DELAWARE ESTUARY

MONITORING REPORT

Report Prepared by:

Edward D. Santoro
Delaware River Basin
Monitoring Coordinator

In Cooperation With The
Monitoring Implementation Team
of the Delaware Estuary Program

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DELAWARE
ESTUARY PROGRAM

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1.O EXECUTIVE SUMMARY

The Delaware Estuary has shown large improvement in many aspects of water quality in the past and improvements in some parameters continue. From the late 1960s through 1990, large increases in dissolved oxygen content are demonstrable. Since that time, oxygen concentrations, which are often close to atmospheric saturation, remain stable. Today, along the mainstem of the Estuary minimum oxygen levels are at 3.5 to 4.0 mg/l at all DRBC Boat Run Stations. The minimum required dissolved oxygen standard within the upper Estuary from the area of the Pennsylvania - Delaware border to the mouth of Pennypack Creek over a 24 hour period is 3.5 mg/l. Fecal coliform bacteria levels over the period 1989-1997 showed a significant decline. The recent levels for both Fecal coliform and Enterococcus suggest levels of these bacteria in the area from the Pennsylvania - Delaware boundary line to Fieldsboro, New Jersey to be lower than Federal Fishable /Swimmable Criteria. Ammonium nitrogen showed a large decline in the past, with much of the decline coinciding with increased nitrate nitrogen. The total inorganic nitrogen (ammonium and nitrate) concentration is slightly lower today than in the late 1960s. Total phosphorus declined dramatically in the early 1970s. Concentrations of both nitrogen and phosphorus remain stable today and, although concentrations are high, there is no indication of problems from these nutrients.

A number of fisheries have shown a resurgence in recent years. In addition, a greater number fish species have been noted in the tidal Delaware River. Increases have been noted in the abundance of American shad, weakfish, striped bass, Atlantic croaker, Atlantic silversides, bay anchovy, black drum, hogchoker, northern kingfish and striped anchovy. Survey data suggest an increase in blue crab abundance as well. American eel landings for both adult and juvenile fish have been steadily increasing in recent years. The current commercial landing data for adult eel is spotty. Efforts are being made in the State of New Jersey to collect better information for this species. A number of data sets suggest a decline in the population level of horseshoe crabs in the Estuary. A fishery management plan is being prepared by the Atlantic States Marine Fisheries Commission to provide management recommendations for this species. Atlantic sturgeon numbers continue to show a decline. The 1996 population estimates place the levels for this species at 430 fish.

There is still progress to be made in restoring the important resource that is the Delaware Estuary. For example: There are fish consumption advisories for striped bass, white perch and catfish in all three states due to Polychlorinated Biphenyls (PCBs) and chlorinated pesticides. Aquatic sediments collected from the upper reaches of the Estuary continue to contain elevated levels of PCBs, Polycyclic Aromatic Hydrocarbons (PAHs), chlorinated pesticides and selected metals. These contaminants appear to be bio-available to organisms.

Other activities of the Monitoring Implementation Team regarding Delaware Estuary Program coordination, mapping and the development of a sortable data base of ongoing monitoring efforts the Estuary are discussed.

2.0 OVERVIEW

The National Estuary Program requires a monitoring plan in the Comprehensive Conservation and Management Plan (CCMP) of each estuary program. The plan is needed to assess the effectiveness of management action plans in meeting goals identified in the plan. Monitoring can identify environmental problems that require additional management action. For example, the toxic pollutant management strategy is built around the identification of events at an early stage so corrective action can be initiated. Historically, ambient water quality monitoring in the Delaware Estuary has served as an indicator of regulatory compliance toward managing urban and industrial pollution inputs to the system. The goal of the regulatory compliance has been attainment of the federal Clean Water Act's target of "fishable - swimmable" waters. Some living resources monitoring has been conducted to manage commercial and recreational fisheries.

A comprehensive monitoring program to assess the condition of natural resources in the Delaware Estuary (herein after referred to as The Plan) is extremely valuable to document a degrading condition. Appropriate monitoring provides a way to accurately assess potential damages and to develop corrective programs and plans. The availability of good monitoring information makes these efforts less costly in terms of time and funds to the agencies involved. It also supports quicker resolutions of problems and restoration actions.

Initially, the Delaware Estuary Program provided necessary characterization of the extent of knowledge of this resource. Four characterization reports [Najarian Associates, Philadelphia Academy of Natural Sciences (1991), Frithsen et.al., (1991), Sullivan et.al., (1991) and Sutton et. al., (1996)] prepared a characterization of the physical, biological, ecological and land use trends in the Estuary. These reports, prepared for the Scientific and Technical Advisory Committee of the Estuary Program helped to establish the status of the Estuary at the beginning of the CCMP implementation. Other Estuary Program supported activities have provided additional definition regarding such topics as living resources (Dove and Nyman, eds.,1995) and contaminant inputs (Reidel and Sanders, 1993). Based upon ongoing work by several agencies, the CCMP presented several aspects regarding the health of the Estuary. These include: non-compliance with primary contact recreation in sections of the upper Estuary and heavy usage of surface and groundwater. The latter can affect industrial and domestic use and the maintenance of habitat and living resources. The CCMP also identified concerns regarding: elevated levels of toxic substances in the sediments, water column and biota dependent on the Estuary, degraded benthic communities North of the Chesapeake and Delaware Canal to Trenton and habitat fragmentation and alteration. These efforts have helped the Delaware Estuary Program to establish a series of objectives to guide the development of management activities.

Taken together, these program objectives are designed to address the overall objective of the Clean Water Act to "restore and maintain the chemical, physical and biological integrity of the nation's waters." With the above in mind, the cooperative monitoring plan for the Delaware Estuary includes four specific goals:

- To obtain information on variables that may influence the condition of the Delaware Estuary, and to assess environmental indications of achievement of the management goals set by local, State and Federal authorities.

- To measure, with known confidence, the current status and trends in indicators of the condition of the Delaware Estuary (and surrounding watershed) on a system-wide basis.

- To estimate, with known confidence, the extent of the environmentally critical landscapes of the Delaware Estuary system.

- To evaluate and revise, periodically, the action plans to address dynamic developments in the Delaware Estuary.

The cooperative monitoring plan for the Delaware Estuary has four subject areas for which different monitoring strategies apply:

1. water quality
2. toxics
3. living resources
4. habitat/land cover/land use.

The monitoring plan developed by the Monitoring Committee of the Delaware Estuary Program is intended to be a cooperative and coordinated effort of the three surrounding States, the Federal government, the private sector, citizens groups and academia.

One key element within the cooperative monitoring plan was the establishment of the role of Monitoring Coordinator and the establishment of the Office of Monitoring and Mapping. This office was initiated in June 1997. Initial efforts have included enhancement of cooperation, assembling a sortable data base of ongoing monitoring efforts, assistance with ongoing programs, and facilitating data compilation. This first annual report represents an ongoing commitment by researchers, regulators and the private sector to enhance the multi-jurisdictional management of the Estuary. This report contains some data synthesis and trends, a feature which will be included in future reports.

3.0 STATUS REPORT

3.1 Water Quality

3.1.1 Long Term Trends

The Delaware Estuary includes a heavily urbanized tidal river, tidal tributaries and a broad saline bay that is surrounded by extensive salt marshes. The tidal freshwater portion was once considered one of the most polluted in the USA. From the early part of this century until the 1970s, very high biochemical oxygen demand rendered the Philadelphia /Camden region nearly anoxic for several months of the year. Control of industrial effluents and upgrades in municipal sewage treatment plants, completed by the late 1980s resulted in one of the most successful estuarine water quality improvements in the world. However, water quality problems continue to exist.

Like most urbanized estuaries, the Delaware has seen a long-term increase in nutrient loading (Ketchum, 1969; Jaworski, 1981). Figure 3-1 shows chloride and nitrate data for the Marcus Hook station. This figure shows a four-fold increase in nitrate concentration for the Delaware River near Philadelphia from 1913 to the 1980s. Some of the input for Figure 3-1 for the period 1911 - 1988 is based on sparse data of unsure quality. Since 1967, more extensive monitoring records are available for transects going down the majority of the length of the Delaware Estuary navigation channel (DRBC Boat Run Program). In the period from 1900 to 1950, the human population in the drainage basin increased significantly, but has been relatively constant since then. The observed increase in nutrient loading mirrors that of the human population for the first 50 years of the record period, but the increase in chloride only for the latter 40 years of the period (Sharp,1997).

Figure 3-2 shows Duncan's Multiple Range Test for dissolved oxygen for all stations in the Delaware River Boat Run conducted by Delaware Department of Natural Resources and Environmental Control (DNREC) for the Delaware River Basin Commission (DRBC). That figure presents, for each year, a single average value. Using a least square method, each mean is evaluated to other years. Those years that are not significantly different ($\prec$ = 95%) are grouped together. Statistically non-significant groupings suggest that data from all stations over the period 1977-1986 had lower average oxygen levels than the period 1988-1994 (refer to Appendix C). Trend data over the 1994 - 1995 period show minimum dissolved oxygen values in the mainstem of the Delaware River to be generally above 5 to 6 mg/l in the lower and middle Estuary (Ship John Light (River Mile 36) to Marcus Hook (River Mile 78). Further North in the Philadelphia area (River Mile 84 - 111) minimum dissolved oxygen levels were typically above 3.5 mg/l , which is the DRBC criteria within a 24-hour period (See Figure 3-3 and Appendix C). Annual average values are approaching 7 - 8 mg/l.

Figure 3-4 shows nitrate for the 1967 - 1997 period. In Figure 3-5, ammonium nitrogen for the 1967 - 1993 period shows a dramatic decline. Values are reported in micromoles N per liter (100 **μ**MN/l = 1.4 mg/l). Some of the ammonium decline (3.9 μM N/l/yr.) can be accounted for by the nitrate increase (1.4 μM N/l), although there is also a slight overall decline in total inorganic nitrogen. Combining these data sets, one can see a large increase in nitrate during the population increase and then a relatively level nitrate concentration for several decades but a large change in nitrogen speciation. As presented in Sharp (1997) the shift in nitrogen speciation can be evaluated stoichiometrically with the increase in oxygen content of the water. In fact, although the concept was developed for subsurface oceanic waters (Redfield et.al., 1963), Redfield stoichiometry can be applied to coastal (Sharp and Church, 1981) and estuarine (Culberson, 1988) waters. In doing this, the ammonium oxidation to nitrate over the quarter century period accounts for about 40% of the oxygen decrease. Figure 3-6 shows a similar trend for total phosphorus; unfortunately, the data set does not consistently contain dissolved phosphate data. The presumed cause of this very large decrease has reportedly been attributed to the detergent phosphate ban of the early 1970s (Jaworski 1997). Sharp (1997) noted that in all probability, the total phosphorus reduction involves changes in partitioning between dissolved and soluble phases for the phosphorus and changes in solubility of phosphate (Lebo, 1991; Lebo and Sharp, 1992), as well as decreases of phosphorus inputs. The relation of total inorganic nitrogen decrease (2.5 μM N/l per year) to total phosphorus decrease (1.2 μM P/l) could account for only about 10% of the phosphorus change. Thus, much of the decline in phosphorus concentration appears to be actual removal from the water column.

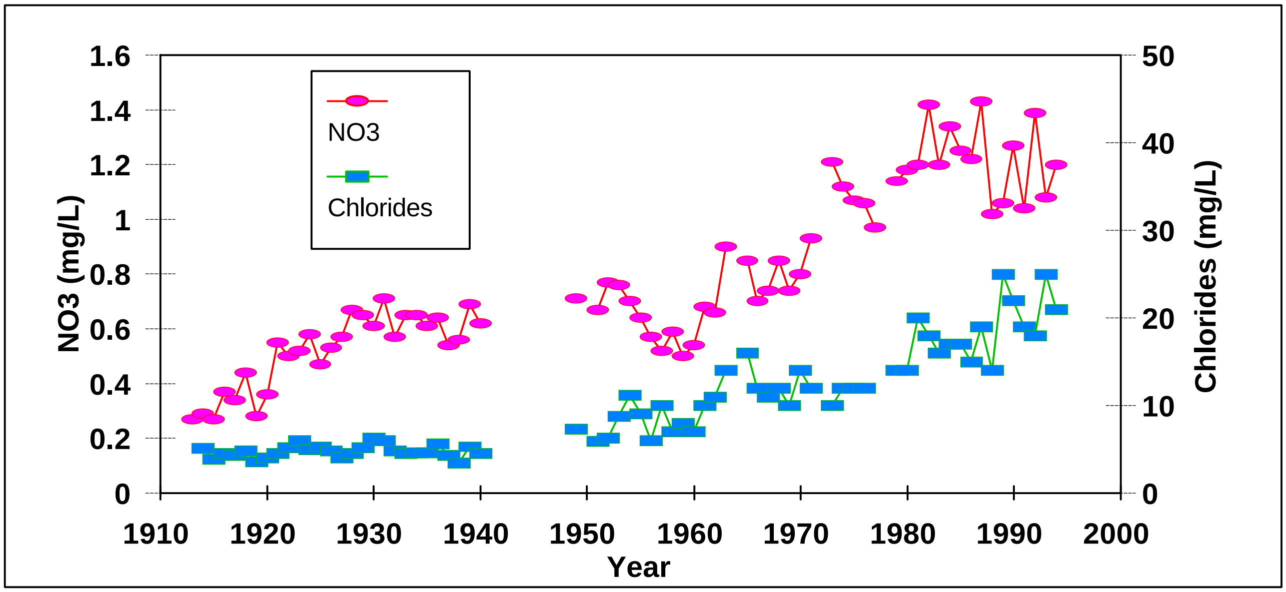
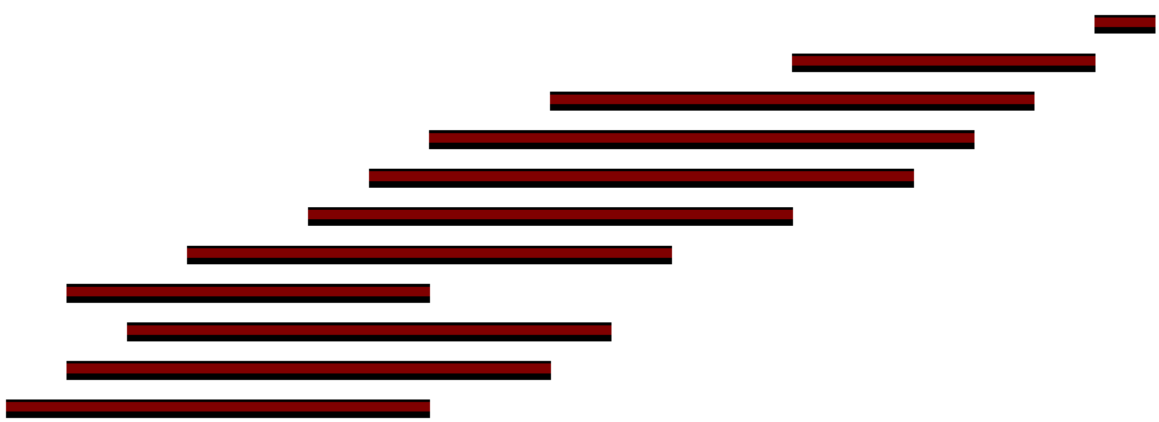


FIGURE 3-1 LONG TERM NITRATE AND CHLORIDE DATA FOR THE MARCUS HOOK STATION (FROM SHARP, et. al., (1997) BASED UPON DATA FROM N. A. JAWORSKI).

FIGURE 3-2 DUNCANS MULTIPLE RANGE TEST - DISSOLVED OXYGEN OVER THE PERIOD 1977 - 1995 FOR ALL DRBC BOAT RUN STATIONS.

Mean O_2 (mg/l)	6.3	6.5	6.6	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.3	7.4	7.4	7.45	7.5	7.55	7.64	7.8	8.0	9.4
N of Analyses	354	323	262	249	268	317	337	350	359	389	355	303	393	323	88	323	92	36	291	67
YEAR	85	84	83	79	96	82	78	77	81	86	95	88	87	91	89	90	92	93	94	80



BARS DENOTE NON-SIGNIFICANCE AT ALPHA = 0.05, df = 5227

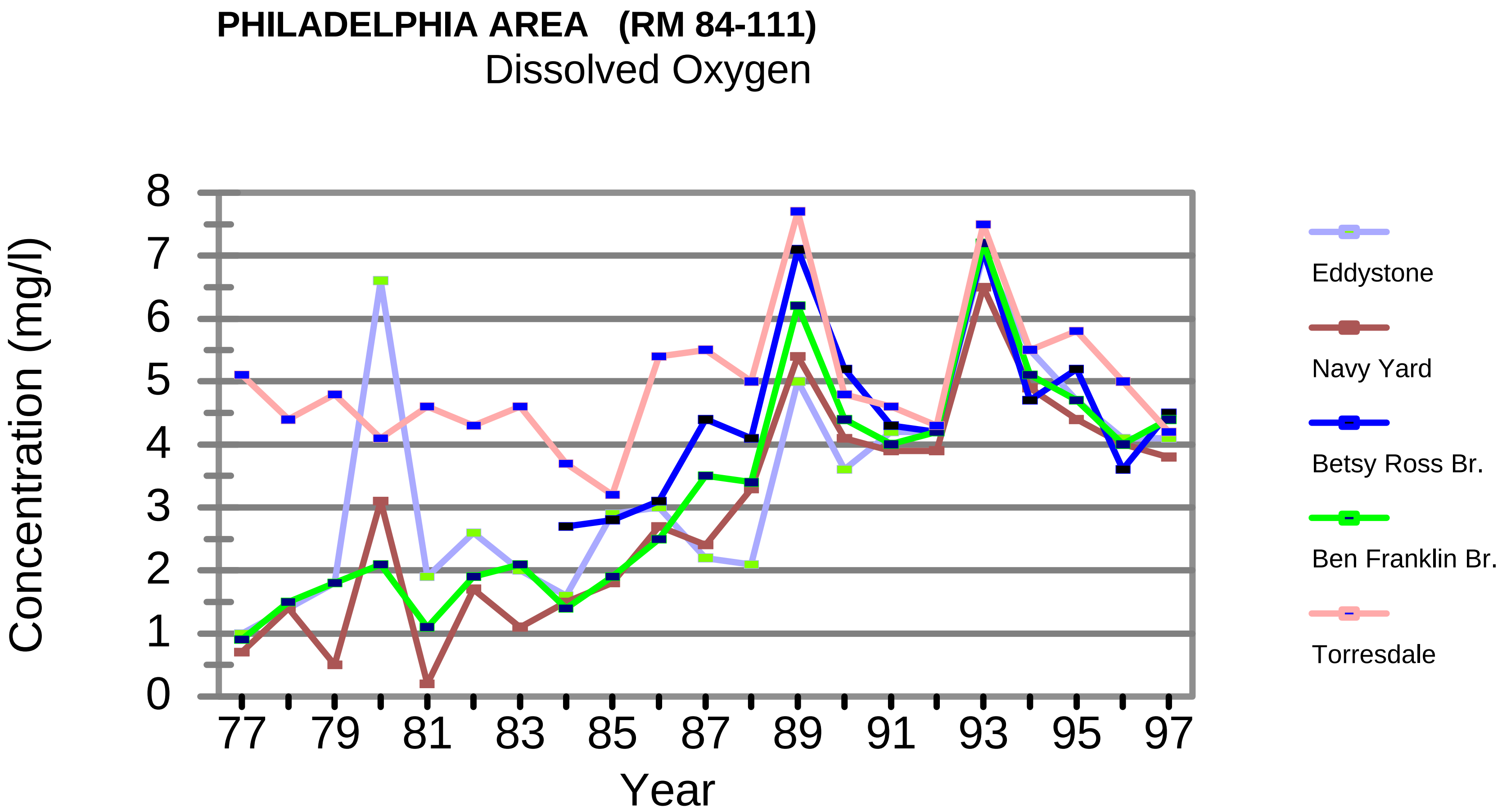


FIGURE 3-3 DISSOLVED OXYGEN MINIMUM VALUES FROM 5 BOAT RUN STATIONS IN THE PHILADELPHIA / CAMDEN AREA OVER THE PERIOD 1977 to 1997.

FIGURE 3-4 NITRATE-NITROGEN TREND 1967-1997 FROM THE MARCUS HOOK STATION - MONTHLY AVERAGES FROM SAMPLING PERIOD MARCH - NOVEMBER. SQUARES ARE 4-YEAR RUNNING AVERAGES CENTERED AROUND JULY OF EACH YEAR, BASED UPON DRBC BOAT RUN DATA (SHARP et. al., 1997).

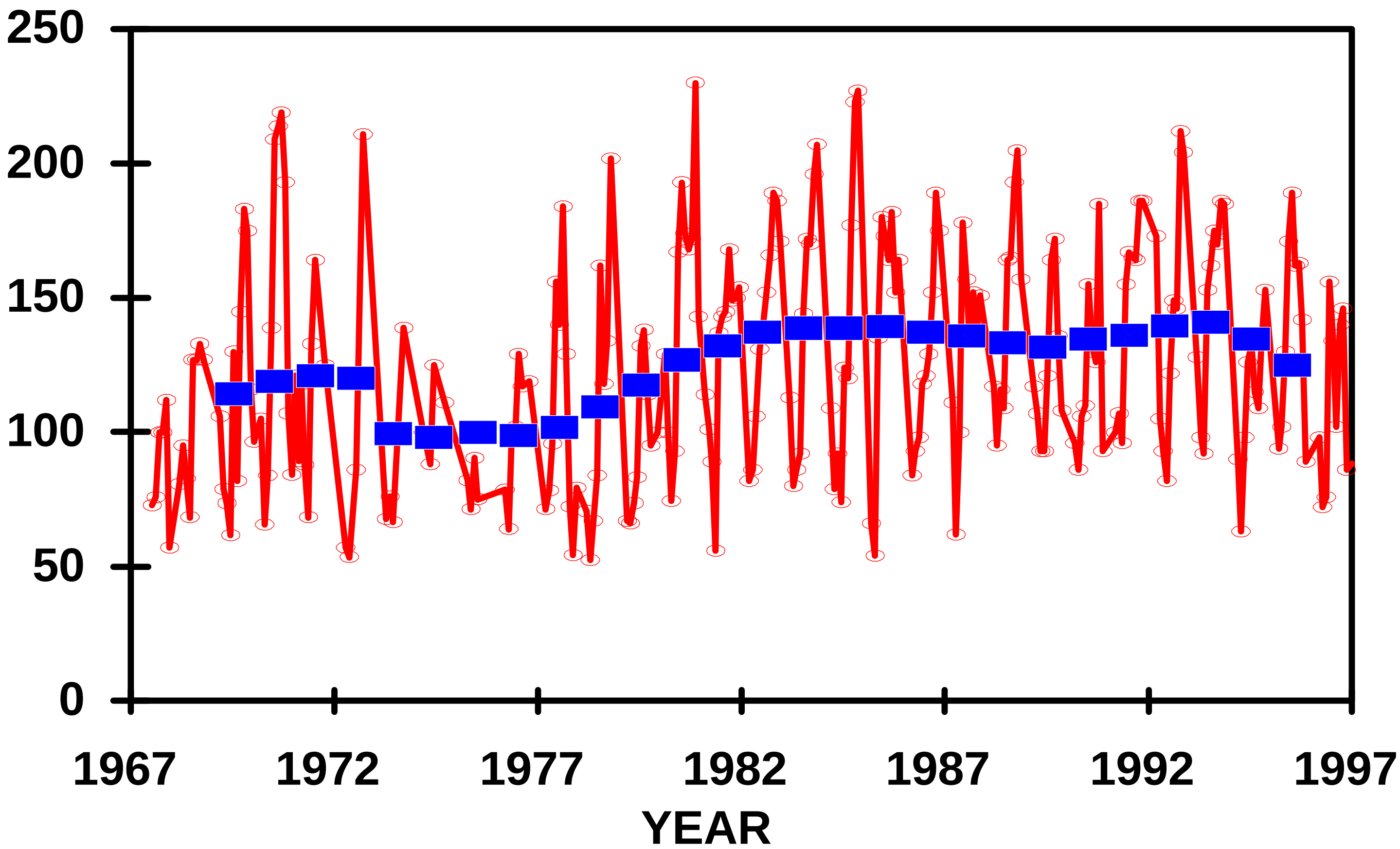


FIGURE 3-5 AMMONIUM-NITROGEN TREND – MARCUS HOOK STATION FROM THE PERIOD 1967-1997. MONTHLY AVERAGES FROM SAMPLING PERIOD MARCH - NOVEMBER. SQUARES ARE 4-YEAR RUNNING AVERAGES CENTERED AROUND JULY OF EACH YEAR BASED UPON DRBC BOAT RUN DATA, (SHARP, et. al., 1997)

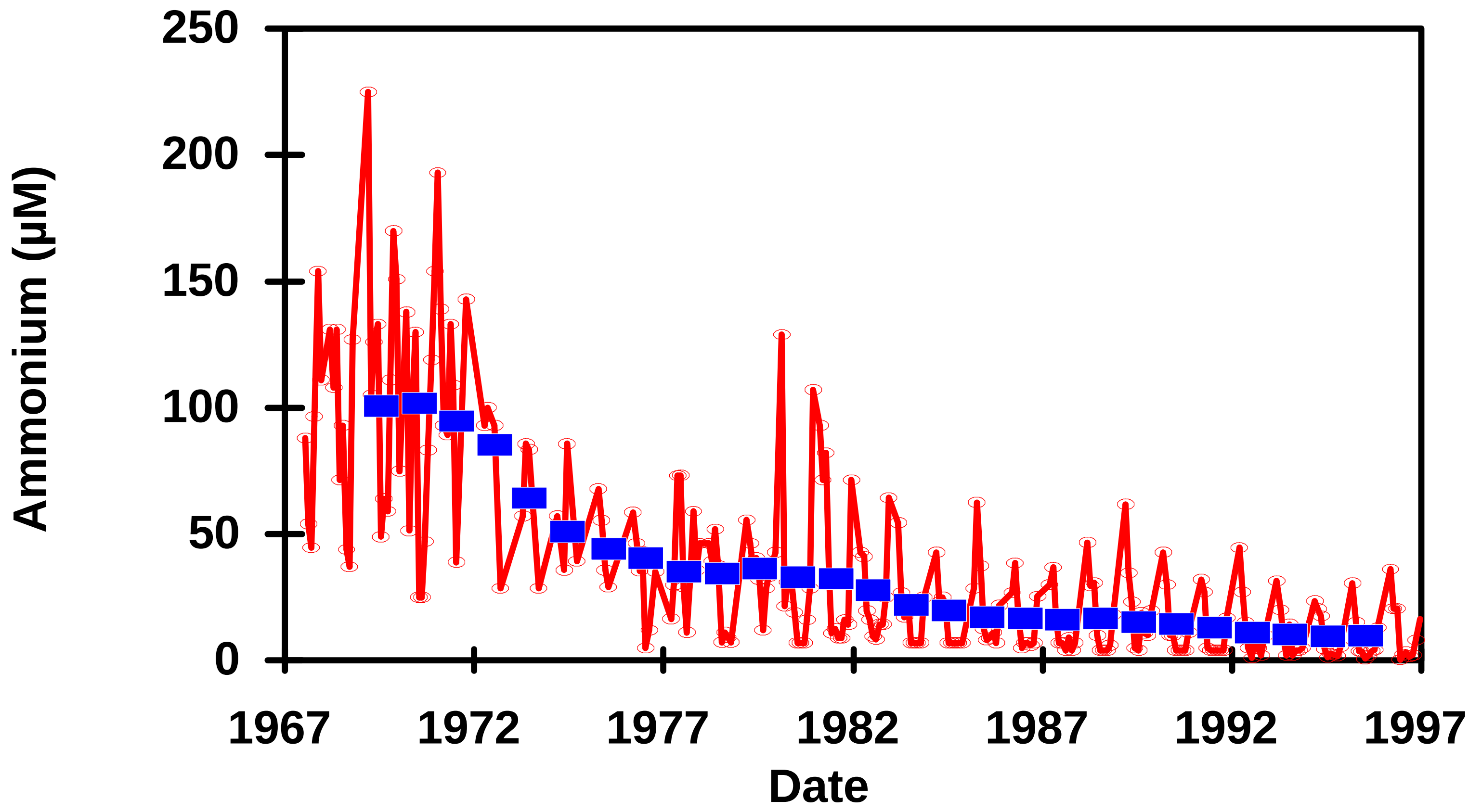
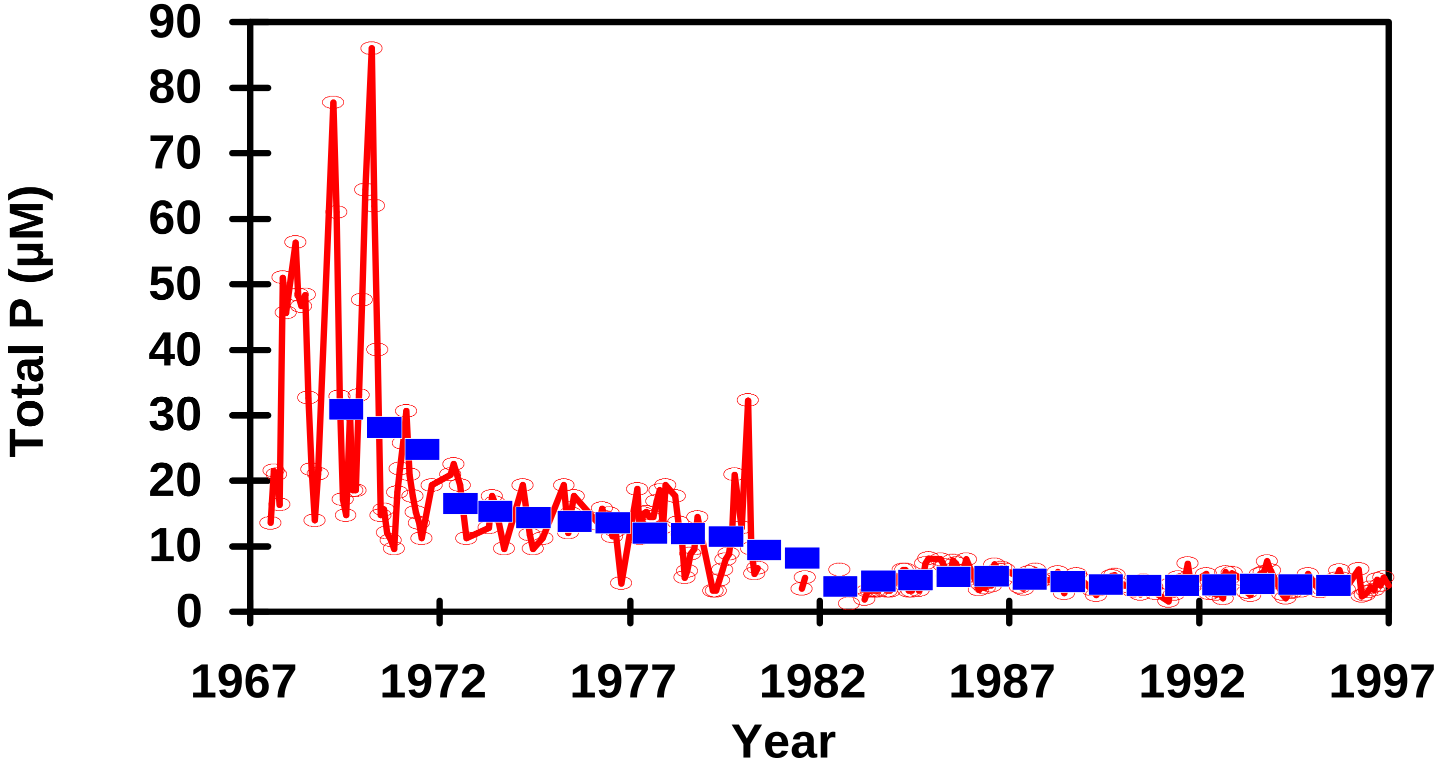


FIGURE 3-6 TOTAL PHOSPHOROUS TREND FROM THE MARCUS HOOK STATION MARCUS HOOK STATION FROM THE PERIOD 1967-1997. MONTHLY AVERAGES FROM SAMPLING PERIOD MARCH - NOVEMBER. SQUARES ARE 4-YEAR RUNNING AVERAGES CENTERED AROUND JULY OF EACH YEAR BASED UPON DRBC BOAT RUN DATA, (SHARP et. al., 1997)



3.1.2 Nutrient/Algal Productivity Relationship

Despite higher dissolved oxygen concentrations in the Delaware River today and some sporadic declines in nutrients, overall nutrient concentrations remain high. However, these high nutrient concentrations do not appear to pose a serious eutrophication problem (Sharp, 1994). Figure 3-7 shows nitrate and ammonium nitrogen concentrations along the length of the Estuary. There are considerable seasonal patterns of the nitrogen species with seasonally varying rates of nitrification (Cifuentes et. al., 1988; 1989), nitrogen transport to the lower Estuary (Cifuentes et. al., 1990), and of phytoplankton use of nitrogen (Pennock, 1987). The values in Figure 3-7 are annual averages and they indicate a major input of nitrogen in the urban region of the Estuary from sewage effluents. Also, a large phosphorus input isin the same location (Sharp, 1994;1997).

In spite of the upper Estuary high nutrient concentrations, the major algal primary production occurs in the lower Estuary distant from the urban inputs and high nutrient concentrations. Figure 3-8 shows the primary algal production measured as mmol carbon/m^2/day for four seasons along the length of the estuary. Samples are not routinely collected for algal speciation. Superimposed on this figure is the suspended sediment concentration (Setson). There is very low primary production in the tidal river region except in the uppermost portion (upstream of 170 km (105.6 mi)) in the summer. A spring bloom of moderately high production with very high chlorophyll occurs in the lower Estuary followed by high production with low chlorophyll in the summer (Pennock and Sharp, 1986; 1994). The nutrient maximum region of the Estuary is about 80 - 150 km (49.7 - 93.2 mi.). The primary production in this region is not high. Low light levels caused by the turbidity maximum limits primary productivity in the 80 - 100 km (49.7 mi. - 62.14 mi.) zone. The 120 - 150 km (74.5 mi. - 93.2 mi.) region has sufficient light and high nutrients; the low primary production here is somewhat puzzling and possibly due to cumulative effect of toxic substances and wastewater treatment plant disinfection and chlorination (Sharp, 1994; Sanders and Riedel, 1992). The overall effect is that of extremely high nutrient inputs in the urban region with little stimulation of algal production, followed by dilution of the nutrients, that supports moderately high production only in the lower estuary. The lower estuary is well mixed throughout the summer and fall, so that the primary production appears to be fairly well consumed and does not contribute to signs of eutrophication (Sharp et. al., 1986; 1994; 1994). Based upon the above information, nutrient and oxygen levels appear to be stable despite very high nutrient levels. Chlorophyll-a concentration and productivity in a tidal river are not high despite high nutrients. Clearly, monitoring for nutrients, light, chlorophyll-a and productivity should continue as they are important indicators of the health and productivity of the estuary.

FIGURE 3-7 NITRATE (□) AND AMMONIUM NITROGEN (○) CONCENTRATIONS ALONG THE LENGTH OF THE ESTUARY BASED UPON MONTHLY WEIGHTED ANNUAL AVERAGE VALUES DURING 1987 - 1988 (FROM SHARP et. al., 1994).

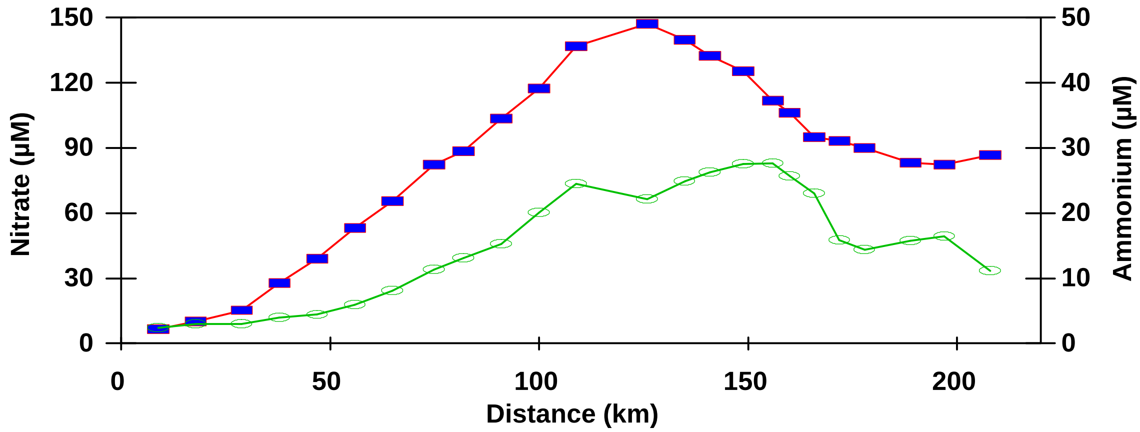
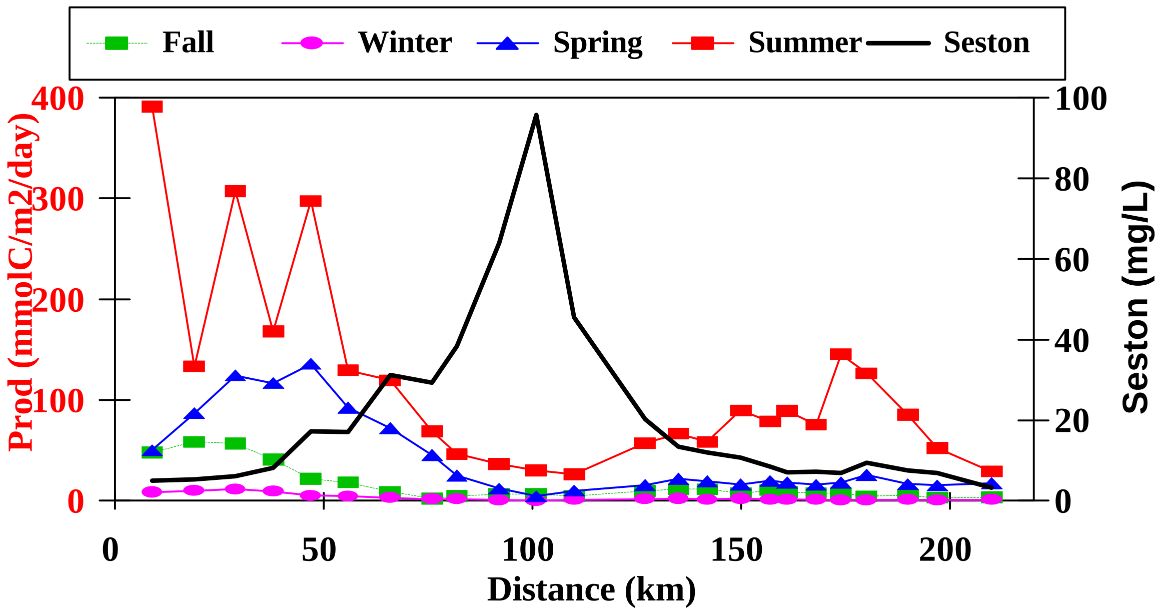


FIGURE 3-8 PRIMARY ALGAL PRODUCTION BY SEASON -DELAWARE ESTUARY (FROM SHARP et. al., 1994)



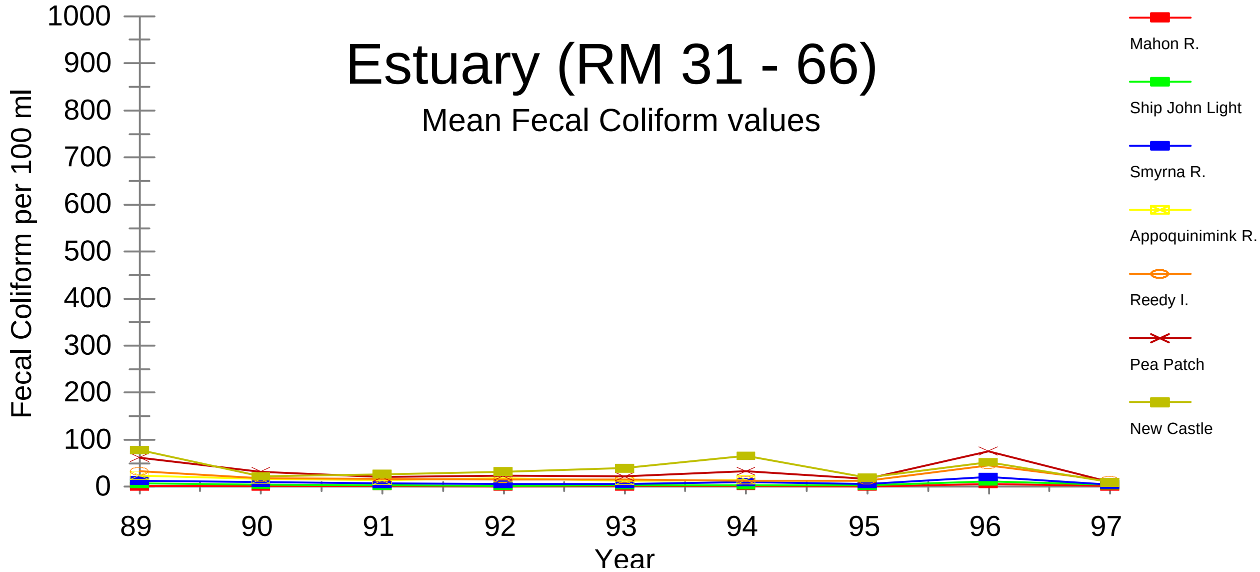
3.1.3 <u>Bacteria Levels</u>

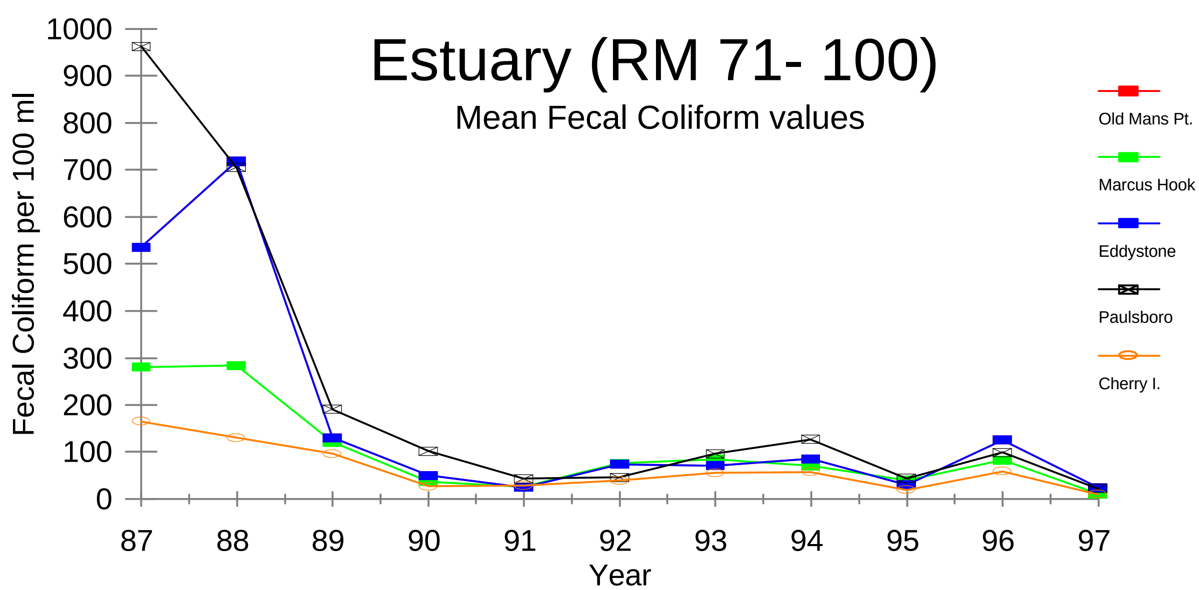
Bacteria samples collected during the DRBC Boat Run Program are presented in Figure 3-9. From 1989 to 1997 (excluding the months of December to February, inclusive), levels of fecal coliform drastically dropped at almost all stations. Most notably for River Miles 71-100 which revealed a drop from an average of approximately 1000 fecal coliforms/100 ml in 1989 at Paulsboro to less than 50 fecal coliforms/100 ml, at that same station, in 1997. It should be noted that no disinfection of sewage effluent was conducted from Trenton to the Delaware State line from fall 1987 to spring 1988, as part of a seasonal disinfection study conducted and approved by the DRBC (DRBC 1990). Full disinfection occurred prior to fall 1987 and after spring 1988. It is anticipated that the eventual merging of data sets from NJDEP, PADEP and other DNREC data to the Boat Run data set will further define fecal coliform trends. In the near future, merging of the fecal coliform Boat Run data sets prior to 1989, which utilized different methodology, will be merged with post- 1989 data for use by the Monitoring Implementation Team members.

Log mean fecal coliform values were calculated for Boat Run data for the period 1987 - 1997. The data are presented on Figures 3-10 a & b. Data for the period 1989 to 1997 show mean levels would be consistently below the Federal fecal coliform criteria of 200/100 ml for primary contact recreation and well below the DRBC fecal coliform standard, which is a maximum geometric average of 770 cells/100 ml for secondary contact recreation (Zone 3) and portions of Zone 4 above RM 81.8.

Levels of enterococcus bacteria were also evaluated for the DRBC Boat Run data for the period 1987 - 1997. In the areas of Zone 3 and Zone 4, the mean level of enterococcus was considerably below both the DRBC standard (for secondary contact recreation) of 88 cells per 100 mL (geometric average) and the Federal requirement of 33 cells/100 mL (geometric average) for primary contact recreation in saline waters (See Figure 3-11 a & b). The lower mean levels for both enterococcus and fecal coliform bacteria clearly suggest that the DRBC should adopt a standard which is commensurate with the attainment of primary contact goals in Zones 3 and 4. Clearly, we need to continue bacteriological monitoring to track these parameters.

FIGURE 3-9 FECAL COLIFORM DATA COLLECTED DURING THE BOAT RUN PROGRAM OVER THE 1989 - 1997 PERIOD





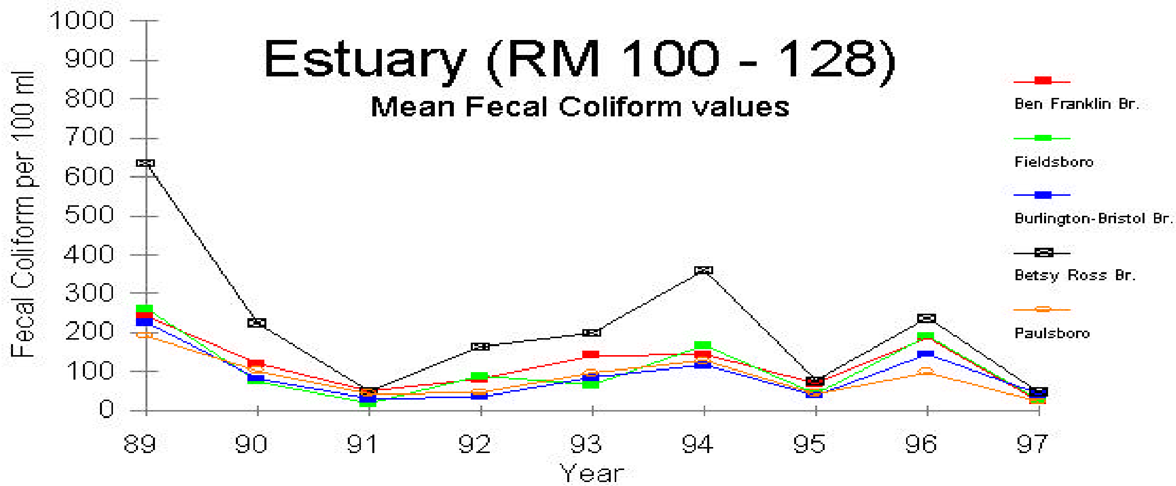


FIGURE 3-10a - FECAL COLIFORM - BOAT RUN 1987 - 1997 - ZONE 3

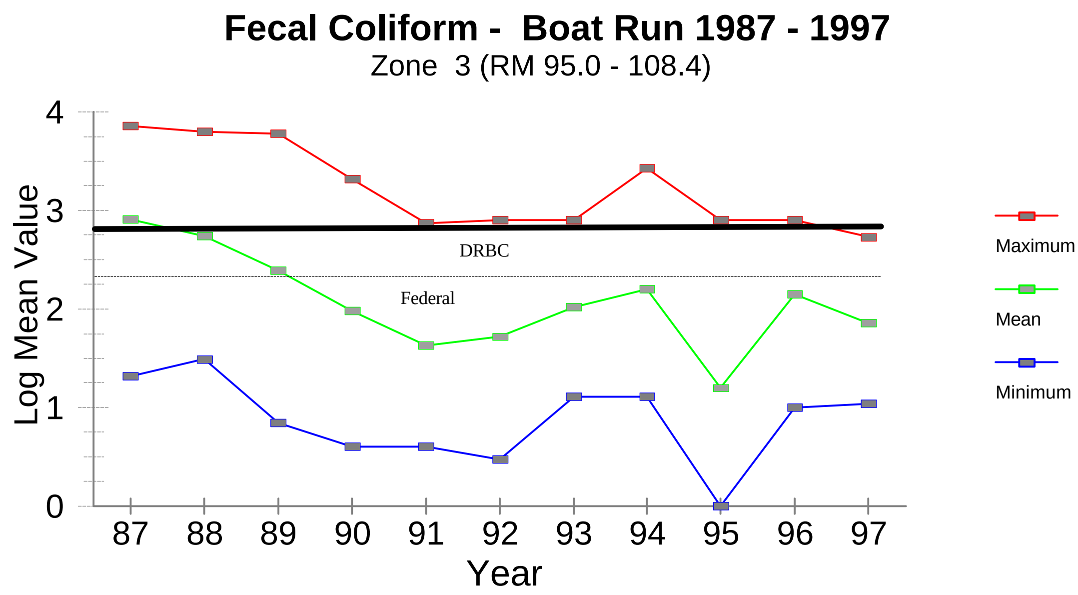


FIGURE 3-10b - FECAL COLIFORM - BOAT RUN 1987 - 1997 - ZONE 4

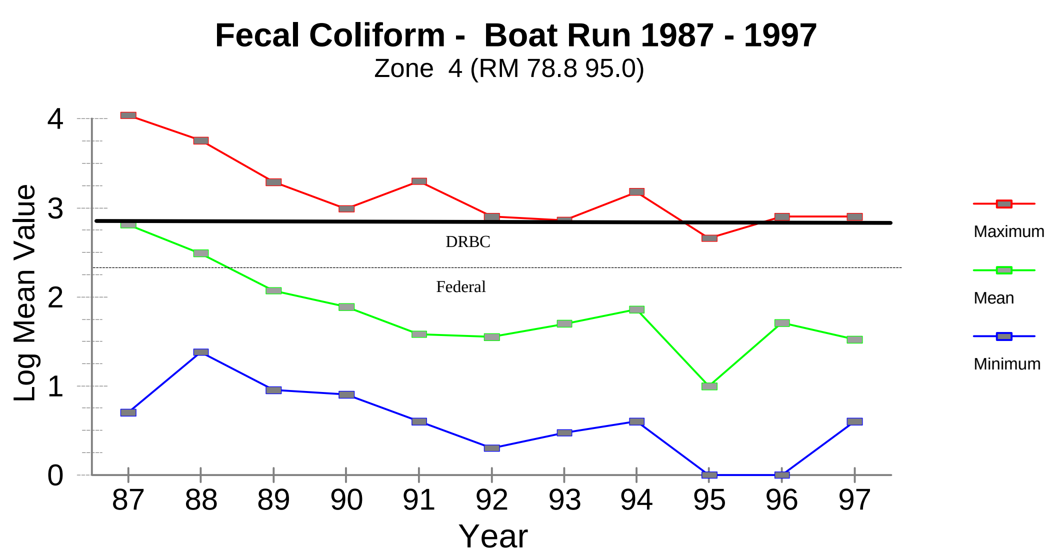


FIGURE 3-11a - ENTEROCOCCUS BACTERIA - BOAT RUN 1987 - 1997 - ZONE 3

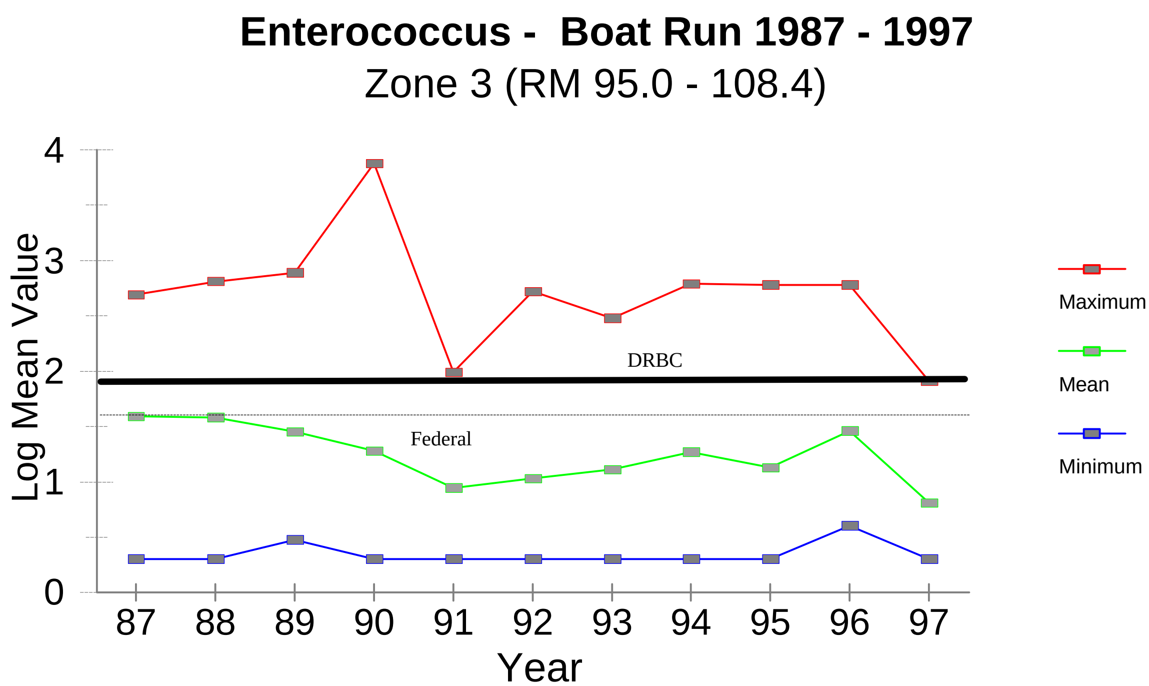
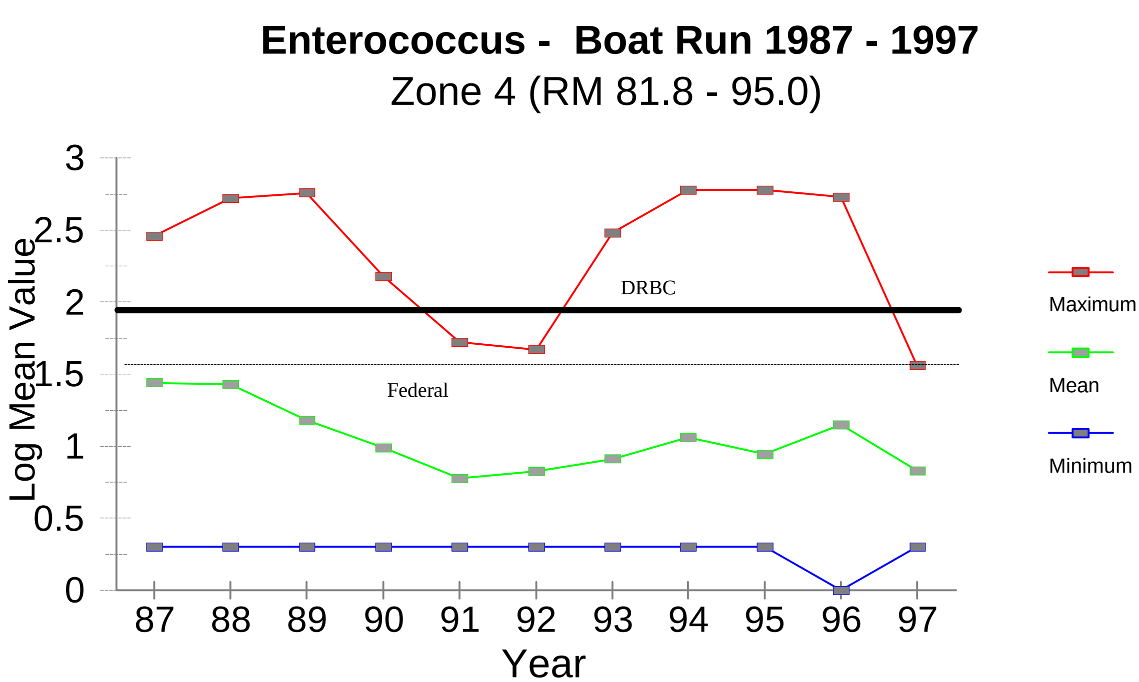


FIGURE 3-11b - ENTEROCOCCUS BACTERIA - BOAT RUN 1987 - 1997 - ZONE 4



3.2 Toxic Pollutants

Concerns about toxic pollutants in the Delaware Estuary rose in the mid-1980s as dissolved oxygen levels improved, fish populations rebounded, and regulatory efforts focused on controlling toxic pollutants. In 1989, fish consumption advisories were issued by New Jersey and Pennsylvania, based upon studies performed by the DRBC, and in 1996 additional advisories were issued in Delaware as well. The DRBC initiated the Estuary Toxics Management Program in 1989 to identify, address, and control toxic pollutants impacting the estuary. Several categories of pollutants affecting the Estuary are briefly discussed below:

3.2.1 Volatile Organic Compounds

Based upon a preliminary review of the Boat Run Data for volatile organic compounds in water for the period March 1997 through early June 1977, and compared to DRBC water quality criteria, all 32 parameters tested were found to be below the limits of detection (detection limit: 1 - 2 µg/l) at most sampling locations. One sample collected at the Burlington Bristol Bridge Station did contain 1.3 μg/l of 1,1,-Dichloroethene (sample collected on April 22, 1997).

3.2.2 Polynuclear Aromatic Hydrocarbons (PAH)

Arthur D. Little, Inc. (1994) performed an extensive study on sediments in the Estuary for the USEPA and DRBC. Potential PAH inputs were noted from several different petrogenic sources (e.g. oil refineries). Furthermore, a consistent background of pyrogenic, high-molecular-weight PAHs was found in sediments throughout the estuary.

PAHS concentrations, which correlated strongly with toxicity across the 16 stations surveyed, exceeded sediment effects levels at 10 stations, with the highest concentrations measured at stations between River Miles 80 - 115. PAHs were detected in many of the samples collected in the upper estuary. Compounds with the highest concentrations included benzopyrene, benzo(b)fluoranthene, fluoranthene, phenanthrene and pyrene. Total PAH concentrations were highest between the Tacony-Palmyra Bridge (RM 107.0) and at RM 92.9 near the mouth of the Schuylkill River.

Arthur D. Little, Inc. (1994) further suggested that a full complement of alkylated PAHs, in addition to those on the priority pollutant list should be collected and analyzed to document relative inputs of background non point sources of pyrogenic PAHs and localized point sources of petroleum.

3.2.3 Pesticide/PCBs

PCBs and chlorinated pesticides are classes of pollutants of concern, and several synoptic studies and ongoing monitoring programs have been conducted to document the spatial distribution and temporal patterns of selected pollutants (Arthur D. Little, Inc., 1994); (DRBC, 1994). PCBs, DDT and its metabolites (DDE and DDD) have not declined to acceptable risk levels in the tissues of white perch and catfish. A recent study of PCB concentrations in 10 tributaries and point source discharges conducted by the DRBC and Delaware DNREC found the highest concentrations in municipal discharges and in tributaries following wet weather events (DRBC 1998). These point source locations are presented on Figure 3-12.

Sediment sampling conducted by the U. S. Army Corps of Engineers in 1996 found elevated levels of PCBs in surface and subsurface sediments collected in the channel above New Castle, Delaware. These concentrations were significantly less than those observed in samples collected from shoal areas in 1993 (Arthur D. Little, Inc., 1994). Evidently, PCBs accumulate in shallow depositional areas when compared to samples collected in deeper navigational channels.

From the Arthur D. Little, Inc. (1994) study, PCBs were found to be far more widespread in sediments throughout the estuary than previously reported. PCB concentrations exceeded sediment effects levels (ER-L) at 13 of 16 stations sampled, with the highest concentrations measured at stations within River Miles 80 - 115. Concentrations of DDT and its DDE and DDD metabolites exceeded sediment effects levels (ER-L) at 15 of 16 stations, with the highest concentrations measured at stations within River Miles 80 - 115. Concentrations of dieldrin, another chlorinated pesticide, exceeded sediment effects levels at 44% of the stations sampled, with the highest concentrations measured at stations within River Miles 80 - 115.

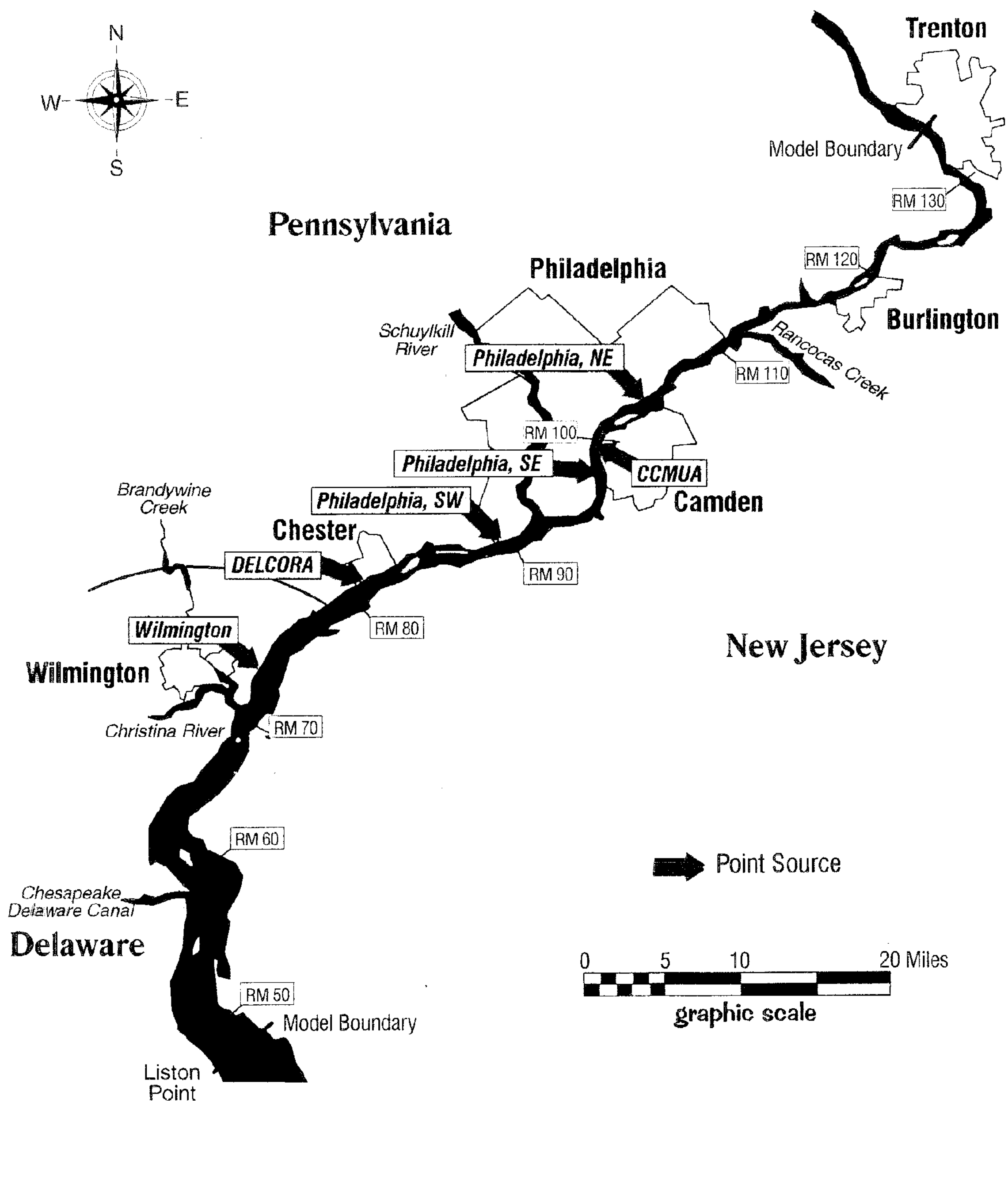
DRBC (1994) found DDT and its metabolites at elevated levels, dieldrin, and many of the PAHs in sediments collected from the tidal river. PCB Arochlors were not detected in any of the samples. However, the laboratory reported that individual PCB cogeners may have been present. The highest concentrations of most pollutants occurred in the upper portion of the estuary between river miles 93 and 107. The lowest concentrations were generally observed in the lower portion of the tidal river. No significant lateral differences in pollutant concentrations were detected at the sampling locations.

Sediment-bound PCBs, DDT-related pesticides, and to a lesser extent PAHs were found to be accumulated by benthic organisms. Through food-chain transfer, the bio-accumulation of these toxic contaminants may result in adverse impacts to organisms that bio-magnify these contaminants and may pose potential health risk to humans who consume fish from the Estuary. A. D. Little, Inc. (1994) suggested that all future chemical analyses should require cogener-specific quantification of PCBs to ensure quantification in the absence of identifiable Aroclor patterns.

3.2.4 Metals

Chromium, copper, lead, mercury, and zinc levels reported in the DRBC (1994) study all exceeded sediment effects levels at stations within River Miles 80 - 115. As reported by the DRBC (1994), the heavy metals with the highest concentrations included chromium, copper, lead and zinc. Data on loadings from point sources and the results of a study on the Raritan River basin suggested that copper,

FIGURE 3-12 - MAJOR POINT SOURCE SAMPLING LOCATIONS FOR PCBs IN A PORTION OF THE TIDAL DELAWARE RIVER (RM 60-133). (DRBC 1998)



lead, and zinc levels are predominately anthropogenic in origin, while chromium has significant natural sources (McLaughlin et. al., 1988). Metals were detected in all of the estuary sediment samples (Table 3-1). The results of one-way analysis of variance tests of these parameters indicated that significant differences existed between the sampling locations for cadmium, lead and zinc. The highest concentrations of these three metals occurred between river miles (RM) 97.5 and 107, with the lowest concentrations occurring at locations in the lower estuary. The results of non-parametric tests for those metals whose distributions were not normally distributed (arsenic, chromium, copper and nickel) indicated significant differences between sampling locations for copper only (DRBC 1994). The highest concentrations of copper also occurred between river miles (RM) 97.5 and 107.

Results of statistical analyses of metals data normalized to the percent fine-grained particles in the sample indicated that site-related differences existed for cadmium, copper, lead, silver and zinc were normally distributed (DRBC 1994). In general, normalized concentrations of all four metals were highest in the upper estuary between RM 101.0 (North of the Ben Franklin Bridge) and RM 125.0 (Roebling). Elevated concentrations were also observed at RM 88.5 (Paulsboro) for cadmium and zinc.

DRBC (1994) noted several possible sources for the observed concentrations of these metals: natural sources, point source discharges from industrial and municipal facilities located on the mainstem or tributaries, non-point sources such as storm water runoff, and atmospheric inputs. Several of these municipal point source sampling locations are presented in Figure 3-12 . Natural sources of these metals are unlikely to account for the observed distribution in the estuary. The highest concentrations are not located near the major freshwater inputs to the estuary, the Delaware and Schuylkill Rivers. Data on loadings of these metals from point sources indicate that these five metals also rank among the highest in terms of both inorganic and organic pollutants discharged to the estuary (See Table 3-2).

TABLE 3-1 CONCENTRATIONS OF INORGANIC CONTAMINANTS IN SEDIMENT SAMPLES COLLECTED FROM THE TIDAL DELAWARE RIVER, JULY 1991. (SOURCE DRBC 1994)

CONCENTRATION (mg/kg or PPM)						
SAMPLE ID	ARSENIC	BERYLLIUM	CADMIUM	CHROMIUM	COPPER	LEAD
12-NJ	1.19	1.50	0.50	48.0	36.6	36.1
12-PA	3.53	1.50	5.40	40.2	50.0	90.7
11-NJ	2.22	0.90	1.40	34.9	62.3	63.7
11-PA	2.65	1.00	0.50	17.6	43.1	39.2
10-NJ	1.17	0.90	0.50 U	18.2	36.0	159.0
10-PA	1.99	1.00	1.00	26.7	73.3	113.0
09-PA	2.03	1.00	2.50	26.7	94.1	113.0
08-NJ	1.56	0.90	0.50	73.6	36.8	86.3
08-PA	5.79	1.90	9.70	116.0	141.0	314.0
07-NJ	4.90	2.40	9.80	164.0	245.0	397.0
07-PA	4.46	1.30	3.10	60.3	83.0	117.0
06-NJ	1.76	1.00	1.00	18.0	39.8	63.1
06-PA	33.30	1.40	3.30	149.0	86.7	159.0
05-NJ	32.80	1.50	4.90	121.0	94.6	157.0
05-PA	4.07	1.00	1.00	22.5	17.6	22.0
04-NJ	4.07	1.00	1.00	36.8	17.1	35.3
04-PA	8.19	1.00	1.50	76.5	50.0	68.6
14-PA	4.43	0.90	0.90	51.4	63.2	68.4
15-NJ	7.04	1.40	1.40	91.3	72.8	103.0
03-NJ	7.79	1.40	1.00	71.2	32.7	61.5
03-DE	6.27	1.50	1.00	57.8	12.7	20.6
02-DE	7.20	1.50	1.00	67.6	33.3	55.4
01-NJ	3.08	1.00	0.5	28.4	13.5	24.5
01-DE	4.50	1.00	0.50 U	44.5	11.4	15.3

U - undetected at the value indicated.
J - Estimated value (less than laboratory quantitation limit).

TABLE 3-1 (cont.): CONCENTRATIONS OF INORGANIC CONTAMINANTS IN SEDIMENT SAMPLES COLLECTED FROM THE TIDAL DELAWARE RIVER, JULY 1991

	CONCENTRATION (mg/kg or PPM)					
SAMPLE ID	MERCURY	NICKEL	SELENIUM	SILVER	ZINC	ALUMINUM
12-NJ	0.200 U	41.1	0.05	0.50	470.0	3360
12-PA	0.200 U	30.4	0.44	1.50	515.0	10500
11-NJ	0.200 U	23.6	0.23	0.50	283.0	7480
11-PA	0.200 U	16.7	0.10	0.50	186.0	5280
10-NJ	0.200 U	14.5	0.09	0.50	88.8	3720
10-PA	0.200 U	18.4	0.14	1.00	228.0	5450
09-PA	0.200 U	25.2	0.20	1.50	287.0	7260
08-NJ	0.200 U	22.2	0.05	0.50	99.0	3610
08-PA	0.500	43.1	0.88	3.70	833.0	16700
07-NJ	0.300	50.5	1.18	3.40	882.0	16400
07-PA	0.200	30.8	0.40	2.20	368.0	11800
06-NJ	0.200 U	14.1	0.14	0.50	131.0	4240
06-PA	0.600	34.8	1.09	0.90	952.0	14600
05-NJ	0.500	38.2	1.32	2.00	895.0	16600
05-PA	0.200 U	14.7	0.10	0.50	118.0	4160
04-NJ	0.200 U	18.1	0.24	0.50	108.0	8740
04-PA	0.200 U	35.3	0.78	1.00	230.0	15800
14-PA	0.200 U	27.8	0.47	0.50	203.0	10700
15-NJ	0.200 U	37.9	0.44	1.00	282.0	14500
03-NJ	0.200 U	34.6	0.58	6.70	187.0	21200
03-DE	0.200 U	30.9	0.29	0.50	78.4	18900
02-DE	0.200	36.3	0.64	1.50	176.0	18600
01-NJ	0.200 U	16.8	0.24	0.50	101.0	8440
01-DE	0.200 U	25.2	0.30	0.50	59.4	17200

U - undetected at the value indicated.
J - Estimated value (less than laboratory quantitation limit).

TABLE 3-2 LOADING ESTIMATES FOR THE MAJOR POINT SOURCE DISCHARGERS TO THE DELAWARE RIVER (RM 60-130)

PARAMETER	# OF DISCHARGERS DETECTED	MAXIMUM TOTAL LOADING (KG/DAY)
Zinc	83	464.5
Chromium (total)	39	435.8
Copper	58	246.0
Nickel	46	229.5
Lead	53	72.4
Cadmium	25	26.7
Arsenic	16	14.1
Silver	22	12.0
Selenium	8	1.7
Mercury	24	0.6
Beryllium	3	0.02

DRBC 1994

The evaluation of metals data analyzed in water column samples from the DRBC Boat Run Program is difficult to discern due to changes in analytical methodology over the twenty (20) year period. These analytical changes have resulted in a two orders-of-magnitude decrease in the detection limit for many of the parameters studied.

A number of metallic elements, notably arsenic, lead, silver and zinc, were consistently below the limit of detection (most recently 5 μg/l). The levels found in sediments would then suggest that these elements are not in a dissolved form.

Mean values for copper collected from the Boat Run Program over the period 1977 - 1983 ranged from 108 to 161 μg/l. Duncan's multiple range tests for total manganese for the 1977 - 1992 period showed a decreasing trend. However, some of this change undoubtedly resulted from a change in analytical methodology over the period.

Clearly, problems with toxic pollutants continue to exist in the Estuary. The Toxics Subcommittee is continuing to address the loadings from these point sources and continued monitoring is anticipated to occur.

3.2.5 **TOXICITY**

Sediments

Acute sediment toxicity appears to be more widespread in the Delaware Estuary than previously documented, with the highest toxicity found in sediments along the Delaware River between Torresdale and Marcus Hook, which corresponds with the more urbanized and industrialized portion of the estuary. This acute toxicity in the Delaware Estuary appears to be associated with the presence of petrogenic PAHs, copper, and mercury, and to a lesser extent, zinc, DDT-related pesticides, and PCBs (A. D. Little, Inc. 1994). That report suggests that future toxicity testing in the estuary should consider sub-lethal responses in addition to mortality. Bio-assays should be supported by measurements of porewater salinity, and concentrations of unionized ammonia and hydrogen sulfide, which have been found to impart toxicity to sediments under conditions approaching anoxia.

DRBC (1994) compared concentrations of pollutants to biological effects ranges developed by the National Oceanographic and Atmospheric Administration (NOAA) and to proposed sediment quality criteria for three PAHs developed by the USEPA. Levels of cadmium, lead, zinc, phenanthrene, dibenzo(a,h)anthracene, dieldrin and total DDT exceeded the values that were acutely toxic to benthic organisms. Concentrations of the three PAHs did not exceed the respective proposed sediment quality criteria.

Clearly, based on the results of the above, the surficial sediments of the tidal Delaware River are significantly degraded with several metals, chlorinated pesticides, and polynuclear aromatic hydrocarbons. The data indicate that, for several parameters, there is substantial variability in the concentration of contaminants between sites at each sampling location. This variability may reduce the power of the statistical tests to detect differences between sampling locations. The area of the river where all three groups of contaminants occur in significantly higher concentrations lies between River Mile 92.9 (the mouth of the Schuylkill River) and River Mile 107.0 (the Tacony-Palmyra Bridge). Comparisons of the levels observed in this study to effects ranges developed by NOAA. (Long and Morgan, 1991) suggest that the levels of cadmium, dieldrin, lead, zinc and the DDT series exceed levels that are frequently acutely toxic to benthic organisms. However, one should recognize that chronic toxicity to benthic organisms may occur at levels lower than the effects ranges reported.

Water Column

A study was conducted in November 1990 (DRBC, 1991) to determine if the ambient waters of the Delaware River Estuary were toxic to freshwater and estuarine test species commonly used to assess and control the toxicity of wastewater discharges from point sources.

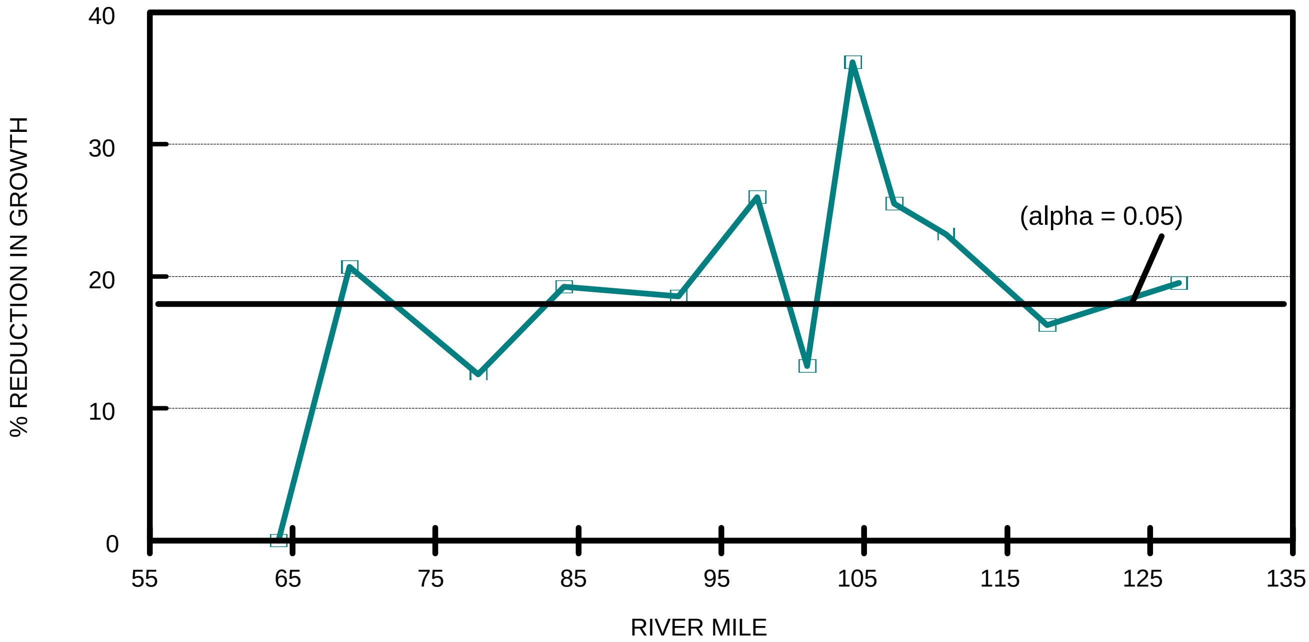
Ambient water samples were collected at 12 sites in the tidal Delaware River between Trenton, New Jersey (River Mile 133.3) and Artificial Island (River Mile 50). Sampling sites were selected to correspond with the stations sampled in the 1986 study and to evaluate the occurrence and magnitude of chronic toxicity in areas of the tidal river not previously studied.

All water samples were tested as recommended by the U. S. Environmental Protection Agency for assessing the chronic toxicity of effluents and receiving waters to freshwater and estuarine/marine fish and invertebrates.

The results of the DRBC (1991) study show growth of fathead minnows to be significantly reduced compared to the control at eight of the twelve sampling sites. The greatest reduction in growth was observed at River Mile 97.5 (South of the Betsy Ross Bridge). This study indicated an area of chronic toxicity to fathead minnows between River Miles 95 and 110 (North of the mouth of the Schuylkill River to Torresdale) as well as at the Delaware Memorial Bridge (River Mile 69.0), Eddystone (River Mile 84.0) and Fieldsboro (River Mile 127.0). Comparison testing using the Duncan's Multiple Range Test confirmed that fathead minnow growth was depressed in samples collected in the area between River Mile 95 and 110 (Figure 3-13).

The results of this study indicate that substantial portions of the estuary may be chronically toxic to aquatic life under specific hydrological and effluent conditions. Areas where chronic toxicity to aquatic organisms were identified are associated with high levels of whole effluent toxicity loading from industrial and municipal sources. Further study is planned to evaluate the frequency of occurrence of chronically toxic conditions, the hydrodynamic and tidal conditions which contribute to this occurrence, and the magnitude and variability of whole effluent toxicity from point sources near the areas identified in this study.

FIGURE 3-13 - PERCENT REDUCTION IN GROWTH OF FATHEAD MINNOWS (PIMEPHALES PROMELAS) EXPOSED TO AMBIENT WATER SAMPLES FROM 12 SITES IN THE TIDAL DELAWARE RIVER, NOVEMBER 1990.



3.3 Habitat

The Habitat and Living Resources Implementation Team (HLRIT) of the Delaware Estuary Program is focusing on natural habitat systems (upland, wetland, freshwater and marine) that support living resources of the estuary. The HLRIT is concerned that resource improvement resulting from estuary projects will not show improvement that can be measured by the monitoring currently being undertaken. The following are some of the items that need to be periodically evaluated by the HLRIT:

Collect information suitable to assess cumulative wetland losses and gains. Wetland reports should provide an estuary-wide summary as well as summaries by sub-basins that would reflect trends in habitat quality or quantity, focus areas, etc. within the Estuary.

Baseline wetland condition needs to be established. Possible methods to establish baseline conditions to track wetland losses or gains include:

- ♦ Utilize the Delaware Valley Regional Planning Commission's (DVRPC) Land Use Monitoring Project. This would provide a picture of wetland losses or gains. However, the cost of aerial photos and staff time to map wetlands and to field verify will be large. Aerial photo mapping often misses small and less visible wetlands.

- ♦ Compare National Wetland Inventory (NWI) maps with new aerial photos and re-map wetlands. Compare past and present acreage.

- ♦ Track wetland permits to determine losses. (For the most part, permits are already being tracked by the Corps of Engineers and States. Unpermitted activities resulting in wetland loss cannot be tracked.

- ♦ Use of satellite imagery to establish baseline conditions.

Total acreage of <u>Phragmites</u> in the Estuary need to be determined and mapped as a baseline for measuring percent reduction or change.

Baseline <u>Phragmities</u> coverage needs to be established. Potential methods to establish baseline conditions and track reduction include:

- ♦ Count number of acres successfully controlled each year and determine cumulative acreage. The comparison of the cumulatitive acreage controlled with baseline acreage would give a measure of success. This method would not take into account new invasion of <u>Phragmites</u>, and re-invasion of <u>Phragmites</u> into previously controlled areas.

- ♦ Periodic <u>Phragmites</u> mapping needs to be done to determine temporal changes in total acreage. Periodic monitoring of Phragmites would show actual progress on control in that, it would take into account new invasion of Phragmites, re-invasion of Phragmites into controlled areas, and successful control of Phragmites. Cost of aerial photos and staff time to map wetlands and field verify).

- ♦ Use of satellite data to track progress of percentage increase of important ecological habitat.

A project tracking system that reflects number of completed projects and the benefitted areas (acreage, lineal feet, etc.) would provide ample monitoring for progress in the Estuary for the above items should be considered for implementation by the HLRIT.

3.4 Land Use

The Delaware Estuary watershed incorporates parts of three states, 22 counties and 529 distinct local municipalities over an area of 6,755 square miles. Centered around the Philadelphia and Wilmington metropolitan area, the Estuary encompasses the fifth largest metropolitan region in the country, with a total population of over 6.5 million people. As the Delaware Estuary Program looks toward the implementation of the policies and recommendations of the comprehensive Conservation and Management Plan, the continuing regional trends of decentralization and suburban sprawl become important factors that will influence the Program’s objectives of resource protection.

The total population of the Estuary grew modestly between 1970 and 1990, but the land use changes and impacts during this period were dramatic. Over this twenty (20) year period, the Estuary’s total population increased by 177,206 people, including an 86,744 person increase in the Delaware portion, a 193,380 person increase in the New Jersey portion, a 258,999 person increase in the Pennsylvania suburbs, with a 361,917 person decrease in the City of Philadelphia. These changes have accelerated since 1990, with continuing increases in suburban and rural communities and a population loss within Philadelphia of 107,575 between 1990 and 1996 (Seymour 1997).

This regional reapportionment of population has a direct impact on the land use and land coverage within the Estuary. In the nine-county area, residential and non-residential developed area increased by over 270 square miles, or almost 175,000 acres between 1970 and 1990. This despite a net population increase during this period of only 60,000 people.

Future forecasts predicted by the DVRPC within their planning area suggest continued population loss in Philadelphia, Delaware and Schuylkill counties and significant growth in Bucks, Chester, Burlington, New Castle and Gloucester counties. The challenge for the Delaware Estuary Program is to find the means to influence the process of local land use decision-making and these regional patterns which consumes more land, reduces habitat, and increases impacts on water quality (Seymour, 1997).The Monitoring Implementation Team is to assist in defining these patterns. The coordination of the Year 2000 mapping effort including mapping coverage of the State of Delaware counties within the estuary, but outside of the DVRPC planning area is an important charge for the team.

3.5 Living Resources

A first meeting of the Living Resources Subcommittee of the Monitoring Implementation Team (MIT) was conducted in March, 1998. Initial issues discussed by the sub-committee included the following:

- Efforts to facilitate consistency between various living resources monitoring programs.
- Creation of a centralized data storage location to increase access by researchers and managers; and
- Ways to provide and/or assist data acquisition and compilation.

3.5.1 Fisheries

As reported in Weisberg, et. al., (1996) fisheries resources are returning to the Delaware Estuary. Sixty-three (63) species representing twenty-seven (27) scientific families were collected in the Estuary. More recent years had a greater number of species than prior years (See Figure 3-14).

Fisheries landings data have been assembled for the past century for the Delaware Estuary. Although it is extremely difficult to interpret population levels of the finfish and shellfish species from the landings data (Killam and Richkus, 1992), long-term trends in the landings give some indication of changes in species abundance. The severe oxygen sag in the upper estuary imposed an effective block to migration of anadromous fish species such that water quality has been attributed with the crash in the American shad fishery (McHugh, 1981). This crash may also be attributed to loss of habitat and over fishing as well. While over harvest may have also contributed to the decline in population of anadromous fish, the populations of many anadromous fish species in the Delaware Estuary was seriously jeopardized for the majority of this century because of poor water quality. Recent data from state agencies (McCloy et. al., 1997) indicate that the harvests of the late 1980s and early 1990s are the best of this century.

American Shad

Since 1975, the Delaware River adult American Shad population has fluctuated from a low of 106,202 in 1977 to a high of 882,600 in 1992. In 1996 hydro-acoustic methods estimated that 792,000 American Shad returned to the Delaware River to spawn (Table 3-3).

Monitoring programs for Delaware River juvenile American shad (Figure 3-15) have been conducted throughout the river from the vicinity of Artificial Island to Milford, PA, a distance of approximately 180 miles. All sampling programs document good recruitment of American Shad throughout the river. The latest Atlantic States Marine Fisheries Commission (ASMFC) stock assessment has not demonstrated a level of over fishing for American shad in the Delaware River.

FIGURE 3-14 - ESTIMATES, BASED ON THE JACKKNIFE PROCEDURE OF SMITH AND VANBELLE (1984), OF NUMBER OF SPECIES IN EACH RIVER REGION FROM 1980 TO 1993 (WEISBERG et. al., 1996)

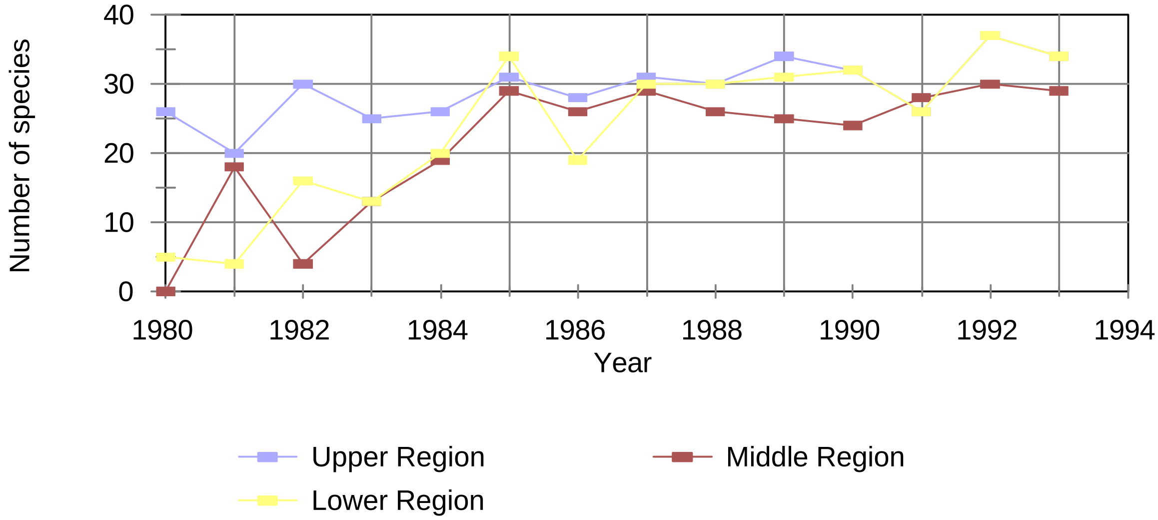


FIGURE 3-15 JUVENILE AMERICAN SHAD CATCH PER UNIT OF EFFORT (CPUE) IN THE DELAWARE RIVER (TRENTON-BYRAM/LUMBERVILLE) - SOURCE: MARK BORIEK, N.J. DIVISION OF FISH GAME AND WILDLIFE

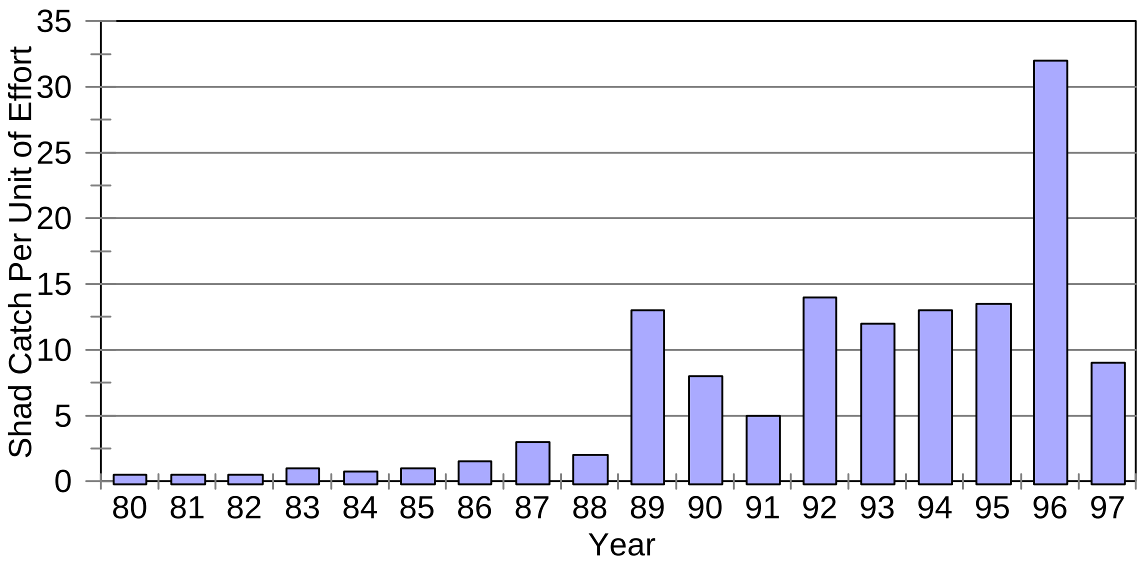


TABLE 3-3 DELAWARE RIVER ADULT AMERICAN SHAD POPULATION ESTIMATE FROM 1975 TO 1996. (SOURCE : N.J. DIVISION OF FISH AND WILDLIFE, MARK BORIEK AND RUSS ALLEN)

YEAR	PETERSEN METHOD	SCHAEFER METHOD	HYDRO ACOUSTICS
1975*	118,700 ± 93,773		
1976	178,760 ± 96,150	150,187	
1977 *	106,202 ± 65,058	88,415	
1978 *	233,060 ± 171,126		
1979 *	111,839 ± 32,191	101,249	
1980	181,880 ± 55,058	137,641	
1981	546,215 ± 133,590	551,599	
1982	509,201 ± 176,680	450,200	
1983	249,578 ± 87,342	212,248	
1984			
1985			
1986	595,407 ± 231,060		
1987			
1988			
1989	831,595 ± 235,608		
1990			
1991			180,00 to 450,000 **
1992	882,648 ± 197,250	542,865	535,000 ± 14,000
1993			
1995			510,000 ± 17,000
1996			792,000 ± 4,000

* Conducted by the Delaware River Basin Fish and Wildlife Cooperative
** Feasibility Study

Weakfish

Weakfish is one of the most economically important fishery resources in the Delaware Bay, utilizing the estuary for vital spawning and nursery habitat. Weakfish populations within the Delaware Bay are monitored by the State of Delaware. The 1996 annual weakfish density was the highest recorded for the entire time series that began in 1966. The 1996 catch-at-age (i.e., year class abundance in catch) data showed slightly improved age structure relative to the years 1991 - 1995, with more age three (3) fish represented in the catch. The slightly expanded age structure may be a result of management efforts to reduce fishing mortality and/or above average young-of-the-year recruitment.

Figure 3-16 shows the annual weakfish densities for adults and juveniles collected by otter trawl in Delaware Bay from 1966 to 1996 (Stewart Michels, DNREC, personal communication). Some of the fluctuations may be due to very different fishing pressure: From the 1950s to the present, this has been one of the primary recreational and commercial species sought in the Delaware Bay and may have benefitted from the decimation of the menhaden populations in the late 1950s (Killam and Richkus, 1992).

Striped Bass

The Delaware River population of striped bass has experienced a remarkable recovery within the last decade, largely attributable to an improvement in the water quality of the Delaware River and strict fishery management measures. Young-of-year recruitment surveys, using electro fishing an gillnetting methods, conducted by both New Jersey and Delaware show the resurgence in spawning success within the Delaware River. The striped bass spawning stock in the Delaware River is monitored by both Delaware and Pennsylvania during the spring migration. The age composition of spawning females sampled in 1996 was mostly seven (7) to nine (9) year old fish. A preponderance of 8+ year old female fish on the spawning grounds has been used as one of several criteria for restored stock status for striped bass in the Hudson River (Table 3-4, McCloy et. al., 1997).

Atlantic Sturgeon

A yearly tag and recapture program (using gill nets) in the lower Delaware River for Atlantic sturgeon has been conducted by the State of Delaware since 1991. The annual population estimate of sub adult Atlantic sturgeon utilizing a portion of the lower Delaware River has generally declined since 1991 from 5,600 individuals to a low of 862 individuals in 1995 (Table 3-5). Population estimates are unavailable for 1996 and 1997, since no tagged fish were recaptured. The 1996 estimates reduced the 1995 estimate by about half, while 1997 data suggests slight improvement (Craig Shirey, DE Division of Fish and Wildlife, personal communication)

Attempts to locate other areas within the lower river where Atlantic sturgeon congregate have been unsuccessful. Future monitoring of Atlantic sturgeon in the Delaware River should include some radiotelemetry studies to address in-river migration. The Living Resources Subcommittee will monitor these activities.

FIGURE 3-16 ANNUAL WEAKFISH DENSITIES IN DELAWARE BAY 1966 - 1996 (STEWART MICHELS, STATE OF DELAWARE, DNREC, PERSONAL COMMUNICATION)

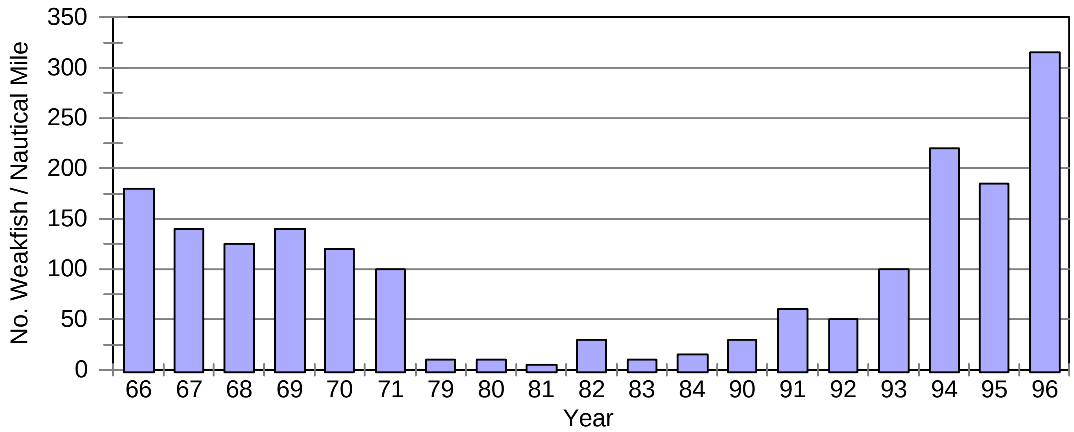


TABLE 3-4 CATCH PER UNIT OF EFFORT (CPUE) BY YEAR CLASS OF STRIPED BASS IN THE DELAWARE RIVER DURING 1996 (SOURCE: DE DIVISION OF FISH AND WILDLIFE, CRAIG A. SHIREY)

FEMALES

Year Class	Age	No. Taken	Percent	CPUE (N/Hr)
1993	3	1	1.6 %	0.06
1992	4	0	0.0	0.0
1991	5	0	0.0	0.0
1990	6	8	13.1%	0.45
1989	7	16	26.2	0.90
1988	8	14	23.0 %	0.79
1987	9	15	24.6 %	0.85
1986	10	2	3.3%	0.11
1985	11	1	1.6 %	0.06
1984	12	3	4.9 %	0.17
1983	13	1	1.6 %	0.06
Mean Age	8.03	61	Total	3.44

American Eel

The American Eel fishery has been an important component of the Delaware Bay fisheries for many years. In the past, eels were sold as bait for the blue crab trotline fishery and, to a lesser extent, for human consumption. Today there are essentially two fisheries for American (yellow) eels. The larger eels are used for food primarily in Europe. The smaller, pencil eels are used by recreational fishermen as bait for striped bass and cobia. This bait fishery goes mostly unreported and may be as valuable, or more so, than the food fishery.

Over the last 30 years, American Eel landings in New Jersey have ranged from 84,000 to 534,000 pounds. The New Jersey share of the Delaware Estuary's landings has been steadily increasing. In 1989, Cumberland and Salem counties accounted for 26% of the reported landings. By 1996, that figure had increased to 62% (Personal communication N.J. Department of Fish and Game).

The Glass Eel fishery harvests eels one and one-half to three inches long for export to Taiwan or China, where they are raised in ponds to marketable size and sold in Japan for food. This fishery has greatly expanded in recent years, requiring more stringent management measures to insure that the resource is not depleted.

Efforts are continuing to establish better recording of landing data for glass eels. Currently, there is a Legislative Bill in the New Jersey State Assembly which, if passed, would establish reporting requirements. The Living Resources Subcommittee of the Monitoring Implementation Team of the estuary program will monitor these activities.

TABLE 3-5 POPULATION ESTIMATE OF ATLANTIC STURGEON IN THE LOWER DELAWARE RIVER (SOURCE: CRAIG A. SHIREY, STATE OF DELAWARE DIVISION OF FISH AND WILDLIFE)

		CONFIDENCE INTERVALS	
YEAR	N	Upper C.I.	Lower C. I.
1991	5,600	8,536	3,852
1992	3,392	4,866	2,438
1993	4,154	10,385	1,854
1994	3,470	8,008	1,639
1995	862	2,350	395

Blue Claw Crab

The Blue Claw Crab fishery is the dominant commercially harvested species in Delaware Bay. Based upon New Jersey Division of Fish, Game and Wildlife survey data over the period 1991 - 1997, the catch-per-tow ranged from a low of 5 per tow in 1992-93 to a high of 20 per tow in 1995-96 (See Figure 3-17). However, recent data from the 1996 - 1997 period suggests a decline.

The legal crab pot fishery season begins March 1 and ends November 30 in Delaware and runs from April 16 to December 14 in New Jersey. The legal dredge crab fishery season begins December 15 and ends March 30 in Delaware and from November 15 - April 15 in New Jersey. Participants are eligible to use up to two dredges, and observe the same minimum crab size limit in Delaware.

In view of the importance of the Blue Claw Crab commercial fisheries, and the need for accurate and timely harvest data, DNREC designed and implemented two fisheries independent surveys to evaluate blue claw crab harvest and crabbing effort. These surveys produce estimates of harvest and effort, and both surveys fundamentally use the same sample design, methodology, and analytical protocol, with slightly different sampling stratification (Whitmore 1996). The consistency of data sets from Delaware DNREC and NJ Division of Fish and Game will be evaluated by the Living Resources Subcommittee.

Horseshoe Crabs

Recent concern has been expressed over the status of population of horseshoe crabs in the Delaware Estuary. Clearly, the horseshoe crab is a species synonymous with the Estuary. Less clearly, a number of data sets suggest a decline in population levels (Personal communication Dr. Stephen Grabowski USFWS). The Atlantic States Marine Fisheries Commission (ASMFC) is currently developing a fishery management plan (FMP) for horseshoe crabs. This FMP is being developed similarly with the Commission's American eel FMP and will provide recommendations to all Atlantic coastal states on managing the horseshoe crab resource on a regional basis. Until this FMP is completed, resource managers will continue to monitor the condition of the stock through annual biological trawl surveys and fisheries-dependent monitoring of commercial catch and effort. Observed population declines should be tempered with the need to obtain consistent data sets which minimize the variability of independent factors such as weather, tidal stage, temperature and moon stage. Sampling and resource management is further compounded by the lengthy life cycle of over ten years (Shuster 1955; 1979; 1982) and a maximum age of 17 - 18 years (Botton and Ropes, 1987). The crabs also show spatially patchy spawning activity in the Delaware Estuary (Botton et. al., 1988). A consistent data set for horseshoe crabs is viewed as a high priority by the Living Resources Subcommittee.

American Oyster

Another estuarine species that has been of interest in the Delaware Bay is the oyster. Figure 3-18 shows century-long oyster harvest records. The decline from very large harvests in the early part of this century to almost none today has largely been attributed to two diseases, MSX and Dermo (Haskin et. al., 1984).

For the past 150 years, the New Jersey Delaware Bay Oyster Fishery has been dependent on the success of transplanting oysters from the State controlled areas of the upper bay to leased sub-tidal areas in the lower bay. More recently, during the last forty (40) years, this mode of oyster culture has been rendered ineffective by the presence of these two diseases which are most common in the higher salinity areas of the Estuary. Beginning in 1995, the industry moved from a transplant program to a direct harvest strategy. The direct marketing program has been the focal point for the industry during the past two years (1996 and 1997) with very limited quantities of oysters being transplanted to the leased areas.

During 1996, the statutes governing the oyster fishery were modified to permit the harvest of oysters from the State controlled natural seed beds for designated periods throughout the year. Prior to these changes, harvest from these natural seed beds was restricted to selected periods during the Spring. The harvest season(s) for the direct market program are controlled by New Jersey's Department of Environmental Protection with consideration given to the recommendations presented by the Delaware Bay Section of the Shellfisheries Council (DBSC). The DBSC also provides recommendations as to the areas of harvest and per-vessel allocations.

During 1996, the natural beds were opened in both the Spring (April through June) and the Fall (September through October). Thirty-two dredge vessels participated in the fishery during 1996, harvesting an estimated 75,000 bushels. The total per vessel allocation was 2,500 bushels (1,000 in the Spring and 1,500 in the Fall). The dockside value for the harvest was approximately $1,600,000. The direct market harvest program was extended into 1997. The beds were again opened during April, May and June, with approximately 27,000 bushels being harvested during this period. It has been determined that the 1997 Fall harvest will run from the beginning of September to the end of November. The final per vessel allocation for the year has yet to be determined, is estimated at 3,000 to 3,500+ bushels. Through mid-October, 32 vessels have participated in the harvest, landing an estimated 30,000 bushels. It is anticipated that five to seven more vessels will enter the fishery before the end of the year. The vessel allocations are being granted on an incremental basis to provide the harvesters with an equal opportunity in the market. At the time of this writing, the Office of the Monitoring Coordinator did not have information on the Delaware allocations.

Destruction and alteration of habitat has a major impact on many estuarine species. The very fact that the extensive oyster reefs of the early part of this century are no longer viable, decreases the potential for success of oysters and may have a major impact on many other species. A significant portion of the lower Delaware Bay that was once hard substrate is today a highly scoured coarse grain sandy bottom. In addition to lack of hard bottom for other benthic species, the influence of the large oyster populations in removing particulate matter from the estuarine waters has a major impact on water quality.

FIGURE 3-17 RELATIVE ABUNDANCE INDICES FOR BLUE CRAB - DELAWARE BAY TRAWL SURVEY 1991 - 1997 (SOURCE: JEFFREY NORMANT, STATE OF NEW JERSEY DIVISION OF FISH, GAME AND WILDLIFE)

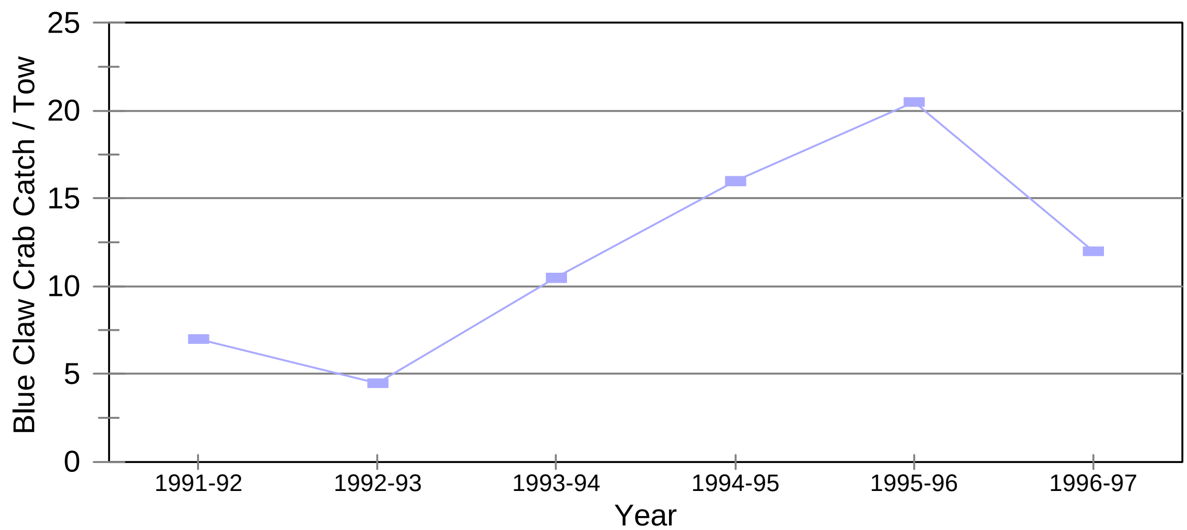
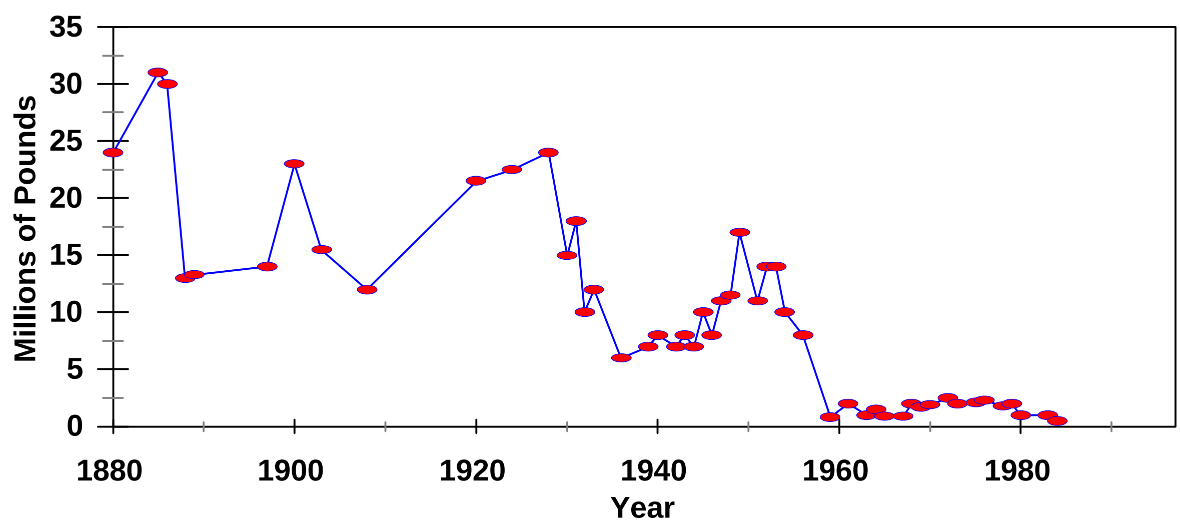


FIGURE 3-18 OYSTER HARVEST FROM THE DELAWARE Estuary (1880 - 1982) (SHARP, 1997)



4.0 ONGOING MONITORING PROGRAMS

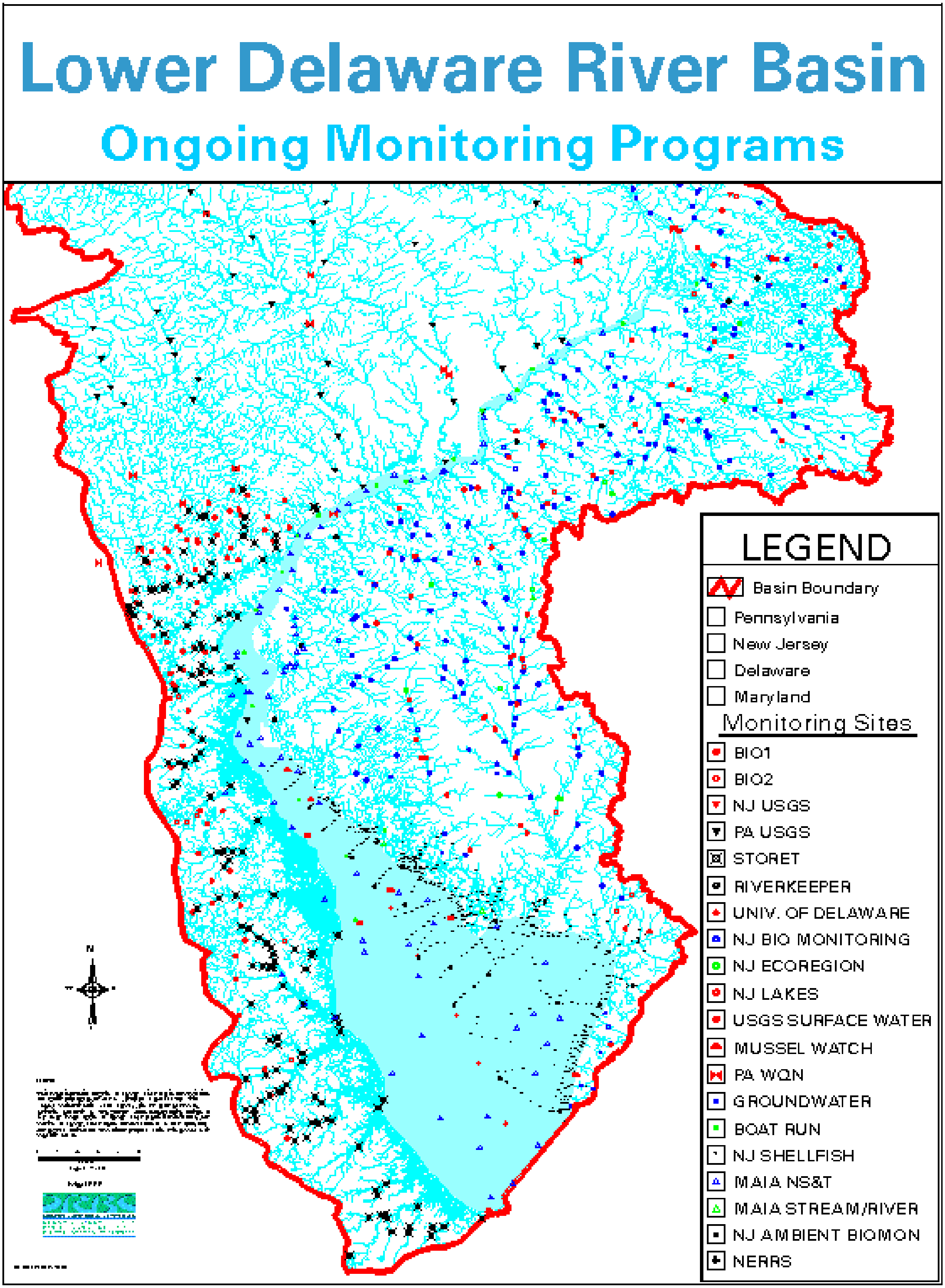
Within the mainstem of the Delaware Estuary, there are over 61 major surveys conducted by USEPA, USFWS, NOAA, USGS, NMFS, DRBC, DVRPC, NJDEP, PADEP, DNREC, and a myriad of county and non-profit groups such as the Delaware Nature Society, the New Jersey Natural Heritage Society, the Manomet Bird Observatory, Delaware Riverkeeper, Audobon Society as well as private sector interests. Many of these are summarized in the Monitoring Matrix presented in Appendix A and categorized in Table 4-1. The approximate locations of sampling stations in the Delaware Estuary for several of these major programs are presented on Figure 4-1.

The Monitoring Matrix developed by the Monitoring Coordinator provides information on ongoing monitoring programs in the Estuary in a consistent manner. This Matrix is further discussed in Section 5.3. Efforts are continuing to collect raw data from the listed programs to integrate the data sets to provide a regional picture of the Delaware Estuary's resources. One recent effort being conducted during the 1997 - 1998 period is the Mid-Atlantic Integrated Assessment (MAIA) Program being conducted by NOAA, USEPA, with local assistance from the DRBC and DNREC. This recent program is discussed below

TABLE 4-1 MAJOR MONITORING EFFORTS IN THE DELAWARE Estuary

Shellfish Surveys	**4**
Finfish Surveys	**20**
Avian Studies	**6**
Algal Surveys	**4**
Water Quality Studies	**14**
Contamination Studies	**5**
Biological Impairment Evaluations	**5**
Mapping Surveys	**3**

FIGURE 4-1 ONGOING MONITORING LOCATIONS IN THE LOWER DELAWARE RIVER BASIN



The MAIA Program

During September and October of 1997, NOAA's Coastal Monitoring and Bioeffects Assessment Division (CMBAD) conducted a study of sediment toxicity and chemistry, benthos, and water quality in Delaware Bay and adjacent waters to assess the status of ecosystem health. Actual field sampling began on September 2, 1997 at sites located outside the mouth of Delaware Bay.

The scientific party consisted of staff from CMBAD, NOAA's Damage Assessments Center (DAC), and Strategic Environmental Assessment Division (SEAD), the USEPA, DRBC and DNREC. The resultant data will be used;

- to calculate an index of the health of the benthic community,
- to evaluate the significance of contaminants to the spatial extent and magnitude of bioeffects, and,
- to assist in site selection of more intensive environmental studies in the future. As of the date of this writing fisheries collection efforts were planned for 1998 (funding permitting).

Samples were collected for sediment chemistry, toxicity and benthic organisms at 91 stations (80 within the Estuary) representing 22 strata. Sixty-two sites were sampled from the ocean survey vessel, FERREL and the remaining 29 sites were sampled using the State of Delaware's Sea Ark and Polar Craft. Conductivity, Temperature and Depth (CTD) profiles were taken using the ship's equipment and facilities at 43 sites. CTD profiles or surface and bottom dissolved oxygen measurements and a secchi disc depth were also obtained at each location. Some of these data were lost due to the inability to download the data until the end of the cruise. Continued deployment resulted in the CTD overwriting previously taken measurements. In addition, at 48 sites, surface and bottom YSI measurements were taken. Surface and bottom or mid-column water quality samples were taken at 46 sites.

Each water sample was filtered and frozen for later determination of dissolved silica, ammonia, nitrite, and nitrate, total dissolved nitrogen, dissolved orthophosphate, and total dissolved phosphorus, particulate organic nitrogen, total particulate phosphorus, particulate organic carbon, total suspended solids, chlorophyll a, and phaeophytin.

Benthic macroinvertebrate samples were obtained with Young-modified, Van Veen grabs of two different sizes. Each grab was sieved and organisms preserved in a mixture of 10% buffered formalin with rose bengal stain. Additional sediment samples were collected for amphipod, sea urchin fertilization/embryonic development, and Microtox® toxicity testing, as well as organic and metal contaminant analyses, P450 Reporter Gene System test, grain size (% silt/clay) and TOC analysis, and AVS (acid-volatile sulfides) analysis.

Sampling was completed on October 8, 1997. Analytical results are anticipated to be received in fall, 1998.

5.0 DATA CONSISTENCY EFFORTS

5.1 Mapping Efforts

The Mapping Subcommittee of the Monitoring Implementation Team of the Delaware Estuary Program has been formed Mr. Barry Seymour of the DVRPC is the Chairman of this subcommittee. The group was asked to review the variety of mapping and aerial photography programs now underway throughout the estuary and consider opportunities to share resources or combine information to create a consistent base for the region. Such a common base is important for the overall monitoring effort. The following provides a brief description of ongoing mapping efforts around the Estuary:

DVRPC

The Delaware Valley Regional Planning Commission (DVRPC) provided an overview and history of the aerial photography program at their headquarters. Since 1959, DVRPC has acquired aerial photography at USGS Quad Scale (1" = 2000') every five years for a nine-county region in Southeastern Pennsylvania and Southern New Jersey, provided photo atlas sheets at 1" = 400' and 1" = 800' scale to member governments and for sale to the general public. In 1995, that coverage was extended to include six additional counties in Southern New Jersey. The DVRPC jurisdiction does not currently include 3 State of Delaware Counties within the Estuary Watershed. The Mapping Subcommittee is addressing this issue to enhance coverage of the Year 2000 effort.

In preparation for the Year 2000 flights, DVRPC recently met with member governments to review their needs. Most counties desire that the DVRPC keep the 1" = 400' scale in order to provide an ongoing comparable historical record, but would prefer a scale of 1" = 200' as well to provide further detail. While photo atlas sheets that provide paper prints are still desirable for public sale and staff planning use, a digital product is also sought for use within GIS applications. Costs for such a program are now being investigated. DVRPC's aerial program for the region has been funded from the DVRPC Work Program. A more comprehensive program would require cost sharing. Coverage outside of the nine-county area is funded by the participating jurisdictions.

New Jersey

New Jersey has a variety of land use/cover and aerial data, beginning with 1986 aerial photographs and maps digitized to 1" = 2000'. They also have soils data, geological coverage, flood-prone areas, and freshwater wetlands at 1" = 1000'. This is all available on CD-ROM. In 1991, they acquired digital imagery through the National Aerial Photography (NAP) program, through a 50/50 cost share with USGS. These consisted of 1:40,000 color infrared photos that were scanned and prepared for use with ArcView. NAP flights were completed again for New Jersey between 1995 and 1997. These were digital orthogonal quarter quadrangle at 1:12,000 with one meter resolution. These are also being converted for digital use.

NJDEP is now preparing a land use file for 1996 (1995-1997) using a one acre minimum area, with impervious cover area for each land use category in 10 percent increments. Land use will be compared from 1986 to 1996.

Pennsylvania

The Commonwealth of Pennsylvania conducts annual aerial photography flights of the coastal zone along the Delaware River from Trenton to the Delaware state line. These flights produce color photos at 1” = 36,000’, which are used to spot wetland disturbance and are also used to update the National Wetland Inventory maps. The 1996-97 aerial photos are at a scale of 1” = 24,000’. Pennsylvania is now establishing a GIS system and will use these photos as part of the wetlands database. Pennsylvania has also acquired black and white, digital ortho quarter quads through the USGS NAP Program. Pennsylvania also utilizes MRLCC 30-meter satellite imagery converted into 15 land-use categories by Penn State University for PADEP’s Unassessed Waters Program.

Delaware

The State of Delaware has digital aerial photos for the entire state from 1992, at one meter resolution. This has been used to prepare land use/cover files in ArcView for limit areas of the state. The land use data is at a four acre minimum mapping unit. Aerials are also being acquired for 1997 and will be available on the DE state GIS system in 1998 and released on CD-ROM.

NOAA

NOAA has recently completed a comprehensive mapping of the Delaware Bay shorelines from the head of the tide at Trenton to the mouth of the Bay. These maps are intended to be used primarily to highlight key resource areas and provide sensitivity for oil spill responses and macro-level review. The mapping is based on 1984 data and does not compare changes over time. The data are compatible for use with ArcInfo and are available on CD-ROM. DVRPC has acquired a copy of these files.

USFWS

The U.S. Fish and Wildlife Service produces aerial and mapping products, and uses them for a variety of review and analysis functions. Their needs include consistent classification data available for the entire three-state estuary region at a scale that permits easy use. This would suggest aerial imagery rather than satellite photos. Appendix B presents a listing of the digital data catalogue available through USFWS.

DRBC

The Delaware River Basin Commission will utilize land use data produced from the Multi-Resolution Land Characterization Consortium (MRLCC), which produced 30-meter satellite imagery for the entire country. This was converted into 15 land use categories for USEPA Regions II and III, which includes New Jersey, Pennsylvania and Delaware. The USGS was the lead agency for this effort. Lacking full-time DRBC GIS staff, the New Castle County Water Resources Agency (NCC WRA) was contracted to develop basic data layers and assist in training staff. Using GIS data available from the states, the NCC WRA has created basin wide coverages, at 1:24,000 scale of political boundaries, streams, watershed boundaries and roads for Delaware and Pennsylvania.

Among the GIS goals for the DRBC are the expansion of the Ground Water Protected Area data layers beyond those available for the Neshaminy Grant Project and base maps for the Delaware Estuary. Working closely with the Monitoring Coordinator to begin obtaining sampling location data files, a draft copy of sampling points in the Estuary was prepared for this report (Figure 4-1). The DRBC is also expanding the monitoring site map to include habitat areas and other pertinent information and cooperating with the National Park Service in the use of the Special Protection Waters watershed model developed by North Carolina State University.

5.2 Coordination Efforts

As a commitment to the objectives and action items identified in the CCMP, the Monitoring Subcommittee is in the process of enhancing the consistency of various programs. Initially this included the conduct of a workshop regarding the measurement of Primary Productivity measurement. This Workshop was held on March 6, 1998 at the University of Delaware's Lewes Campus. Further work on intercalibration efforts is being pursued by the Monitoring Coordinator.

Other activities currently under consideration include side-by-side comparison of the "catchability" of fisheries collection gear used by NJDEP, PADEP, DNREC and Public Service Electric and Gas Company in the Estuary. The ultimate objective of this effort is to identify the selectivity of the various gear types utilized to allow the combination and comparison the various data sets for the entire Estuary. Coordination of the Year 2000 aerial photographic imagery is being taken up by the Mapping Subcommittee.

5.3 Monitoring Matrix Development

To continue efforts to develop consistency and avoid redundancy in the numerous monitoring programs occurring in the estuary, a Monitoring Matrix is undergoing development. This matrix summarizes the current monitoring programs in a sortable database using Microsoft Excel software for Windows 95. This summary, prepared for ongoing studies dealing with the mainstem Delaware River and Bay, is presented in Appendix A. This Matrix has been placed into the Regional Information Management Service (RIMS) program for public use. The Matrix will be periodically updated to include new program information. An update of the Matrix will include additional data fields, including data accessibility, time frames and the ultimate disposition of monitoring data is anticipated in the near future.

A representative example of a basic data sort is presented in Table 5-1, for major programs regarding biological and ecological studies.

Initially, this Monitoring Matrix will be able to be sorted by the following elements:

- River Mile
- Water Quality Zone
- Watershed
- Sub-watershed
- Parameters Collected
- Gear Type

The respective “hidden” codes are presented on Table 5-2, for analytical parameters.
Table 5-3 presents a listing of the “Hidden Fields” identifying collection gear type.

Once incorporated into RIMS, future developments will include methodology sorting files, and may incorporate data file retrieval ability as well.

FIGURE 5-1 ONGOING PROGRAMS SORT FOR BIOLOGICAL/ECOLOGICAL STUDIES

If you wish to receive a copy of this document, please contact the following person.

Edward D. Santoro
Delaware River Basin Commission
P.O. Box 7360
West Trenton, NJ 08628-0360

609-883-9500, extension 268

TABLE 5-2 LIST OF HIDDEN PARAMETER CODES IN THE MONITORING MATRIX

Category ID	Project Name
1	Conventional Parameters
2	Nutrients (Basic)
3	Metals
4	Pesticides
5	PCBs
6	PCB Cogeners
7	Base Neutral Organics
8	Acid Extractable Organics
9	Volatile Organics
10	Radiological
11	Fecal & Total Coliforms
12	Coprastanol
13	Flow
14	Micro Nutrients
15	Biological Collections
16	Tissue Analysis
17	Ecological/Habitat Surveys
18	Total Organic Carbon
19	Sediment
20	Abundance Estimates
21	Benthic Assemblages
22	Water Levels
23	Biological Oxygen Demand
24	Enterococcus
25	Census Activities
26	Tagging Study
27	Fisheries
28	Phytoplankton
29	Chlorophyll A
30	Ichthyoplankton
31	Young-of-the-year
32	Sediment Bioassay
33	Biological Impairment
34	Biomass Assessment
35	Submerged Aquatic Vegetation
36	Chlorides
37	DNA Study
38	Age/Growth
39	Morphometrics/Meristics

40	Visual Assessment
41	Detrital Production
42	Toxicity (LD50/LC50)
43	TSS
44	TDS
45	Phaeophytin
46	Turbidity
47	Toxicity (NOEL)
48	Stable Isotope Analyses
49	Microbial Uptake Studies
50	Benthic Chlorophyll
51	Cytochrome p 450 Assay
52	Chlorophyll B
53	Chemical Oxygen Demand

TABLE 5-3 LIST OF COLLECTION GEAR DESCRIPTIONS WITHIN "HIDDEN FIELDS" OF THE MONITORING MATRIX

Gear Type	Gear Description
1	Gill net 4" stretch mesh
2	Gill net 3" stretch mesh
3	Gill net 2" stretch mesh
4	16' Otter trawl
5	Haul seine 0.5" stretch mesh
6	Haul seine 1.0" stretch mesh
7	Haul seine 1.5" stretch mesh
8	Haul seine 2.0" stretch mesh
9	Longline 100 hooks per 100'
10	Longline 50 hooks per 100'
11	Longline 20 hooks per 100'
12	Sperber Stream Sampler

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APPENDIX A - Monitoring Matrix Summary

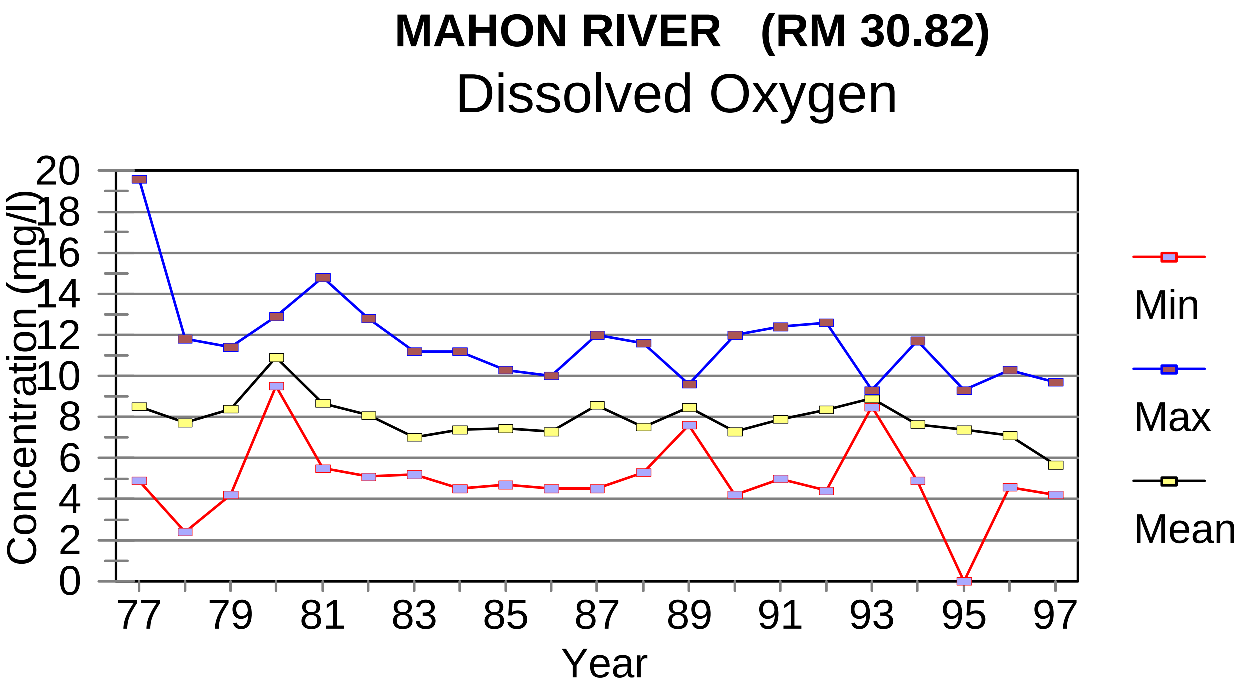
APPENDIX B - United States Fish and Wildlife Service Digital Data Catalogue

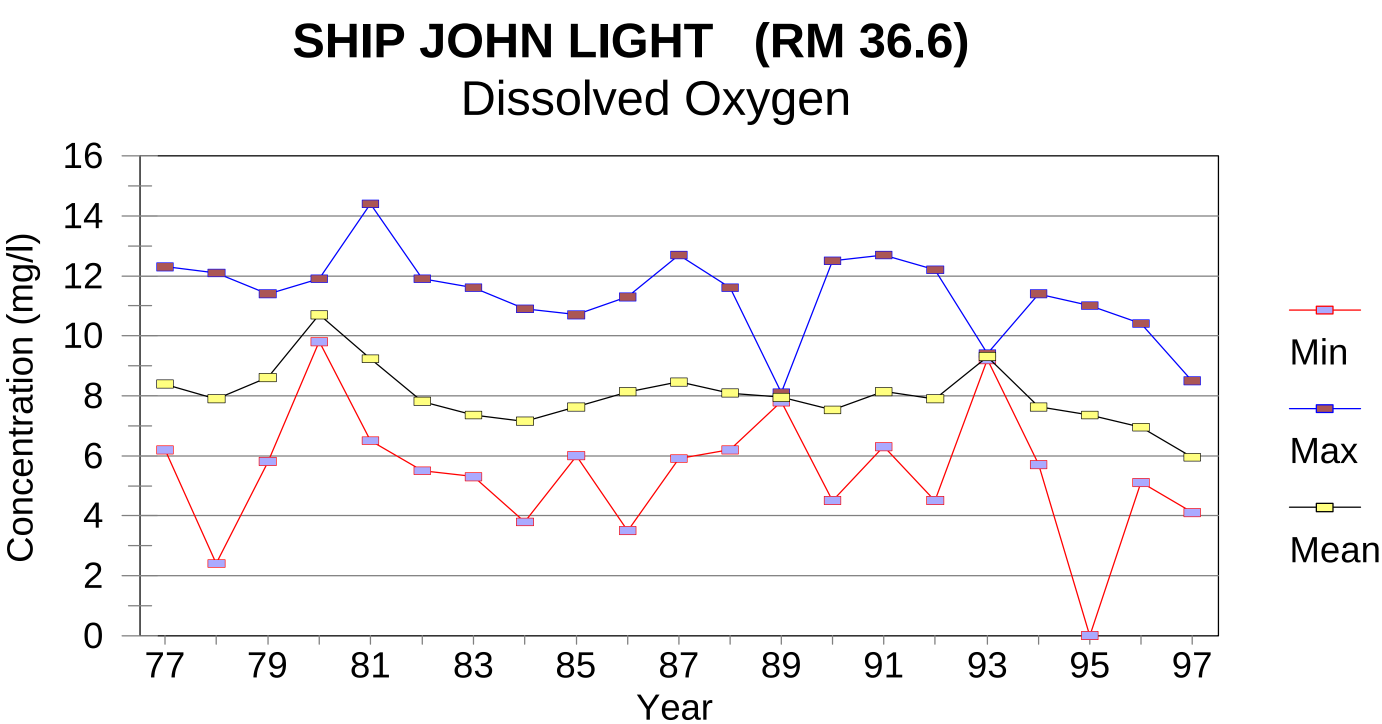
If you wish to receive copies of these documents, please contact the following person.

Edward D. Santoro
Delaware River Basin Commission
P.O. Box 7360
West Trenton, NJ 08628-0360

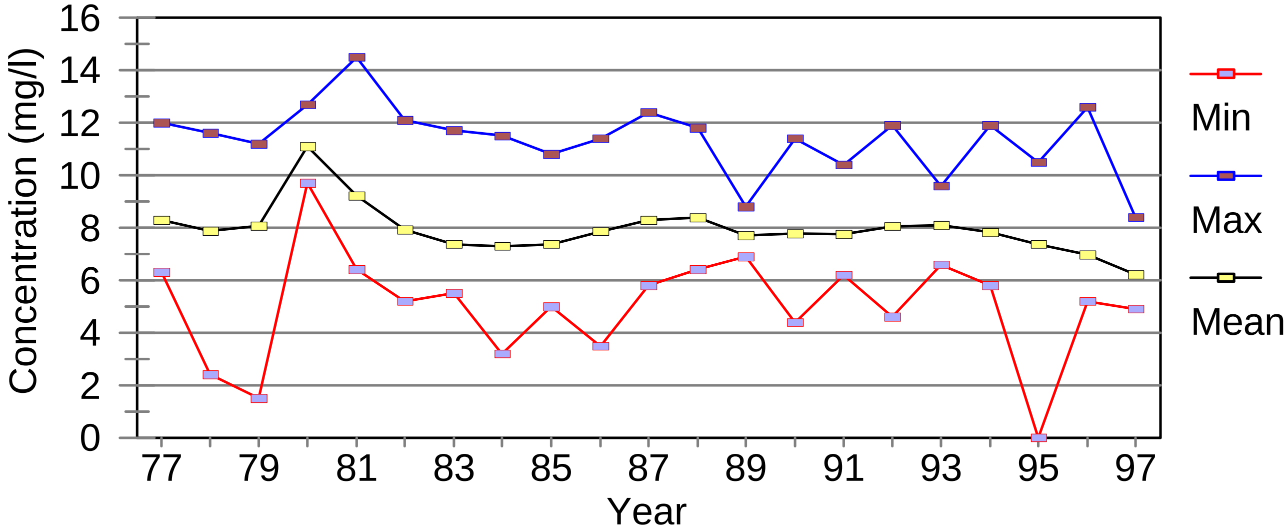
609-883-9500, extension 268

APPENDIX C

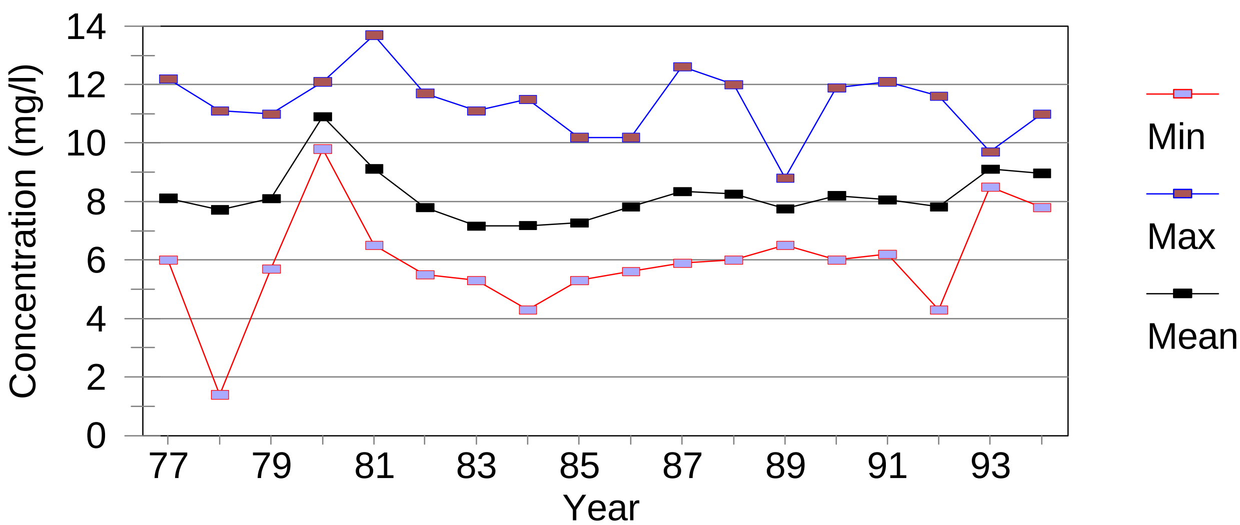

MAHON RIVER (RM 30.82)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
16
18
20
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean

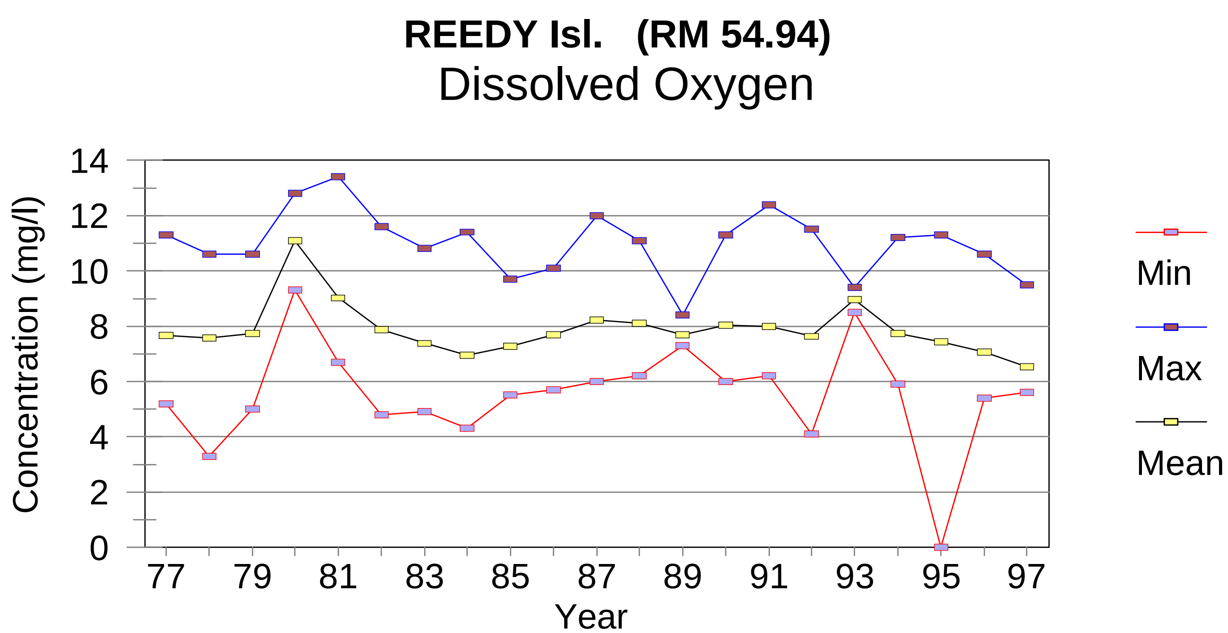

SHIP JOHN LIGHT (RM 36.6)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
16
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean

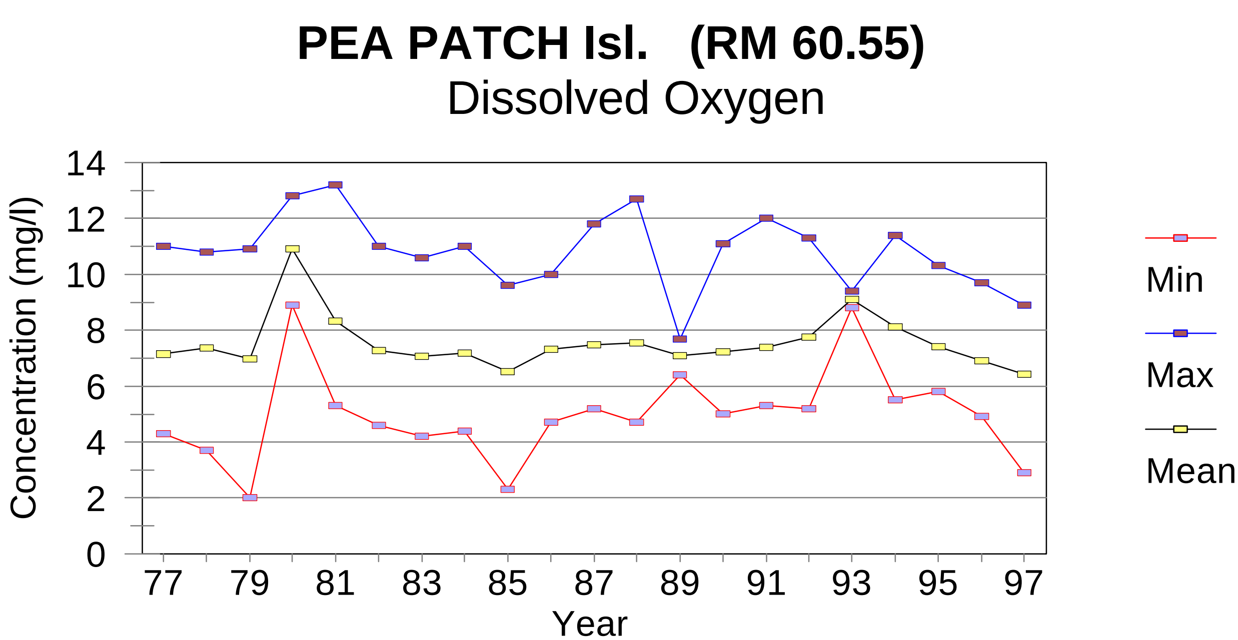
SMYRNA R. (RM 43.55)
Dissolved Oxygen

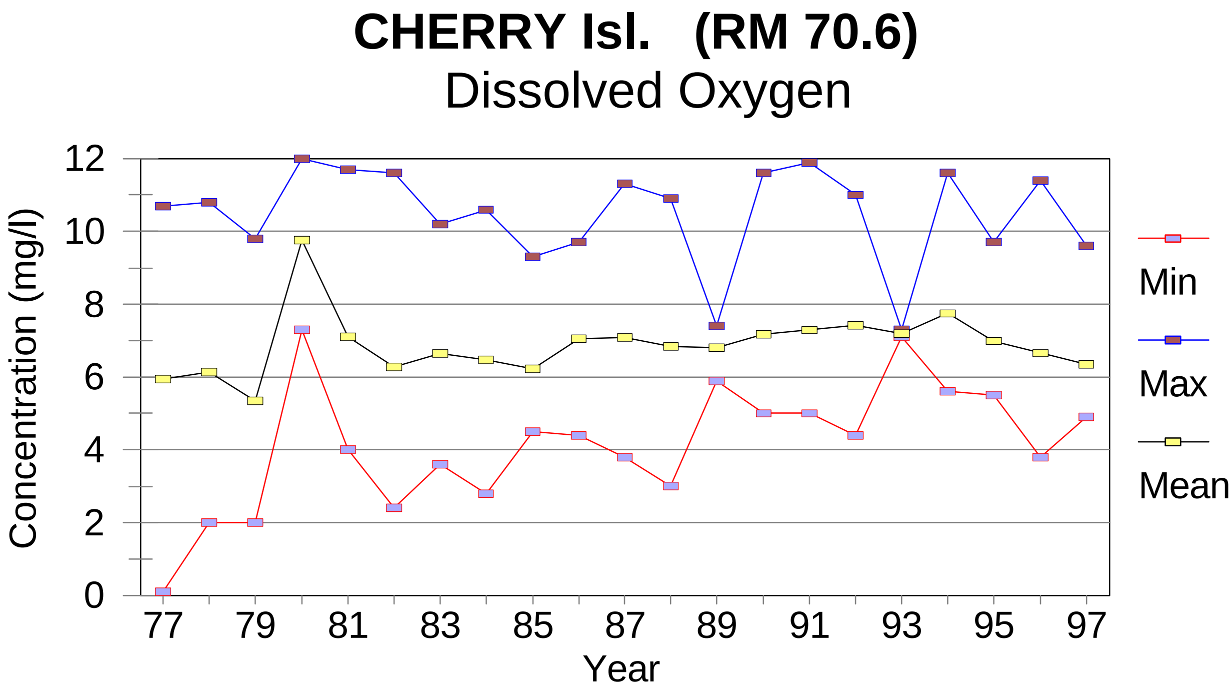


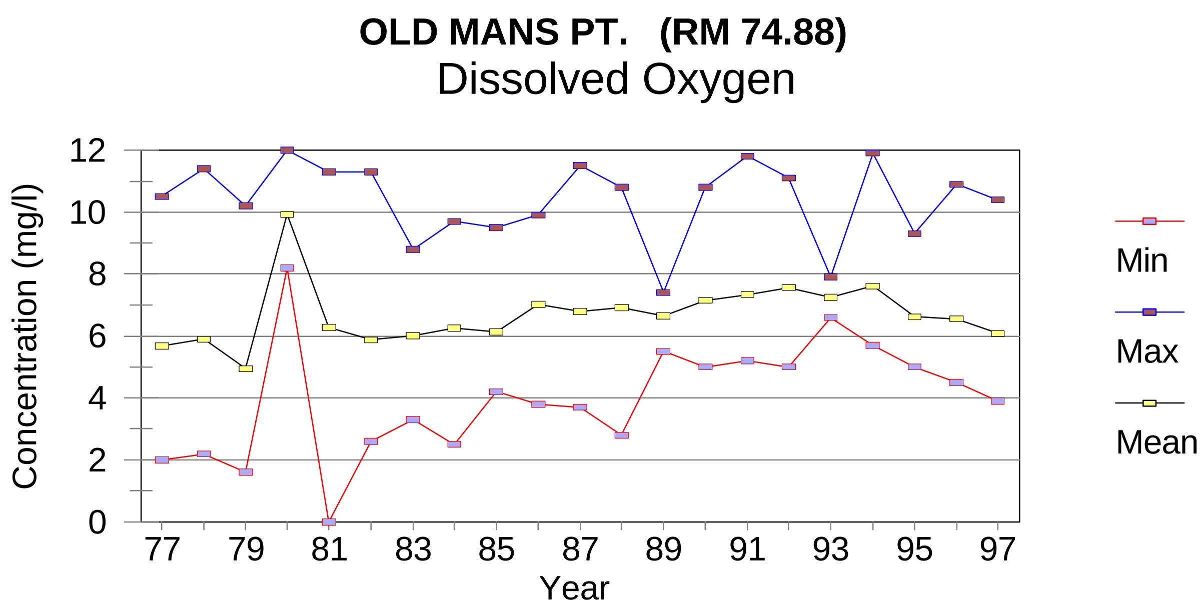
APPOQUINIMINK (RM 50.88)
Dissolved Oxygen

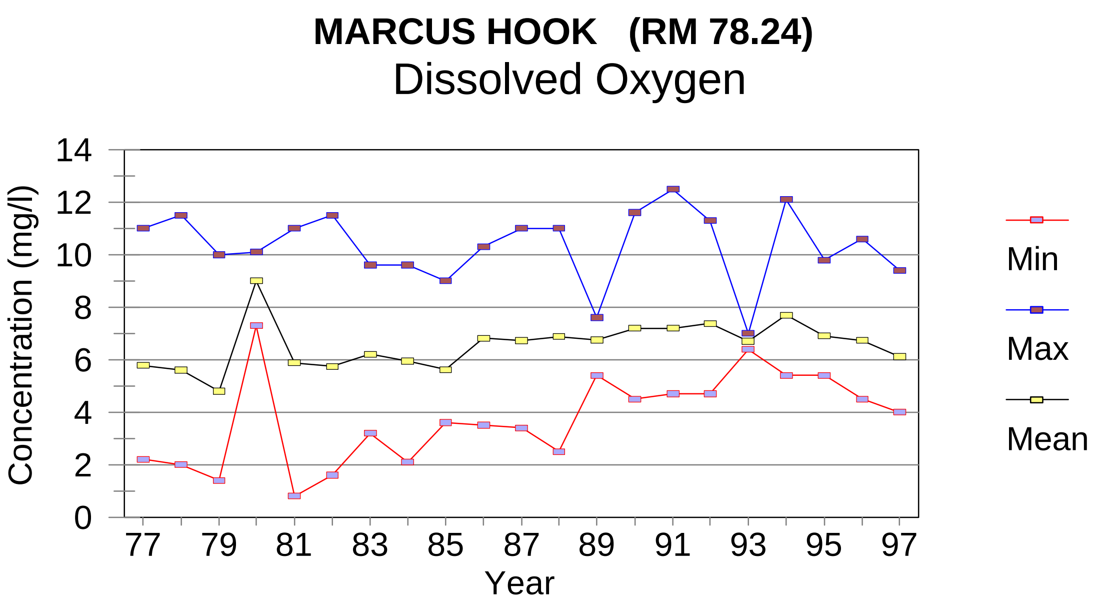


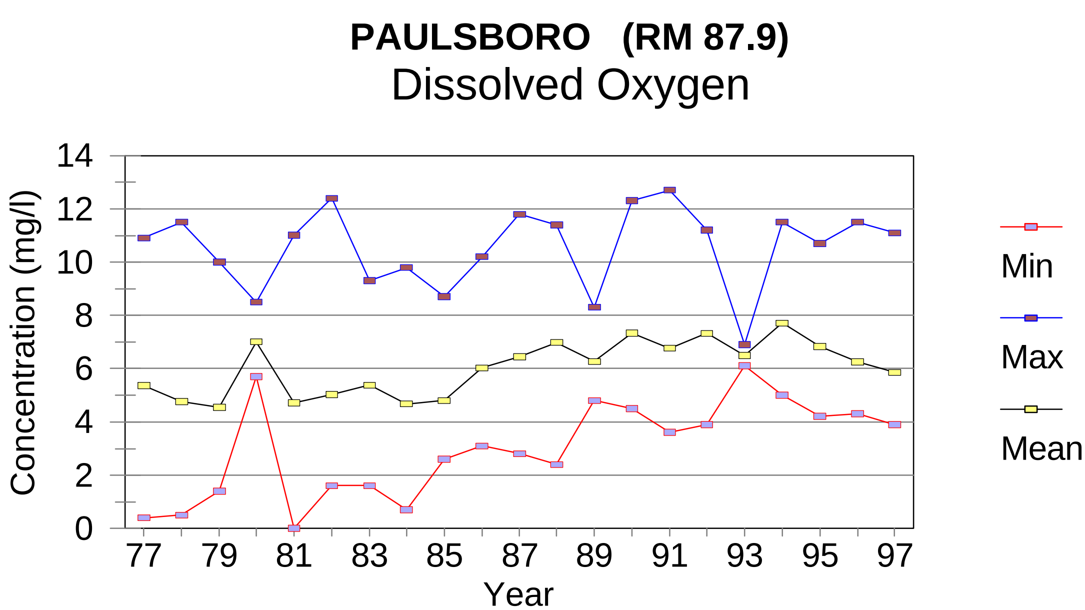

REEDY Isl. (RM 54.94)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean


PEA PATCH Isl. (RM 60.55)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean


CHERRY Isl. (RM 70.6)
Dissolved Oxygen
Concentration (mg/l)
12
10
8
6
4
2
0
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean

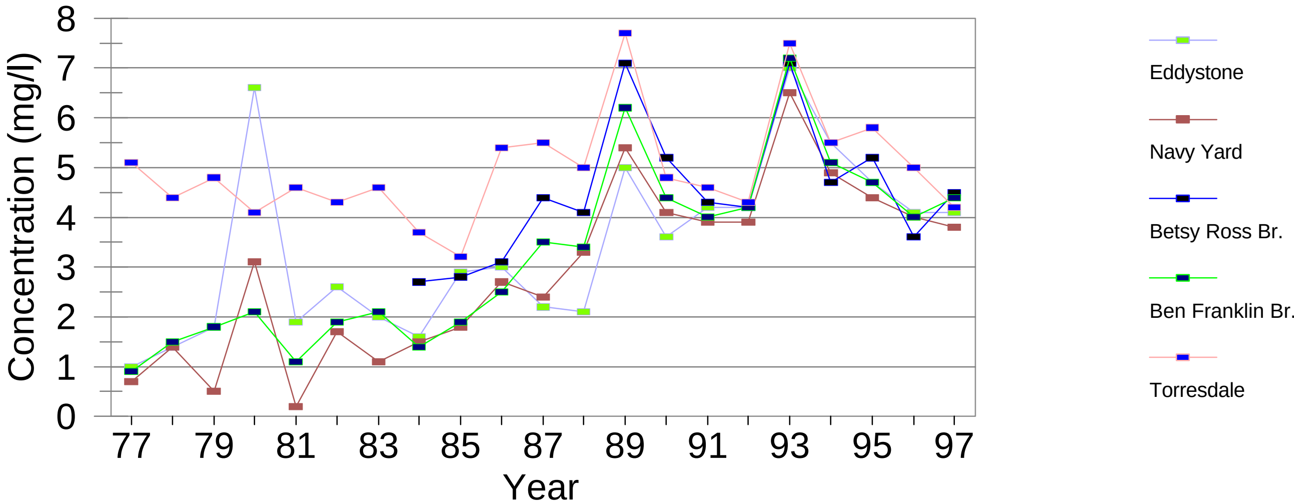

OLD MANS PT. (RM 74.88)
Dissolved Oxygen
Concentration (mg/l)
12
10
8
6
4
2
0
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean


MARCUS HOOK (RM 78.24)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean


PAULSBORO (RM 87.9)
Dissolved Oxygen
Concentration (mg/l)
0
2
4
6
8
10
12
14
77
79
81
83
85
87
89
91
93
95
97
Year
Min
Max
Mean

PHILADELPHIA AREA (RM 84-111)

Dissolved Oxygen



FIELDSBORO (RM 127.48)

Dissolved Oxygen