimates of survival. Estimates of annual catch rates and annual exploitation rates are independent among years. Fish at large for more than one year are not used in the analysis, and each tagged fish is assigned a 365-day recovery period. Consequently, recovery periods for this approach differ from those used for survival analysis,

and may influence comparisons between the two methods. Annual catch rates and annual exploitation rates are adjusted R/M ratios as described below (reporting rate = 0.43, hooking mortality rate = 0.08, R_k = killed recaptures, R_L = recaptures released alive): (1) Annual catch rate = (R / 0.43) / M(2) Annual exploitation rate = ((R_k + R_L * 0.08) / 0.43) / M

Tagging Assessment Results

Estimates of F (fish tagged and released at >= 28 inches) The 2002 estimates for producer area programs Hudson River, Delaware River, and Chesapeake Bay (HUDSON, DE/PA, MDDNR, VARAP) were 0.07, 0.33, 0.31, and 0.28, respectively, with a weighted mean fishing mortality (F) of 0.27 (Tables 18 and 19; Figure 20). The 2002 estimates of F for the four mixed-stock coastal programs (Massachusetts, New York Ocean Haul, New Jersey, and North Carolina winter trawl) were 0.05, 0.35, 0.09, and 0.27, respectively, with an unweighted-mean F of 0.19. *Estimates of F (fish tagged and released at >= 18 inches).* The 2002 estimates for producer area programs of Hudson River, Delaware River, and Maryland Chesapeake Bay were 0.06, 0.37, 0.68, respectively.