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BIBLIOGRAPHY

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FINFISH
BIBLIOGRAPHY

Bigelow, H.B. and W.C. Schroeder. 1953. *Fishes of the Gulf of Maine.* Fish Bull. of Fish and Wildlife Ser. Vol. 53, 577 pp.

Bryant, T. 1992. Interviews With Jim Murray, Shirley Price and Charlie Hitchens, unpublished. Marine Communications Office, Univ. of Del., Newark, DE.

Campbell, T.G. 1975. *The Fishes and Hydrographic Parameters of White Creek, Delaware: A Description and Comparison of 1973-1974 to 1975-1958.* M.S. Thesis

Cao, L.N. and J.A. Musick 1977. *Life History, Feeding Habits, and Functional Morphology f Juvenile Sciaenid Fishes in York River Estuary.* VA Fish Bull. 75(4):657-702.

Chesapeake Bay Program. 1988. *Draft Chesapeake Bay Stock Assessment Plan.* Chesapeake Bay Stock Assessment Committee. Annapolis, MD, 59 pp.

Cole, R. and R.W. Miller. 1991. *Commercial Foodfishing in Delaware in 1991.* Del. Div. f Fish and Wildlife, Dover, DE.

Daiber, F.C. 1969. *A Summary of Biological Studies on Indian River and Rehoboth Bays With Management of Recommendations.* State Planning Office. Dover, DE, 27 p.

Delaware DNREC. 1986. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

Delaware DNREC. 1987. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

Delaware DNREC. 1988. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

Delaware DNREC. 1989. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

Delaware DNREC. 1990. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

Delaware DNREC. 1991. *Monitoring Fish Population in Delaware's Estuaries.* Del. Div. of Fish and Wildlife, Dover, DE.

APPENDIX 4.7-A (Continued)
FINFISH
BIBLIOGRAPHY

Delmarva Power and Light. 1976. *Ecological Studies in the Vicinity of the Indian River Power Plant: a 316 a Demonstration.* Ecological Analysts, Inc.

Derickson, W.K. and K.S. Price. 1973. *The Fishes of the Shore Zone of Rehoboth.* Trans. Amer. Fish Soc. 102(3):552-562

Eckman, J. 1955. *Delaware: A Guide to the First State.* American Guide Series. rev's 1938. Hastings House, New York.

Fowler, H.W. 1911. *The Fishes of Delaware.* Proc. Acad. Nat. Sci. Phila., 63:3-16. Fowler,

Godfrey, D.B. 1953. *Maritime History of Indian River and Indian River Bay.* Baccalaureate Thesis, Univ. of Delaware. Spec. Archives, 55 pp.

Grant, G.C. 1962. *Predation of the Bluefish on Young Atlantic Menhaden in Indian River Delaware.* Ches. Sci. 3:45-47.

Grosslein, M.D. and Asarovitz 1982. *Fish Distribution New York Bight Atlas Monograph 15: NY: Sea Grant Institute of State University of New York and Cornell University.* 182 pp.

Hillman, R.J. and M.J. Kennish, 1984. *Commercial and Sport Fisheries in Ecology of Barnegat Bay, New Jersey*; Kennish, M.J. and R.A. Lutz, eds. Lecture Notes on Coastal and Estuarine Studies, Springer-Verlag, New York, NY, Vol. 6 pp281-301.

Horn, J. G. 1957. *The History of the Commercial Fishing Industry in Delaware.* Baccalaureate Thesis. Univ. of Delaware, Newark, DE, 66 pp.

Horwitz, R.J. 1987. *Fish in Ecological Studies in the Middle Reach of Chesapeake Bay, Calvert Cliffs.* Heck, K.L. ed. Lecture Notes on Coastal and Estuarine Studies, Vol. 23, Springer Verlag. New York, NY.

Jeffries, H.P. and W.C. Johnson, 1974. *Seasonal Variations of Bottom Fishes in the Narragansett Bay Area: Seven-Year Variations in the Abundance of Winter Flounder.* J. Fish. Res. Bd. Can. 31:1057-1066.

Kaplovsky, A.J. and D.B. Aulenbach. 1956. *A Comprehensive Study of Pollution and its Effects on Waters Within the Indian River Drainage Basin.* Report to Del. Water Poll. Commission, 207 pp.

APPENDIX 4.7-A (Continued)
FINFISH
BIBLIOGRAPHY

Kjelson, M.A. and G.N. Johnson, 1978. *Catch Efficiencies of a 6.1 Meter Otter Trawl for Estuarine Fish Populations*. Trans. Am. Fish. Soc. 10(7):246-254.

Martin, C.C. 1974. *Delawares Tidal Streams.* Del. DNREC, Div. of Fish and Wildlife, Dover, DE, 33 pp.

Miller, R.W. 1985. *Commercial Foodfishing in Delaware in 1985.* Del. Div. of Fish and Wildlife, Dover, DE.

Miller, R.W. 1986. *Commercial Foodfishing in Delaware in 1986.* Del. Div. of Fish and Wildlife, Dover, DE.

Miller, R.W. 1987. *Commercial Foodfishing in Delaware in 1987.* Del. Div. of Fish and Wildlife, Dover, DE.

Miller, R.W. 1988. *Commercial Foodfishing in Delaware in 1988.* Del. Div. of Fish and Wildlife, Dover, DE.

Miller, R.W. 1989. *Commercial Foodfishing in Delaware in 1989.* Del. Div. of Fish and Wildlife, Dover, DE.

Miller, R.W. 1990. *Commercial Foodfishing in Delaware in 1990.* Del. Div. of Fish and Wildlife, Dover, DE.

NOAA. 1990. *A Proposed Estuarine Classification: Analysis of Species Salinity Ranges, NOAA.* U.S. Dept. of Commerce.

NOAA. 1991a. *Status of Fishery Resources Off the Northeastern United States for 1991.* U.S. DOC NMFS. Northeast Region, Woodshole, MA, 132 pp.

NOAA. 1991b. *Status of Fishery Resources Off the Southeastern United States for 1991.* U.S. DOC NMFS. Southeast Fish Sci. Center, Miami, F, 75 pp.

Pacheco, A.L. and G.C. Grant. 1965. *Studies of the Early Life History of Atlantic Menhaden in Estuarine Nurseries. Part I - Seasonal Occurrence of Juvenile Menhaden and Other Small Fishes in a Tributary Creek of Indian River, Delaware. 1957-1958.* U.S. Fish and Wildlife Ser. Spec. Sci. Rep. fish No. 504, 32 pp.

APPENDIX 4.7-A (Continued)
FINFISH
BIBLIOGRAPHY

Radle, E.W. 1971. *A Partial Life History of the Winter Flounder (Pseudopleuronectes americanus) Exposed to Thermal Addition in an estuary, Indian River Bay, DE.* M.S. Thesis. Univ. of Delaware, Newark, DE, 74 pp., p. 367-418.

Versar, Inc. 1992. *An Assessment of Key Biological Resources in the Delaware River Estuary.* Delaware Estuary Program, U.S. EPA, New York, NY, 193 pp.

Schwartz, F.J. 1961. *Fishes of Chincoteague and Sinepuxent Bays.* J. Am. Midl. Nat. 65(2) 385-407.

Scotton, L.W. 1970. *Occurrence and Distribution of Larval Fishes in the Rehoboth and Indian River Bays of Delaware.* M.S. Thesis. Univ. of Delaware, Newark, DE, 66 pp.

Shirey, C.A. 1988. *Stream and Inland Bays Fish Survey, Delaware: February 1, 1987-January 31, 1988.* Annual Report. Federal Aid in Fisheries Restoration Act. Del. Div. of Fish and Wildlife, Dover, DE.

Taylor, C.C. 1953. *Nature of Variability in Trawl Catches.* Fish and Wildlife Serv. Fishery Bulletin, No. 83, p. 145-166.

Wang, J.C. and R.J. Kernehan. 1979. *Fishes of the Delaware Estuary: A Guide to the Early Life Histories.* E.A. Communications. Towson, MD, 410 pp.

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APPENDIX 4.7-B

Species Characteristics and Life Histories of Selected Species

Some species have been studied extensively because of their commercial, recreational, and ecological importance. The following summaries are from the literature on the Chesapeake. The Chesapeake Bay Stock Assessment Plan (1988) is the basis for description of Atlantic croaker summer flounder, gray trout, killifish and silverside. Habitat Requirements for Chesapeake Bay Living Resources (1991) is the source of detailed information on hard clam, blue crab, menhaden, anchovy, and spot reported here. Data on the bluefish are from "Chesapeake Bay - A Profile of Environmental Change" 1983.

BLUEFISH, Pomatomus saltatrix

Bluefish spawn offshore in two distinct waves, one in spring in the Gulf Stream and one in summer over the continental shelf. Juveniles appear in coastal waters and penetrate estuaries all the way to fresh water. Juveniles grow quickly feeding on copepods, crustaceans and fish smaller than themselves. They leave the estuaries by late fall, heading offshore and southward.

Sexual maturity occurs at a length of 30 cm. Both mature and immature adults enter coastal bays each summer, feeding on menhaden, silverside, anchovy, and crustaceans.

ATLANTIC CROAKER, Micropongonias undulatus

The Atlantic croaker is a medium-sized member of the Sciaenidae family and ranges from Massachusetts to Mexico on the North American coast and from Surinam to Argentina on the South American coast. The species is most abundant, however, along the southeast coast of the United States and in the northern Gulf of Mexico. The Atlantic croaker is irridescent overall, greenish silver above and silvery white below. Numerous brassy or brownish spots form oblique wavy lines on the upper sides and back.

Adult croaker tolerate a wide range of temperatures 2-30 C (35-86 F) and salinities (0-35 ppt), but the juveniles prefer the lower salinity and oligohaline environment of the estuaries which serve as nursery grounds. Adult croaker, like other sciaenids, spawn in the waters of the continental shelf during the late summer and fall of their second year, but return to the estuaries during the following spring. Spawning occurs from August through December off the Chesapeake Bay and south to Cape Hatteras.

Although estimates vary, reported size and age at maturity suggests that Atlantic coast croaker are sexually mature when 3-4 years old. The smallest reported mature male and female were 24 cm (9.5 in) TL and 27.5 cm (11 in) TL, respectively. Eggs and larvae drift toward land until they are able to actively swim towards land and estuarine nursery areas where they remain until the following fall.

Atlantic croaker are believed to reach a maximum age of 7-8 years when they are >500 mm (20 in) TL, but most are generally smaller and short-lived. The species feeds on polychaetes, mollusks, mysids, decapods, and other invertebrates found on the bottom in addition to occasional small fish.

The croaker is one of the most frequently caught species in estuarine and nearshore waters, particularly from March to October. Maryland and Virginia have generally accounted for the majority of the Atlantic coast croaker harvest.

The abundance of Atlantic croaker seems to be closely related to climatological trends and fishing pressure. Warmer temperatures appear to favor the species as evidenced by increases in landings during the first part of the 20th century. Between 1958 and 1971, increased fishing pressure and cold winters reduced the Atlantic catch to <3,000 mt from 1961-1973. Subsequent increases and decreases in catch after 1973 seem to be correlated with fluctuations in the fishing effort and general temperature trends during that period.

SUMMER FLOUNDER, Paralichthys dentatus

The summer flounder is a commercially important flatfish species that generally ranges from Cape Cod to northern Florida, with occasional capture north of Cape Cod. During the late spring to early fall, adults are found in coastal and estuarine waters, to as shallow as 1 m. Decreasing water temperatures and changes in photoperiod cue the annual fall migration of fish north of Chesapeake Bay to offshore spawning and wintering grounds on the middle and outer portions of the continental shelf respectively. Fish south of Chesapeake Bay spawn and overwinter on the inner/middle continental shelf.

Reproductive data from specimens collected on 1974-1979 NMFS bottom trawl surveys between Cape Cod and Cape Lookout indicate that most spawning occurs between October and February. Fish north of Chesapeake Bay spawn from September to December, whereas fish south of Chesapeake Bay spawn from November to February.

Eggs rise to the surface and are presumably transported by wind driven surface currents. Winds from the NW to NE are believed to cause the successful transport of larvae to estuarine nursery habitats. It has been suggested that the major nursery areas are in Virginia and North Carolina. They seem to prefer mesohaline/polyhaline nursery areas, where maximum growth rates occur. Juvenile summer flounder remain in estuarine and coastal waters until recruited to the stock.

Summer flounder are fully recruited to the commercial fishery at ages 2-3. The optimal age at entry to the fishery is 5-7 years for females and 4-5 years for males. Recreational catch data, though not as extensive as commercial catch data, indicates that 45-70% of total U.S. summer flounder landings can be attributed to the recreational fishery. The recreational fishery has the potential to significantly impact the commercial fishery (coastal and offshore) because it catches younger fish prior to their recruitment to the commercial fishery.

Young flounder are first sampled in the trawl surveys during their second year. Young-of-the-year which inhabit shallow vegetated areas are not susceptible to trawling gear.

WEAKFISH, Cynoscion regalis

The weakfish, Cynoscion regalis, also known as the gray trout or squeteague, is a member of the drum family, Sciaenidae, so named for the drumming sounds created by vibrating the swim bladder. The body is elongate and moderately compressed, olive above and silvery on the sides and underside. Dark blotches mark the upper body in oblique wavy lines. The dorsal and caudal fins are dusky, while the ventral, anal, and margin of the caudal fin are bright yellow. Two large recurved teeth are present in the upper jaw.

Weakfish are found in coastal waters from southern Florida to Cape Cod, Massachusetts, but are most abundant from New York to North Carolina. With rising water temperatures during the spring, weakfish migrate northerly and inshore into bays, sounds, and estuaries. During the fall and winter, the younger weakfish less than 4 years old move offshore and south, often as far south as Florida, while older fish move further offshore and only as far south as North Carolina.

Spawning, hatching, and larval development occur in nearshore and estuarine waters between March and October with peak production between late April and June. The mouth of the Chesapeake and Delaware Bay is the major Virginia-Maryland-Delaware spawning ground. Weakfish grow rapidly and are reported to reach a maximum age of 11 years old (approximately 11.6 pounds). Males reach sexual maturity when approximately 1 year old or 5-6 inches (130-

150 mm) SL, while females are slightly larger (145-190 mm SL or 5.7-7.4 in) before attaining sexual maturity. The species is also highly fecund: a female 500 mm (19.7 in) TL may produce over two million eggs at one time. Young gray trout feed primarily above the bottom on mysid shrimp and anchovies, while older individuals feed throughout the water column mostly on herrings, anchovies, silversides, other fish, and blue crabs.

Weakfish are a valuable commercial and recreational sport fish found along the United States east coast. Commercial catch statistics indicate that weakfish landings have fluctuated widely, increasing from a recent low of 1,397 mt in 1967 to 16,293 mt in 1980. Recreational landings also peaked in 1980 at 21,064 mt.

Results of a weakfish stock assessment indicate that weakfish from Maryland to North Carolina may have experienced both growth and recruitment overfishing in recent years: however, these conclusions are uncertain due to weaknesses in the data set used in the analyses and lack of knowledge of weakfish stock structure.

KILLIFISHES, Fundulus ssp.

The killifishes, principally the common killifish, F. heteroclitus, and the striped killifish, F. majalis, are common marsh grass and tidal creek shore species in the Bay and its tributaries. They inhabit these areas that are often oxygen deficient in summer and exhibit large seasonal temperature extremes. During winter they bury in the mud. Spawning occurs during the spring on the spring tide. Eggs are deposited in shells above the normal high tide where they develop and hatch the next month on the high spring tide. Killifish are omnivorous and are one of the most common forage for the blue, crested night, and green herons.

ATLANTIC SILVERSIDE, Menidia menidia

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The Atlantic silverside, and its cousin, the Tidewater silverside, M. berelina, are common shoreline species along the entire Mid-Atlantic coast. The Atlantic silverside is common in higher salinities, and the Tidewater silverside in lower salinities; below 5 ppt only the Tidewater silverside is taken. In the Chesapeake Bay these two species are important forage for bluefish, striped bass and weakfish. They support no commercial fishery but are one of the most important ecological species in the Bay. The silverside spawn in the spring, laying demersal eggs that are attached to shoreline grasses. They grow rapidly reaching 60-80 mm (2.5-3 in) by the end of the first summer, and after spawning the following spring (April-May) reach 100 mm (4 in) before they die when 14-16 months of age.

In spite of their ecological importance they have not been studied as extensively as many other Bay species.

SECTION 4.8
BIRDS

Information presented in this section summarizes population status and seasonal trends in bird use of the Lower Delaware Inland Bays: Rehoboth Bay, Indian River Estuary, and Little Assawoman Bay. Information provided in this section focuses primarily on two avian groups, waterfowl and raptors. Waterfowl were chosen due to their economic importance as game and recreational species and because of the availability of quantitative population monitoring data. Raptors were also chosen because of the availability of detailed population information and because of their position in the food chain and documented sensitivity to environmental perturbations. Additional information is provided for other bird species when quantitative data was available.

4.8.1 Waterfowl

Ducks and geese are economically and recreationally important components of the Delaware Inland Bay biological system, and although the Inland Bays only support a limited breeding population of waterfowl, their primary value, as with most waterfowl habitat along the Atlantic Coast, is their ability to provide suitable wintering and migratory stopover areas (Bellrose, 1976).

In general, the waterfowl populations throughout North America have shown drastic declines from the 1930's through the early 1980's. The principal reason for these drastic declines has been the destruction of wetland habitats needed for breeding and feeding during migration and over winter (Sanderson, 1976). Along the Atlantic seaboard, the primary factors that have contributed to this habitat loss include:

- Drainage of coastal wetlands, primarily for mosquito control.
- Filling of wetland for highways, flood protection, navigation and commercial/industrial and residential development.

- Pollution from pesticides, herbicides, domestic sewage and urban runoff.
- Invasion by the common reed (*Phragmites australis*).
- Numerous other natural phenomenon like erosion, sea level rise, storms, etc. (Whitman and Cole, 1988).

4.8.1.1 Mid-Winter Waterfowl Populations

The winter waterfowl populations along the Atlantic Flyway have been monitored extensively as part of the Mid-winter Waterfowl Survey that has been conducted by the USFWS and state biologists since 1933 (Martin, et al., 1979). This survey provides some of the most reliable waterfowl population data available and is especially valuable for species like the Canada goose that are now known to winter south of the United States (Bellrose, 1976). Comparative survey data for the Inland Bays area are available from the early 1970's to the present day. These data are based on areal counts conducted in October, November, December and January of each year.

Seven species of waterfowl, all considered important game species, were selected as representative species for the discussion of waterfowl population trends (Table 4.8-1). Populations of these species have been closely monitored through fall and winter aerial surveys conducted by the State of Delaware (Whittendale, 1992) in cooperation with the Atlantic Flyway Council and the U.S. Fish and Wildlife Service.

The Canada Goose was selected because it is recreationally important and is widely distributed through a wide variety of habitats. The mallard has the same characteristics as the goose and is the subject of a significant breeding and release program. The black duck suffered a severe decline beginning in the 1950's and extending through the 70's and now appears stable. The brant is principally a coastal migrant not widely distributed in inland areas. The bufflehead is a diving duck that has moderate recreation value. The mergansers are protected, feed almost exclusively on fish and may serve as an indicator of both fish quality and quantity.

Table 4.8-1

Waterfowl Use of Lower Delaware Inland Bays Frequency of Occurrence

Species		Winter
Canada goose	*Branta canadensis*	High
Brant	*Branta bérnicla*	Medium
Mallard	*Anas platyrhynchos*	Medium
American black duck	*Anas rubripes*	High
Bufflehead	*Bucephala albeola*	Low
Common merganser	*Mergus merganser*	Low
Red-breasted merganser	*Mergus serrator*	Low

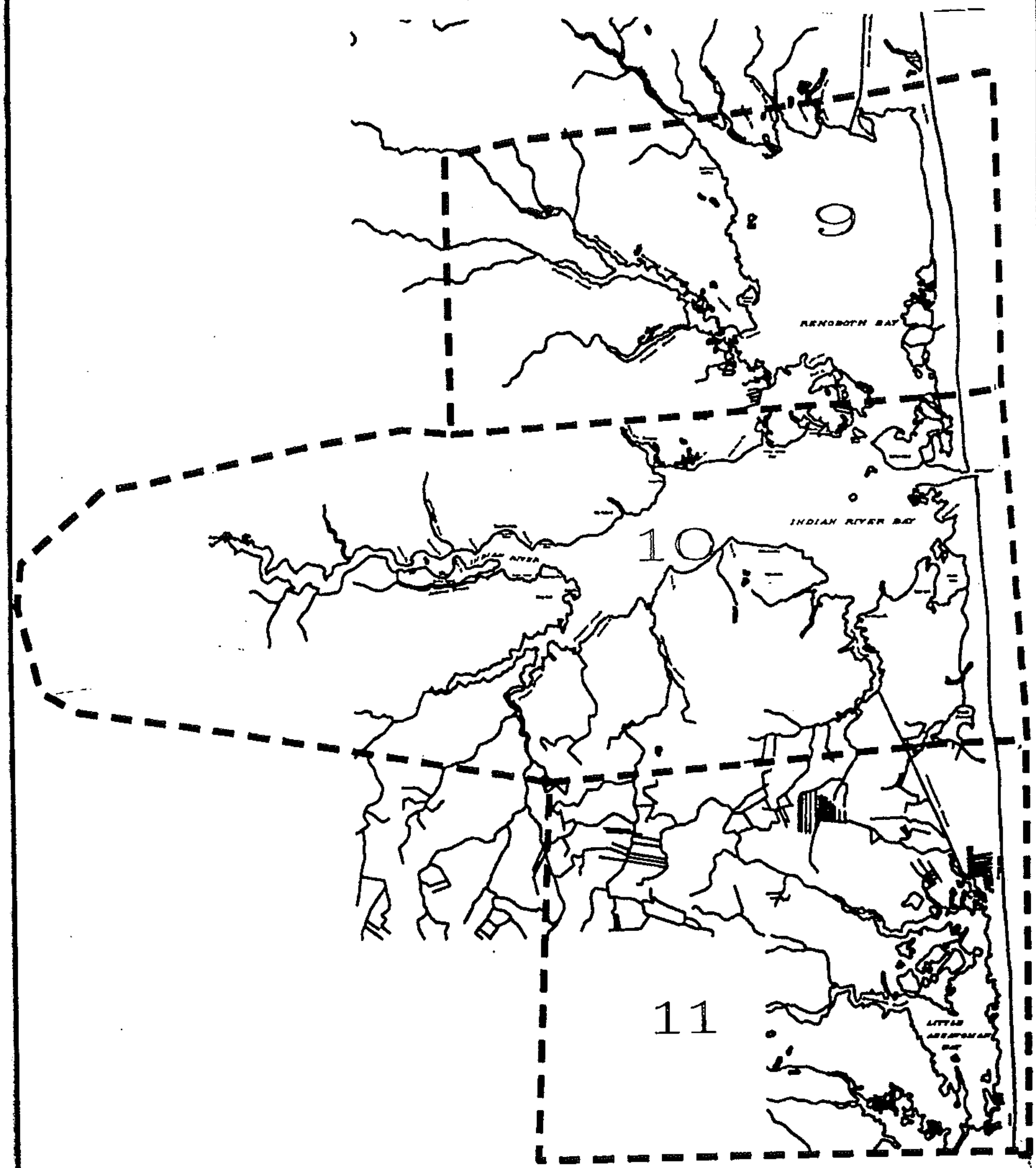

Figure 4.8-1
Delaware Fall and Mid-Winter Waterfowl Survey Units

The technique used for the fall and winter surveys involves low level flights (150 feet) on parallel east to west and west to east transect lines covering each survey area. The spacing of transect lines is such that 100% of each survey unit is covered. In addition, surveys of the Delaware coastal regions have been conducted by the same personnel and in the same manner since 1973 (Whittendale, personal comments, 1990), thereby reducing observer variability that often plagues long-term monitoring programs and strengthening the interpretation that can be used. Figure 4.8-1 shows the location of survey units 9, 10, and 11, the three units that encompass the Inland Bay area. Table 4.8-2 presents cumulative annual data on the relative abundance and distribution of waterfowl in the Lower Inland Bay system during the fall and winter season for a 17-year period (1975-1991).

While data collected annually during four survey events (October-January) is potentially valuable for local population trend analysis, only data collected during the January (i.e., mid-winter) survey is comparable to the Atlantic Flyway winter survey data that is reported annually by the U.S. Fish and Wildlife Service. So that comparisons could be made between the annual Inland Bay waterfowl population data and the annual mid-winter Atlantic Flyway population data, the January waterfowl counts for the Rehoboth Bay, Inland River Estuary and Little Assawoman Bay regions were summarized and graphed for a ten-year period from 1982 to 1991 (see Tables 4.8-3 through 4.8-5 and Figures 4.8-2 through 4.8-4).

Because of the high variability often observed in population estimates from year-to-year, standard practice in long-term monitoring programs like the mid-winter waterfowl survey is to look at population trends overtime. While numerous innovative statistical techniques have been employed to answer specific questions about avian population trends (Geissler and Sauer, 1990; Sauer and Droege, 1990), for the purpose of this report, mid-winter population data for the three Inland Bays over the last ten years was summarized. A ten-year average for each species was calculated to help identify specific trends that may have developed over the ten-year period. This approach, while simplistic, is typically used throughout the Atlantic Flyway and is helpful in evaluating both local, state and regional population trends (Ferrigno, 1989).

Table 4.8-2
Relative Abundance and Distribution of Waterfowl in the Lower Delaware Inland Bays During the Winter Season in a 17-year Period[1]

Species	Rehoboth Bay	Indian River Estuary	Little Assawoman Bay	Total
1975-76				
Black duck	319	382	1,752	2,453
Mallard	72	9	531	612
Red-breasted Common merganser	103	11	7	121
Bufflehead	387	203	67	657
Canada goose	1,140	30	1,248	2,418
Brant	1,600	1,410	0	3,010
1976-77				
Black duck	1,949	2,265	5,441	9,655
Mallard	779	440	2,072	3,291
Red-breasted Common merganser	205	496	0	701
Bufflehead	534	976	360	1,870
Canada goose	6,622	1,040	9,450	17,112
Brant	9,570	6,585	0	16,155
1977-78				
Black duck	1,366	255	4,932	6,553
Mallard	175	27	2,095	2,297
Red-breasted Common merganser	4	18	0	22
Bufflehead	168	255	100	523
Canada goose	3,120	2,513	3,983	9,616
Brant	5,084	4,243	0	9,327

[1]Source: Delaware Division of Fish & Wildlife (1991).

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Table 4.8-2
(Continued)

Species	Rehoboth Bay	Indian River Estuary	Little Assawoman Bay	Total
1978-79				
Black duck	957	858	1,746	3,561
Mallard	555	110	770	1,435
Red-breasted Common merganser	29	24	28	81
Bufflehead	1,223	899	241	2,363
Canada goose	6,373	270	3,108	9,751
Brant	390	432	0	822
1979-80				
Black duck	779	359	4,690	5,828
Mallard	177	52	1,839	2,068
Red-breasted Common merganser	1	5	0	5
Bufflehead	585	474	30	1,089
Canada goose	3,522	271	1,680	5,473
Brant	6,919	6,158	150	13,227
1980-81				
Black duck	1,631	996	5,205	7,832
Mallard	871	15	2,483	3,369
Red-breasted Common merganser	14	37	1	52
Bufflehead	406	2,758	71	3,235
Canada Goose	617	0	1,979	2,596
Brant	2,849	3,903	0	6,752
1981-82				
Black duck	2,558	2,102	7,363	12,023
Mallard	670	958	2,831	4,459
Red-breasted Common merganser	39	110	5	154
Bufflehead	356	726	14	1,096
Canada goose	4,359	2,415	3,829	10,603
Brant	9,070	6,341	1	15,412

Table 4.8-2
(Continued)

Species	Rehoboth Bay	Indian River Estuary	Little Assawoman Bay	Total
1982-83				
Black duck	2,196	506	4,073	6,775
Mallard	781	9	1,095	1,885
Red-breasted Common merganser	218	42	0	260
Bufflehead	381	695	17	1,093
Canada goose	623	72	1,095	1,790
Brant	148	1,373	0	1,521
1983-84				
Black duck	1,414	580	5,531	7,525
Mallard	929	64	4,484	5,477
Red-breasted Common merganser	131	121	3	255
Bufflehead	1,259	853	15	2,127
Canada goose	3,731	81	4,117	7,929
Brant	1,317	1,354	0	2,671
1984-85				
Black duck	3,815	742	4,593	9,150
Mallard	1,210	190	3,435	4,835
Bufflehead	663	1,092	1,153	2,908
Red-breasted Common merganser	295	872	50	1,217
Canada goose	4,654	280	3,400	8,334
Brant	3,559	2,622	0	6,181
1985-86				
Black duck	1,860	937	2,153	4,950
Mallard	1,392	413	1,585	3,390
Red-breasted Common merganser	49	5	3	57
Bufflehead	290	750	3	1,043
Canada goose	790	470	2,100	3,360
Brant	1,023	1,132	0	2,155

Table 4.8-2
(Continued)

Species	Rehoboth Bay	Indian River Estuary	Little Assawoman Bay	Total
1986-87				
Black duck	1,226	819	2,125	4,170
Mallard	1,752	518	1,593	3,863
Red-breasted Common merganser	12	11	0	23
Bufflehead	88	171	10	269
Canada goose	4,390	2,578	3,938	10,906
Brant	0	0	0	0
1987-88				
Black duck	1,717	1,005	2,901	5,623
Mallard	697	353	2,654	3,704
Red-breasted Common merganser	13	13	0	13
Bufflehead	583	2,014	29	2,626
Canada goose	2,388	965	1,195	4,548
Brant	425	1,060	0	1,485
1988-89				
Black duck	1,198	2,133	712	4,043
Red-breasted Common merganser	0	10	0	10
Bufflehead	309	436	1	746
Canada goose	1,650	665	2,607	4,922
Brant	1,525	1,638	0	3,163
1989-90				
Black duck	1,480	658	2,384	4,522
Mallard	1,485	490	1,994	3,969
Red-breasted Common merganser	49	29	0	78
Bufflehead	787	681	821	2,289
Canada goose	2,275	3,326	1,138	6,739
Brant	585	1,983	0	2,568

Table 4.8-2
(Continued)

Species	Rehoboth Bay	Indian River Estuary	Little Assawoman Bay	Total
1990-91				
Black duck	1,359	565	3,484	5,408
Mallard	1,151	294	2,518	3,963
Red-breasted Common merganser	30	215	12	257
Bufflehead	1,521	2,089	14	3,264
Canada goose	1,646	1,201	1,746	4,593
Brant	50	422	0	472
1991-92				
Black duck	1,972	480	4,368	6,820
Mallard	1,625	271	1,915	3,811
Red-breasted Common merganser	245	338	14	597
Bufflehead	2,250	1,225	5,275	8,300
Canada goose	2,250	1,225	5,275	8,300
Brant	615	1,550	350	2,515

Table 4.8–3
January Waterfowl Inventory Results for the Rehoboth Bay Area (Survey Unit #9)

SPECIES	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	10–Year Average
Black Duck	326	1199	552	1146	504	593	673	767	361	511	663.2
Mallard	120	372	388	845	662	378	88	541	467	370	423.1
Merganser	0	5	131	285	13	1	0	10	27	17	48.9
Bufflehead	20	10	1143	407	106	79	210	112	506	468	306.1
Canada Goose	390	425	216	1254	20	1230	510	290	525	570	543
Brant	843	3	932	1757	50	0	200	680	575	0	504
Totals	1699	2014	3362	5694	1355	2281	1681	2400	2461	1936	2488.3

* Mergansers include red–breasted and common mergansers

Table 4.8-4
January Waterfowl Inventory Results for the Indian River Estuary (Survey Unit #10)

SPECIES	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	10-Year Average
Black Duck	1148	96	130	365	355	162	518	677	130	0	358.1
Mallard	883	7	2	137	123	120	220	707	340	31	257
Merganser [a]	11	0	121	842	0	0	6	0	21	113	111.4
Bufflehead	170	21	470	686	238	63	1163	123	174	571	367.9
Canada Goose	1206	12	38	150	430	550	40	130	1320	660	453.6
Brant	1778	68	450	1457	313	0	760	1103	1390	300	761.9
Totals	5196	204	1211	3637	1459	895	2707	2740	3375	1675	2309.9

[a] Mergansers include red-breasted and common mergansers

Table 4.8–5
January Waterfowl Inventory Results for the Little Assawoman Bay Area (Survey Unit #11)

SPECIES	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	10–Year Average
Black Duck	1303	858	1700	1944	1125	820	728	191	568	1335	1057.2
Mallard	400	2	1609	1440	660	160	867	270	670	575	665.3
Merganser [a]	8	0	3	50	0	0	0	0	0	2	6.3
Bufflehead	0	0	0	60	0	0	0	1	0	0	6.[illegible]
Canada Goose	842	590	1052	400	1300	825	445	1104	235	822	761.5
Brant	0	0	0	0	0	0	0	0	0	0	0
Totals	2553	1450	4364	3894	3085	1805	2040	1566	1473	2734	2496.4

[a] Mergansers include red–breasted and common mergansers

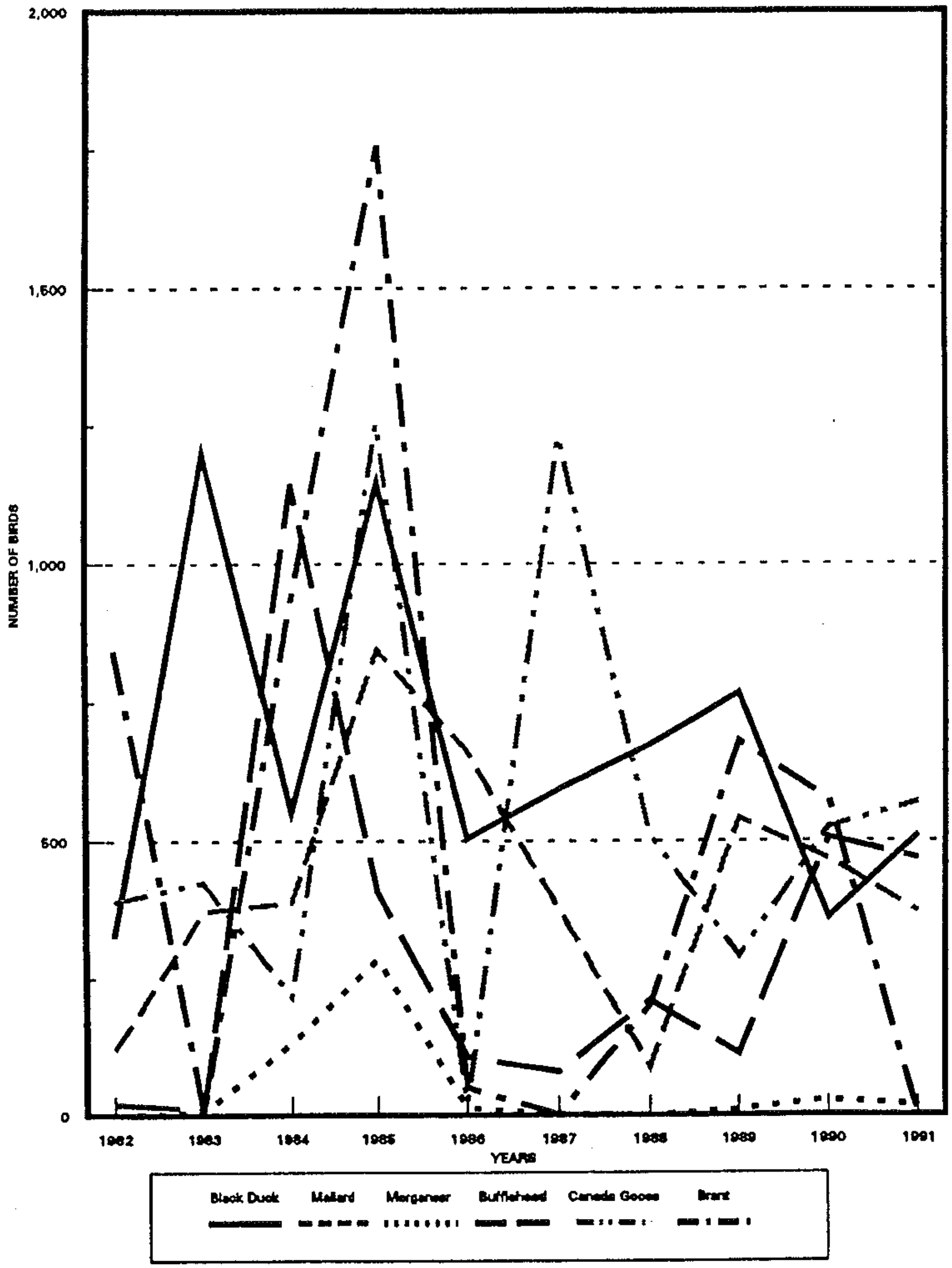

FIGURE 4.8-2
JANUARY WATERFOWL INVENTORY RESULTS
REHOBOTH BAY (SURVEY UNIT #9)

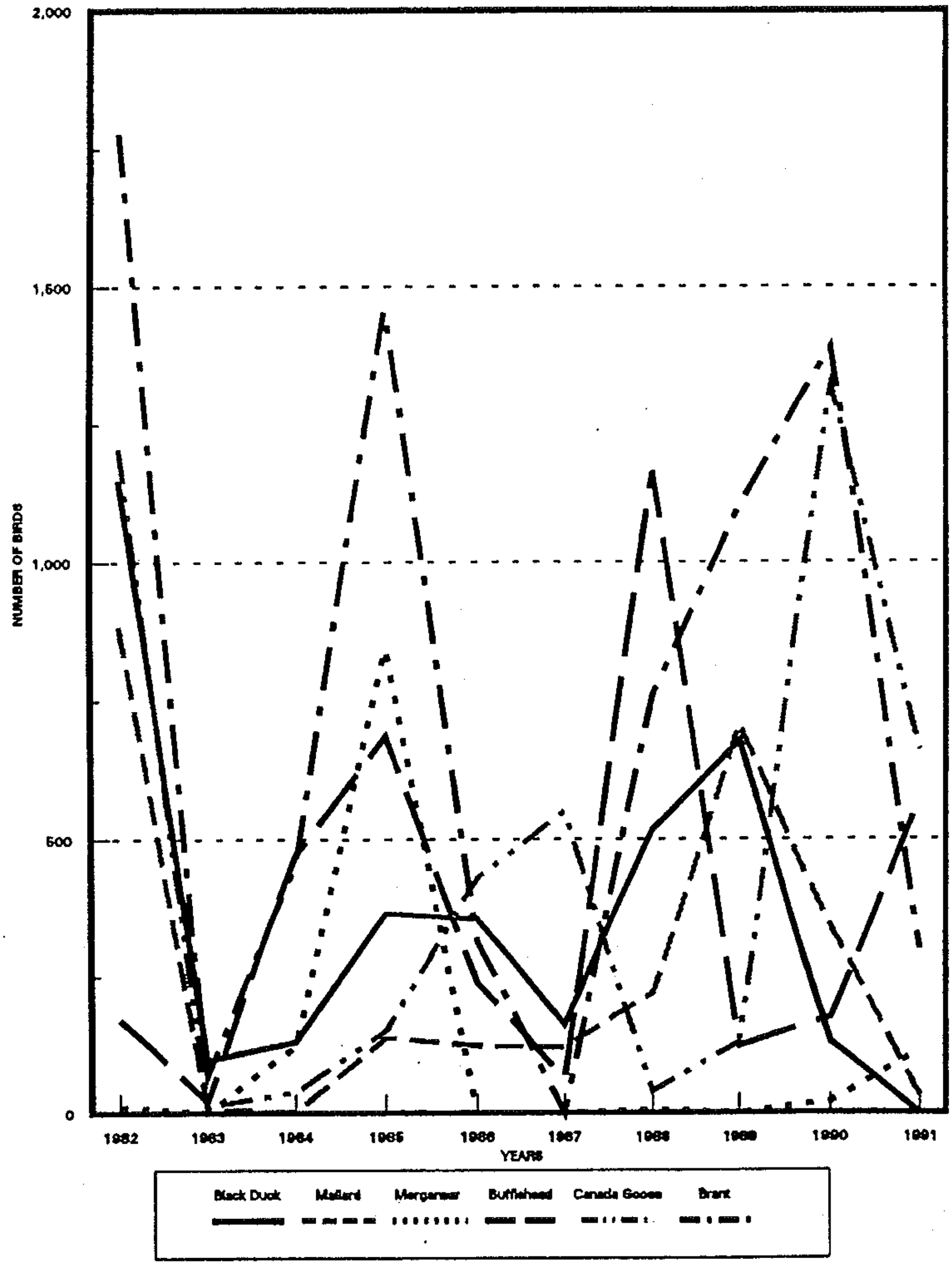

FIGURE 4.8-3
JANUARY WATERFOWL INVENTORY RESULTS
INDIAN RIVER ESTUARY AREA (SURVEY UNIT #10)

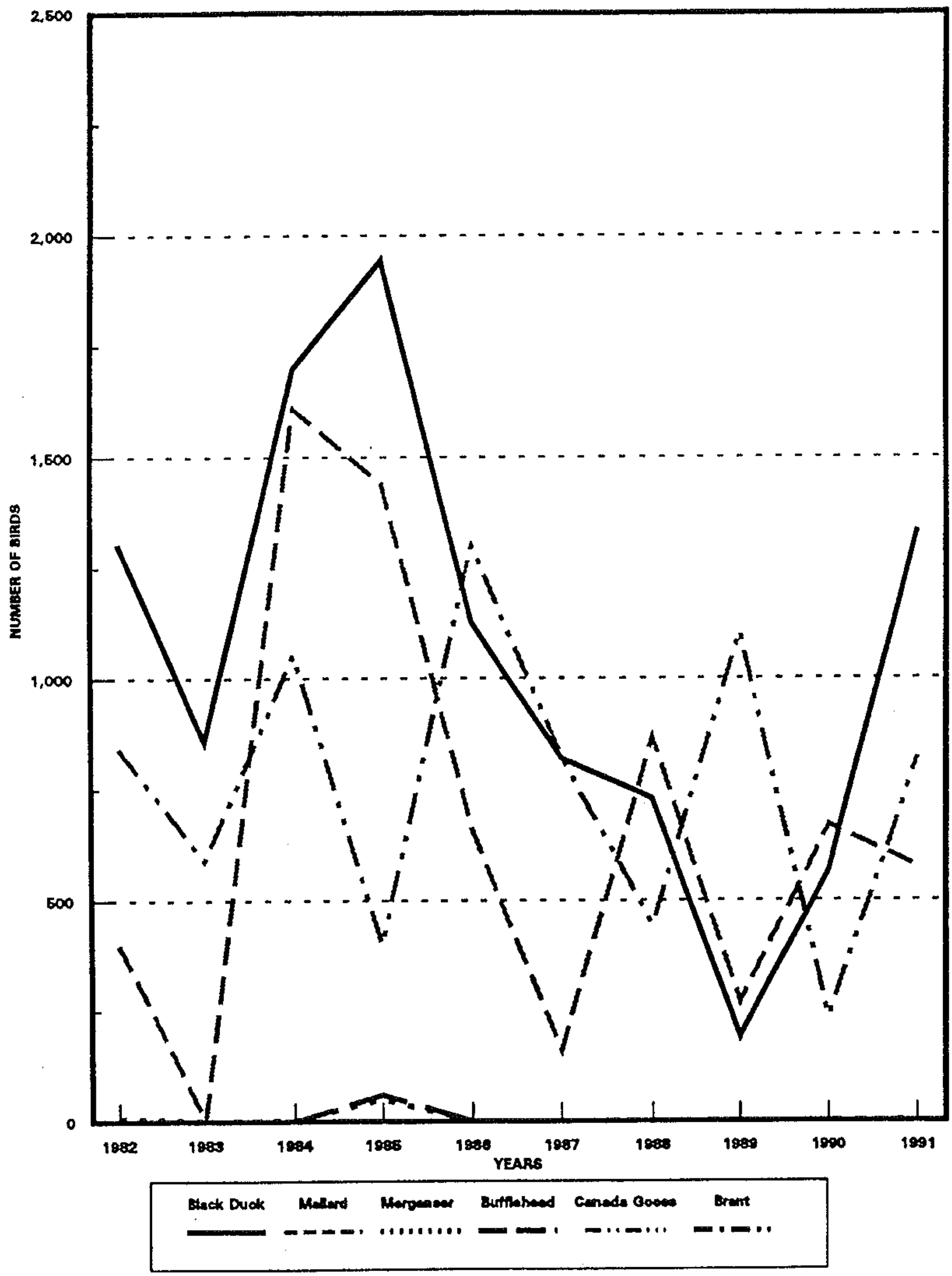

FIGURE 4.8-4
JANUARY WATERFOWL INVENTORY RESULTS
LITTLE ASSAWOMAN BAY AREA (SURVEY UNIT #11)

In general, the average number of birds seen during the winter survey was similar at all three bays based on the ten-year total average [Rehoboth Bay (2,488), Indian River Estuary (2,309), and Little Assawoman (2,496)]. However, Indian River Estuary and Rehoboth Bay appear to support a slightly more diverse waterfowl community than Little Assawoman Bay. The following species accounts briefly discuss population trends at each bay, how they compare to flyway trends and, where sufficient information exists, discuss possible explanations for observed trends.

Black Duck

Throughout the North American continent black duck populations declined dramatically during the 1950's through the mid to late 1970's; however, the Atlantic Flyway winter populations appear to have stabilized over the last ten years. A relatively stable trend was also observed at Rehoboth and Little Assawoman Bay over the same time period, although throughout the State of Delaware, black ducks have decreased 40 percent in the 1980's. Indian River Estuary winter populations appear more volatile and are generally substantially lower than the other bays. Several studies over the last three decades have tried to account for the population fluctuations observed in the black duck throughout North America (Geis, et al., 1971; Ankney, et al., 1987; Conroy and Krementz, 1986, 1990; and Rusch, et al., 1989); however, strong statistical evidence supporting the many hypothesis proposed is still lacking (Nichols, 1991). There is, however, little doubt in the mind of professional waterfowl biologists, that the loss of primary food sources like eelgrass and the degradation of high and low salt marshes along the east coast is an important factor in the winter population dynamics throughout the Mid-Atlantic region, and will continue to be a primary focus in black duck management.

Mallard

The mallard is the most common duck in North America, with highest population occurring in the midwest along the Mississippi Flyway; comparatively, the Atlantic Flyway winter population is relatively small. While North American population estimates showed concurrent increases in mallard numbers during the period of greatest decline for the black duck (1950's to 1970's), the Atlantic Flyway mallard population was declining; however, over the last several years, mid-winter mallard counts have stabilized along the east coast. Mallard population levels in Rehoboth and Little Assawoman Bay appear somewhat stable over the last ten years; population levels in the Indian River Estuary are generally lower and more volatile. Because of their highly adaptive feeding behavior, the continued release of captive-bred birds, and their increased presence in urbanized areas, the North American and Inland Bay mallard population do not appear to be in as serious a condition as many other waterfowl species.

Mergansers

The average winter population of red-breasted and common mergansers on the Atlantic Flyway is approximately 40,000. Historically, they are not typically found in high numbers in Delaware and, with the exception of high numbers observed on Rehoboth and Indian River Estuary in 1985, the population levels on all three bays is low. There is no apparent reason for the typically low number of mergansers seen in the Inland Bays; however, the relationship between their almost exclusively piscivorous diet and the composition and population levels of the Inland Bays small fish community may be areas worth exploring.

Bufflehead

The average January bufflehead population along the Atlantic Flyway is 40,000, with the highest numbers typically seen in New Jersey, Maryland, Virginia, and North Carolina. Mid-winter counts show that the bufflehead is an infrequent visitor to the Little Assawoman Bay, but is normally found in similar numbers on both Rehoboth Bay and Indian River Estuary. The bufflehead population along the Atlantic Flyway has gradually improved throughout the 1980's and appears stable in the Inland Bay area.

Canada Goose

Based on the mid-winter inventory along the Atlantic Flyway, the Canada goose appears to be declining after a dramatic increase from the 1950's to the 1970's; however, the increased use of urban areas (Conover and Chasko, 1985; Conover and Kania, 1991) that are not typically included in most surveys may account for this apparent decline. Mid-winter population levels in the Inland Bays appears stable, with highest numbers typically observed in the Little Assawoman Bay area. Because of their diverse herbivorous diet, highly adaptive nest site selection behavior, and extreme mobility, many geese populations have responded to increased hunting pressure by seeking refuge on privately owned land where hunting is not allowed. In an effort to control the size and spread of these often "nuisance" populations, state and federal wildlife control personnel throughout the northeast have been annually capturing geese during their flightless period and transferring them to states that are trying to increase local, recreational populations.

Brant

Throughout the 1980's, there has been a gradual increase in mid-winter brant numbers along the Atlantic Flyway. Brant were only observed at Rehoboth and Indian River Bay during the mid-winter survey over the past ten years, and the population levels during this time period appear stable in spite of extremely high and low- count years. One possible explanation for the severe fluctuations in abundance is the fact that brant are the most northerly breeding waterfowl, and as such, their reproductive success and subsequent population levels tend to hinge on the extreme weather conditions often found during spring at their Arctic breeding grounds. While dramatic population declines during the 1930's were attributed to the loss of their principal food source, eel grass, over the last five decades, the brant has gradually changed its food habits and now commonly forages on sea lettuce, widgeon grass, salt marsh grass and upland agricultural crops (Lincoln, 1990).

4.8.2 Breeding Bird Survey Results

The North American Breeding Bird Survey (BBS) is run by approximately 2,000 skilled amateur ornithologists and is sponsored jointly by the U.S. Fish and Wildlife Services and the Canadian Wildlife Service (Robbins et al., 1986). The BBS has been operational since 1966, and its main purpose is to estimate population trends of many birds that nest in North America and migrate across international boundaries. The results of the survey provide information, both locally and on a continental scale, about the following subjects:

- short-term population changes that can be correlated to weather conditions
- recovery period, following dramatic declines
- typical year-to-year variations
- long-term population trends
- invasions of exotics

The BBS is basically a roadside survey, consisting of permanent routes that are surveyed annually. Each route is 39.4 km (24.5 miles) long and contains 50 stops spaced 0.8 km (0.5 miles) apart. Every route is run during the local breeding season, and all birds heard or seen during a three-minute observation period at each stop are recorded.

The annual BBS that is run in the Inland Bays area (e.g., the Bethany Beach survey) is conducted in June and begins at Cottonpatch Hills and proceeds north along Route 1 until ending outside Lewes, Delaware. While this survey does not include any portion of Little Assawoman Bay, it is the most comprehensive data available on breeding birds in Rehoboth Bay and Indian River Estuary. The results of these surveys have found that the black duck and mallard are the only breeding waterfowl found in the northern Inland Bays. Table 4.8-6 provides a list of the birds most frequently encountered during the most recent ten years of the Bethany Beach survey. Breeding populations trends based on this data were not evaluated because survey data was not available in 1979 to 1983 and 1988. Figures 4.8-5 and 4.8-6 present the total number waterfowl observed during each Bethany Beach survey since 1970.

Table 4.8-6

Species Most Frequently Observed During the Bethany Beach Breeding Bird Survey

Double-crested cormorant	Carolina chickadee
Great blue heron	Tufted titmouse
Snow egret	Carolina wren
Green-backed heron	American robin
Black-crowned night heron	House wren
American black duck	Marsh wren
Mallard	Gray catbird
Turkey vulture	Northern mockingbird
Osprey	Brown thrasher
Northern bob-white	European starling
Clapper rail	White-eyed vireo
Killdeer	Red-eyed vireo
Willet	Yellow warbler
Laughing gull	Pine warbler
Herring gull	Prairie warbler
Great black-backed gull	Common yellowthroat
Common tern	Northern cardinal
Least tern	Blue grosbeak
Black skimmer	Indigo bunting
Rock dove	Rufous-sided towhee
Mourning dove	Chipping sparrow
Common nighthawk	Seaside sparrow
Chimney swift	Song sparrow
Yellow-shafted flicker	Red-winged blackbird
Great-crested flycatcher	Eastern meadowlark
Eastern kingbird	Common grackle
Purple martin	Boat-tailed grackle
Tree swallow	Brown-headed cowbird
Barn swallow	House finch
Bluejay	American goldfinch
American crow	House sparrow
Fish crow	

This list is in accordance with the Sixth American Ornithologists Union Checklist as amended.

Frequency of Occurrence based on 10 years U.S. Fish & Wildlife Breeding Bird Survey data.

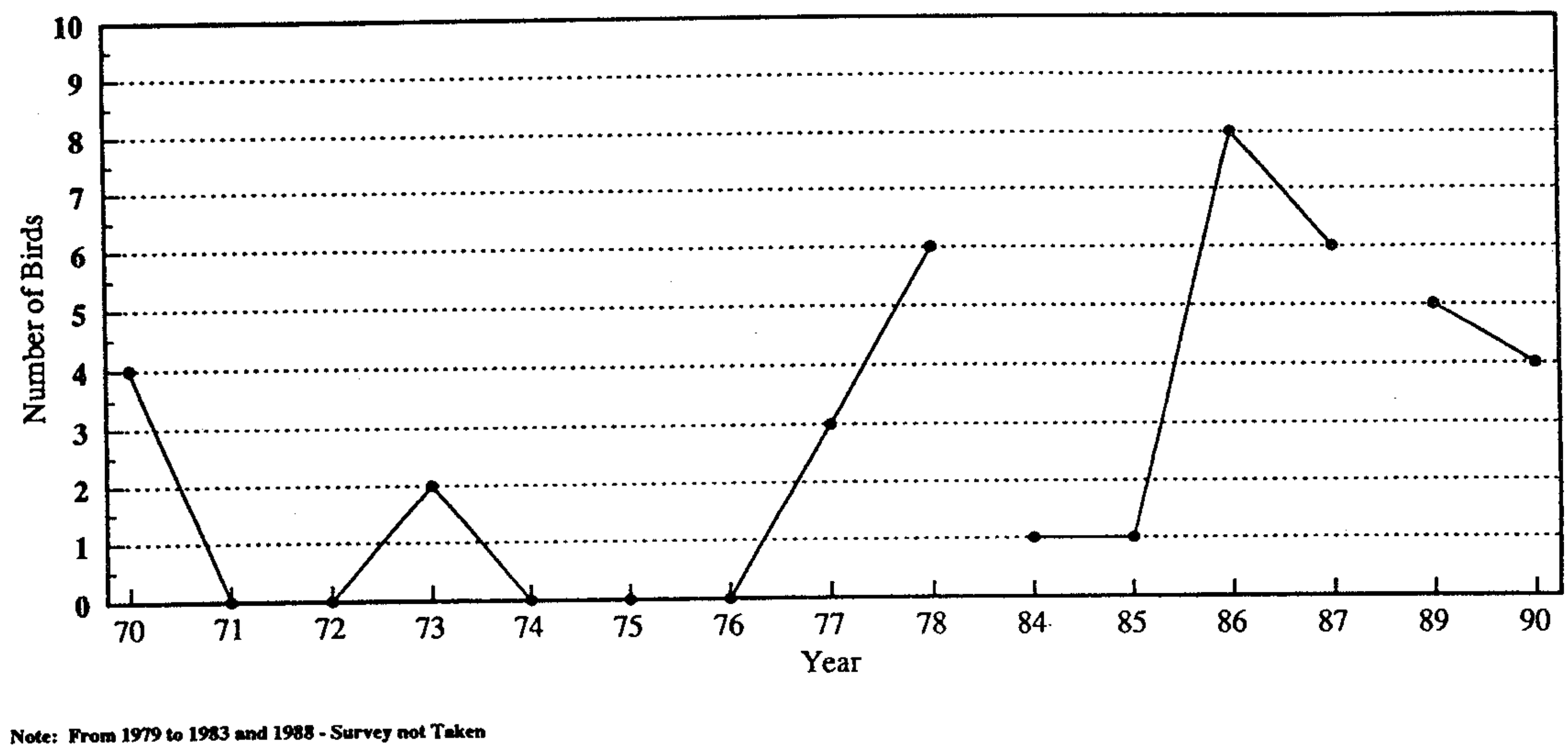

Figure 4.8-5
American Black Duck (15 Year Survey)
US Fish and Wildlife Service
Breeding Bird Survey

Fish48-D18

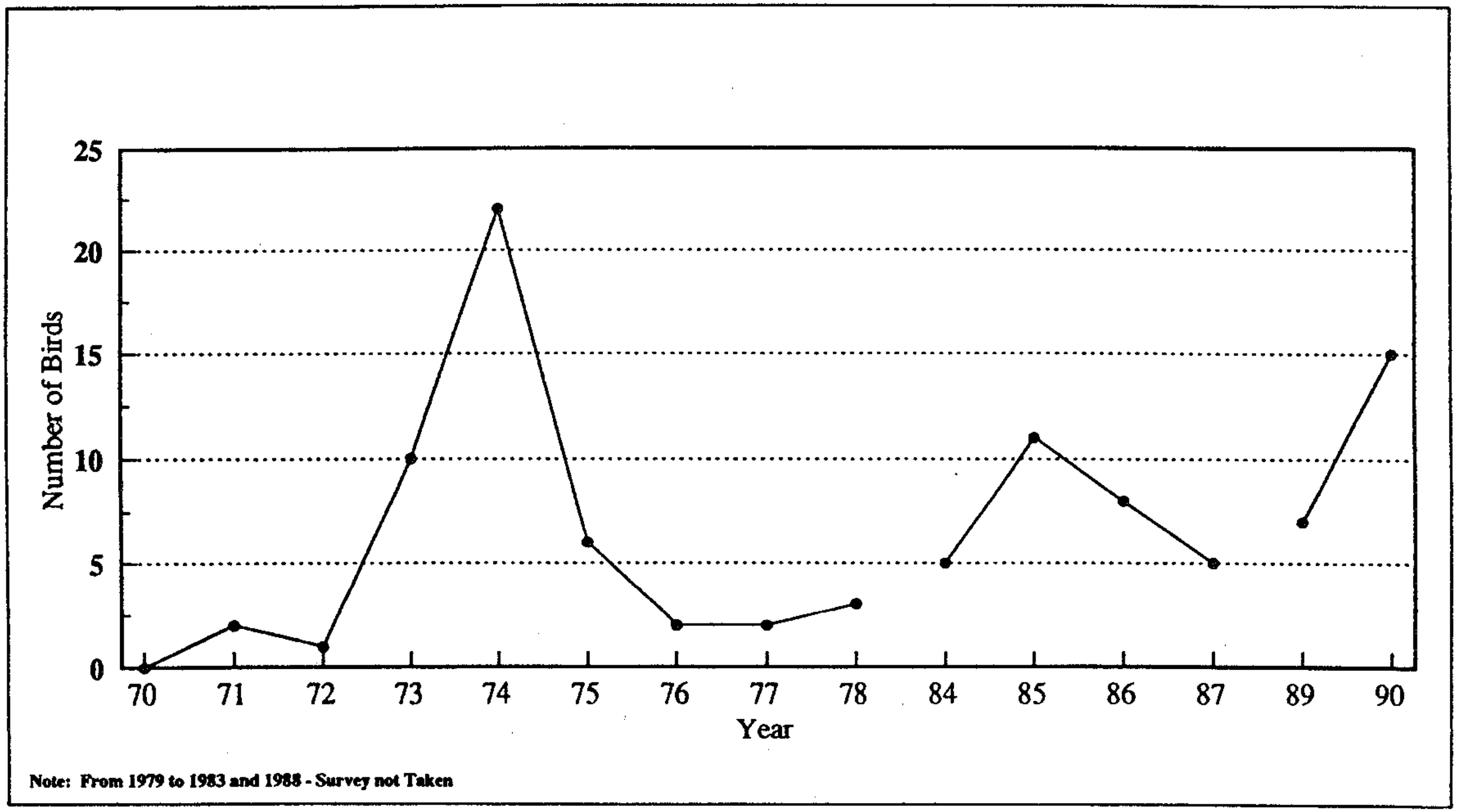

Figure 4.8-6
Mallard (15 Year Survey)
US Fish and Wildlife Service
Breeding Bird Survey

Raptors

Current conditions of biological communities can be evaluated by the identification and monitoring of key biological species. Raptors are an essential part of a well-balanced ecosystem in that they are at the top of the food chain and therefore, are susceptible to an changes that may occur to the food chain below them. Historically, raptors were never abundant (USFWS 1984) but pesticide use and habitat destruction over the past few decades have resulted in dramatic raptor population declines throughout North American (Newton, 1980). In particular, bird eating raptors like the peregrine falcon (*Falco peregrinus*) and fish eating raptors like the osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*) have been affected the most (USFWS, 1990). Both the peregrine falcon and bald eagle are listed as endangered in the State of Delaware (Gelvin-Innvaer, personal communication).

Based on available information on abundance, temporal distribution, and use of Delaware Inland Bays, the following raptor species were selected for evaluation in this report: osprey northern harrier (*Circus cyaneus*) and bald eagle. Ecologically, the osprey and bald eagle are both highly dependent on the tidal marshes and inland bays for forging and nesting habitat. The osprey and bald eagle are primarily fish eaters and are known inhabitants of the Inland Bay region. The northern harrier is also dependent on tidal wetlands for nesting habitat and can be found foraging for small mammals, birds and insects along coastal marshes throughout the northeast.

The osprey and the northern harrier are not typically year-round residents in the Delaware area. The osprey nests in the Delaware area but migrates south for the winter. The northern harrier winters in Delaware, but only rarely breeds there (Stone, Dunne, 1984, Mellon, 1990). The bald eagle is the only raptor species evaluated in this report that is a typically year-round resident in the Inland Bay region.

Most raptors maintain relatively large territories, are secretive, often inhabit inaccessible and remote areas, and are found in such low densities that population monitoring is very difficult.

Therefore, the majority of current raptor population information comes from data collected at migration funneling points (like Cape May, NJ), labor intensive monitoring programs like the Mid-winter Bald Eagle Survey or the Osprey and Bald Eagle reproduction survey. Additional information on raptor population trends and seasonal population indices can be acquired from the USFWS Breeding Bird Census and the Audubon Christmas Bird Count. As discussed earlier the breeding bird census has limitation because the only survey in this area occurs only in portions of the Indian River Estuary and Rehoboth Bay.

Because the Audubon Christmas Bird Counts can cover an area as large as 1,414 square miles and may be influenced by a variety of factors such as observer visibility, yearly changes in effort and weather conditions, etc., data collected from these surveys can only be used as a general index to local winter population levels.

Osprey nesting and reproductive success in Delaware has been monitored since 1978 (Gelvin-Innvaer, 1990). In general, long-term trends indicate that osprey populations in each bay have remained stable and the Rehoboth Bay continues to support a nesting population that is substantially larger than the other two bays (Figure 4.8-7 in 4.8-8), with the largest nesting congregation occurring in Delaware Seashore State Park, near Little Reedy Island. The results of the USFWS Breeding Bird Survey support the state survey results and show that the osprey breeding population in the eastern shores of the Indian River Estuary and Rehoboth Bay, appear to be stable or slightly increasing (Figure 4.8-9). The year population fluctuations observed in both surveys are believed to be the result of spring drought and/or inclement weather. Osprey nesting continues to occur primarily on privately owned land where duck blinds have been erected and, therefore, concern exists as to the ability of the state to provide adequate protection for current nest site locations (Gelvin-Innvaer, 1991a).

The northern harrier was once relatively a common breeder in the Inland Bay region (Mellon, 1990) but population declines that have been observed throughout the Northeast (USFWS, 1990) have also been recorded in Delaware (Mellon, 1990). The USFWS Breeding Bird Survey has failed to identify northern harriers breeding along the eastern shores of the Indian River Estuary

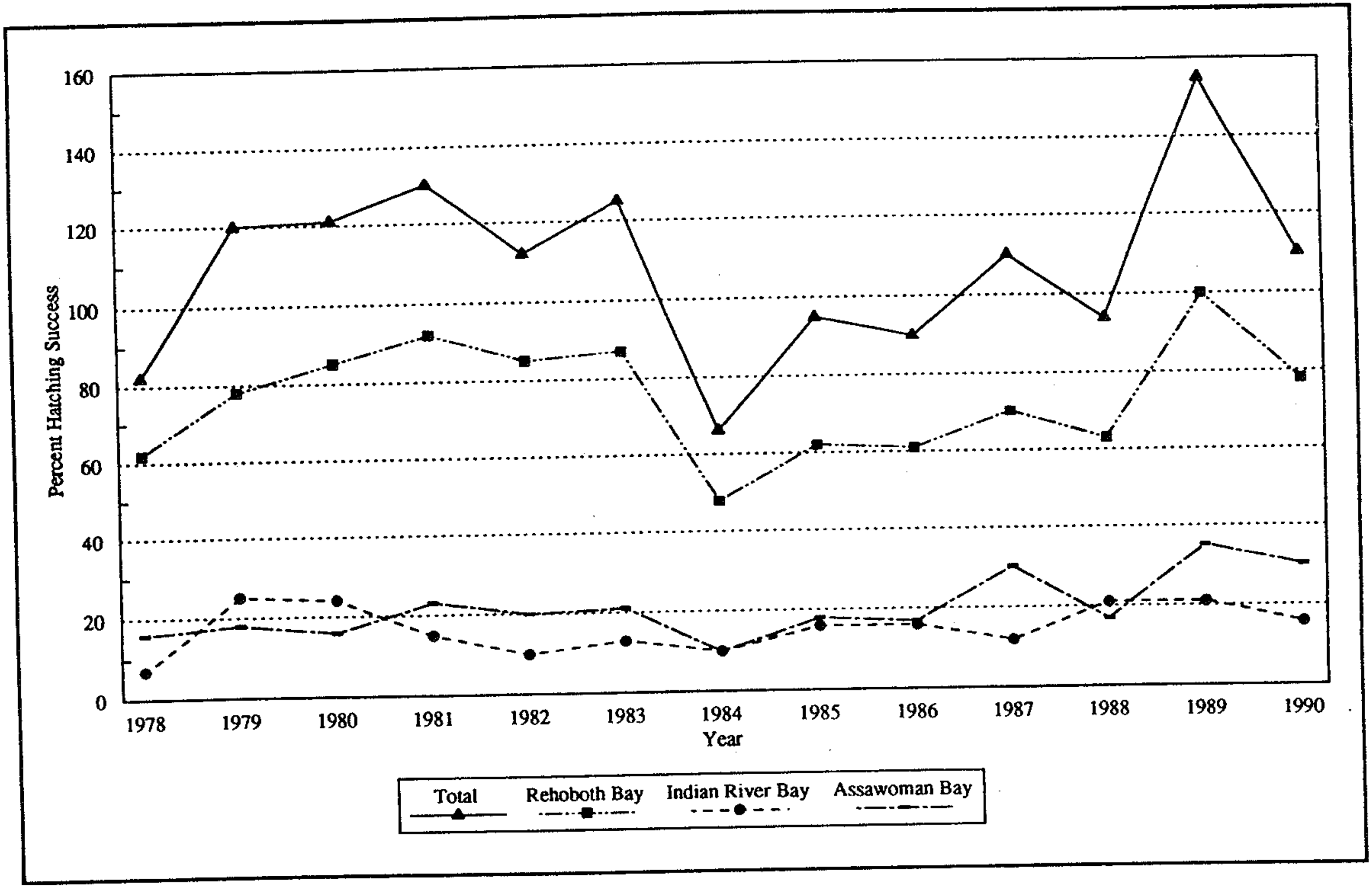

Figure 4.8-7
Number of Eggs Produced by Ospreys Surveyed in the Lower Bays of Delaware, 1978 - 1990
Source of Data: Innvaer, 1990

FhA57-D19

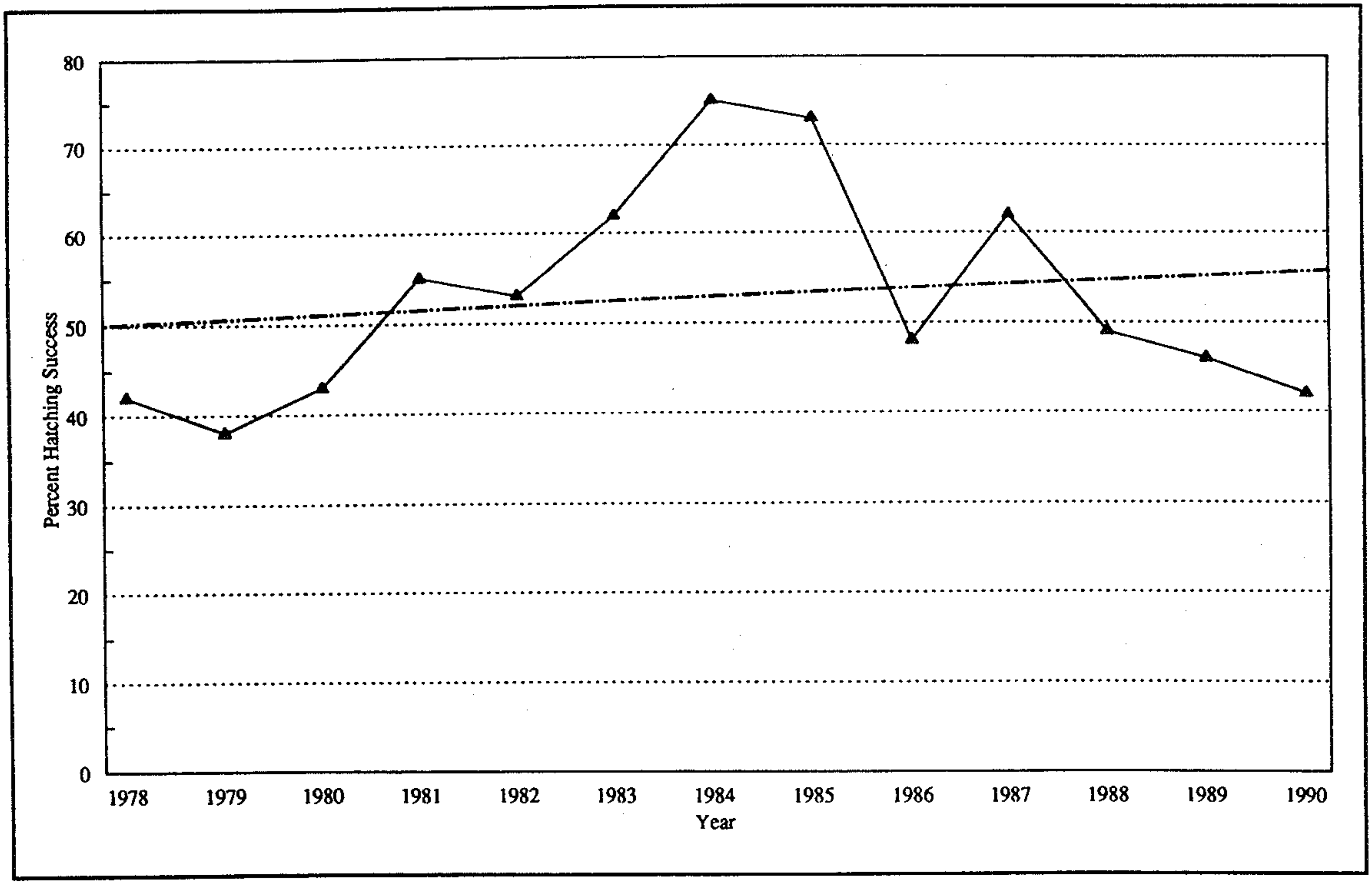

Figure 4.8-8

Hatching Success of Ospreys Surveyed in the Lower Bays of Delaware, 1978 - 1990

Source of Data: Innvaer, 1990

Fish56-D

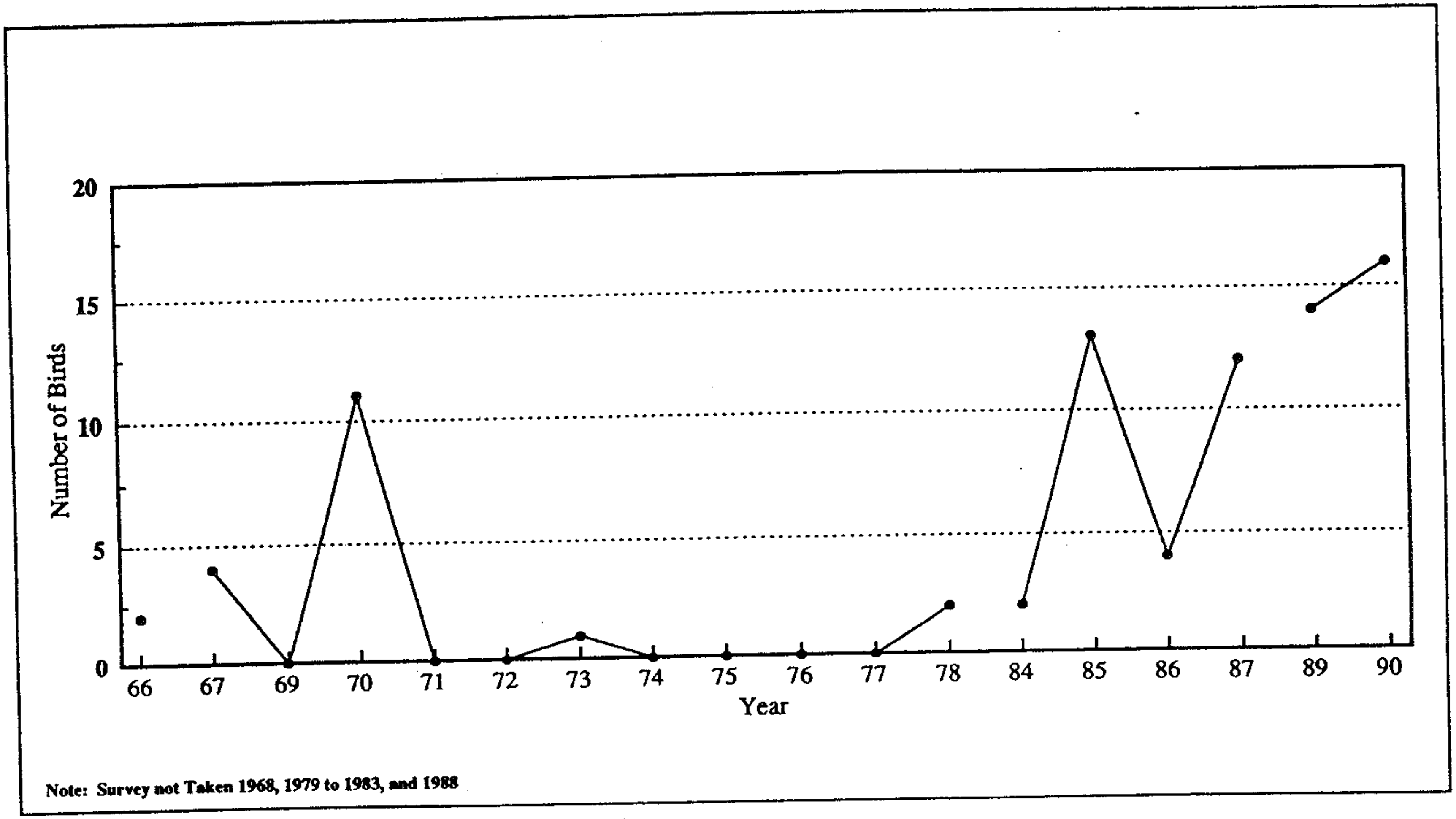

Figure 4.8-9
Osprey (18 Year Survey)
US Fish and Wildlife Service
Breeding Bird Survey

Fish49-D18

and Rehoboth Bay. The only source of quantitative population information for the northern harrier in this region is the Rehoboth, Delaware Audubon Christmas Bird Count. This count is conducted annually on one day in December, is centered near the middle of Indian River Bay, and encompasses the area within a 15 mile radius of the center point. The results of this Christmas Count and all Audubon Christmas counts are reported annually in a following-year issue of *American Birds*. The northern harrier counts from 1985 to 1987 are presented in Figure 4.8-10. While Christmas Bird counts data can provide a realistic indication of a winter-population within the surveyed area it should not be used to evaluate local, regional or national population trends (Bock and Root, 1981).

Bald eagle nesting and reproductive success in Delaware is monitored as part of Delaware's endangered species program. Aerial surveys are conducted annually during the nesting period (February to April) to identify active nesting attempts. Subsequent visits to the nest locations are performed to evaluate reproductive success (Gelvin-Innvaer, 1991b). The results of the bald eagle nest monitoring program have shown a gradual increase in nesting attempts and reproductive success in Delaware and are presented in Table 4.8-7. There are currently two active nesting locations that are associated with the Inland Bay region. While bald eagle reproduction for the state appears to be improving, the effects of toxins may still be contributing to reproductive failure at several nest sites in northern Delaware. In addition, human development pressures continue to threaten critical bald eagle habitats throughout the state. The Division of Fish and Wildlife has recommended that greater protection be afforded this species (Gelvin-Innvaer, 1991b).

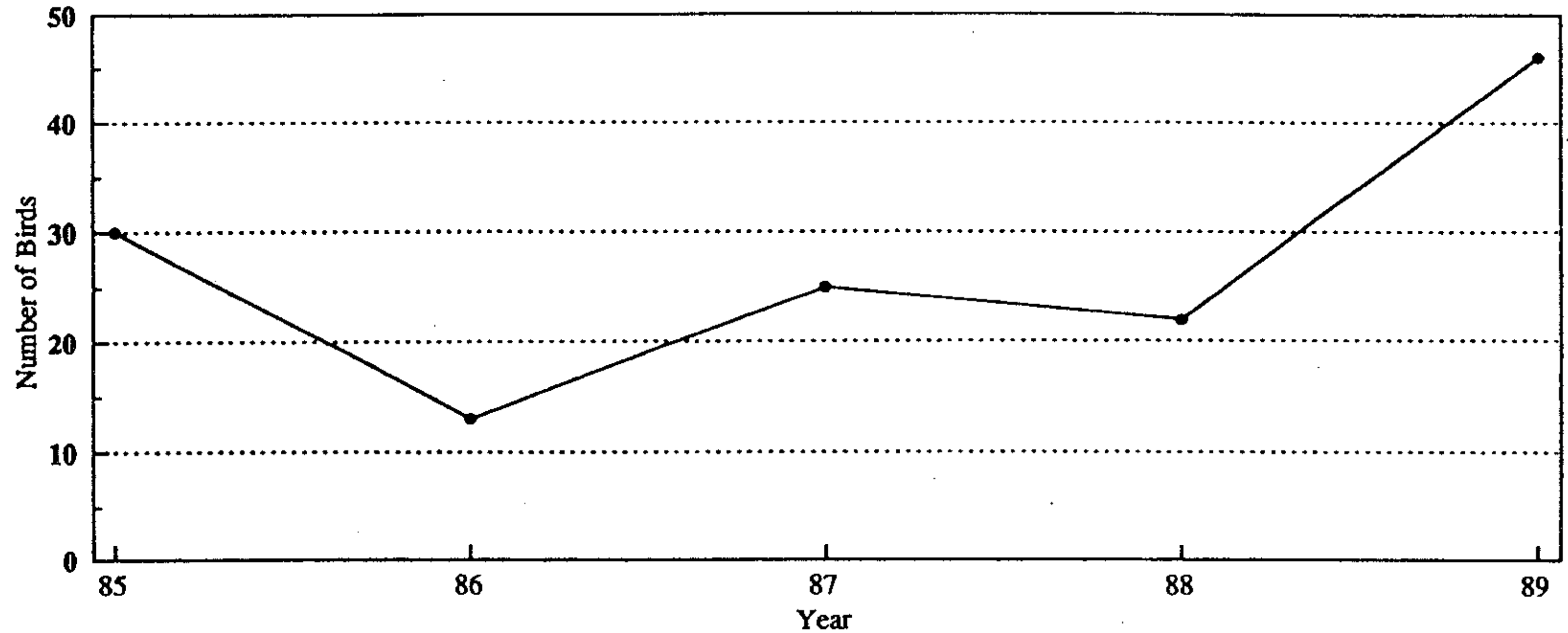

Figure 4.8-10
Northern Harrier (5 Year Survey)
Audubon Christmas Bird Count
Breeding Bird Survey

Fish50-D19

Table 4.8-7

Nest Success of Bald Eagles in Delaware, 1978-1991

Year	Active Nests	Successful[1] Nests	No. Fledged Nests	Unhatched Nests	Productivity[2]
1978	3	0	0	0	0.00
1979	2	2	2	0	1.00
1980	2	1	2	0	1.00
1981	4	2	3	0	0.75
1982	4	2	3	1	0.75
1983	4	3	4	1	1.00
1984	3	2	2[3]	0	0.67
1985	2	2	2[3]	1	1.00
1986	2[4]	2	5	1	2.50
1987	4	2	4	0	1.00
1988	6	4	5	3	0.83
1989	5	4	8	0	1.60
1990	6[5]	4	7	0	1.17
1991	7	4	8	0	1.14

[1] Young raised to banding age.
[2] Young/active nest.
[3] One additional young found dead, not included in data.
[4] One new nest located late in season after 1-2 young fledged, not included in data.
[5] First nesting attempt apparently failed. Successful renesting at same site. Productivity does not reflect initial failure.

Source: Gelvin-Innvaer, 1991

APPENDIX 4.8-A

BIRDS

BIBLIOGRAPHY

Ankney, C.D., Dennis, D.G. and R.C. Bailey. 1987. *Increasing Mallards, Decreasing Black Ducks: Coincidence or Cause and Effect?* J. Wildl. Manage. 51:523-529.

Bellrose, F.C. 1976. *Ducks, Geese and Swans of North America.* Stackpole Books, Harrisburg, PA.

Bock, C.E. and T.L. Root. 1981. "The Christmas Bird Count and Avian Ecology." In: C.J. Ralph and J.M. Scott (eds.). *Estimating Numbers of Terrestrial Birds. Studies in Avian Biology No. 6.* Allen Press, Inc., Lawrence, Kansas.

Conover, M.R. and G.G. Chasko. 1985. *Nuisance Canada Goose Problems in the Eastern United States.* Wildl. Soc. Bull. 13:228-233.

Conover, M.R. and G.S. Kania. 1991. *Characteristics of Feeding Sites Used by Urban-Suburban Flocks of Canada Geese in Connecticut.* Wildl. Soc. Bull. 19:36-38.

Conroy, M.J. and D.G. Krementz. 1986. *Incorrect Inferences Regarding the Effects of Hunting on Survival Rates of American Black Ducks.* Wildl. Soc. Bull. 14:326-328.

Conroy, M.J. and D.G. Krementz. 1990. *A Review of the Evidence for the Effects of Hunting on American Black Duck Populations.* Trans. North Am. Wildl. Nat. Resour. Conf. 55:501-517.

Dunne, P. 1984. *Northern Harrier Breeding Survey in Coastal New Jersey.* NJ Audubon Soc. 10:3-5.

Ferrigno, F. 1989. *New Jersey Aerial Surveys Nov. 1988-April 1989.* Project Number W-58-R-12. N.J. Dept. of Fish, Game & Wildlife.

Geis, A.D., Smith R.I. and J.P. Rogers. 1971. *Black Duck Distribution, Harvest Characteristics, and Survival.* U.S. Fish & Wildl. Serv. Spec. Sci. Rep. - Wildl. 139.

Geissler, P.H. and J.R. Sauer. 1990. "Topics in Route-regression Analysis." In: J.R. Saver and S. Droege (eds). *Survey Designs and Statistical Methods for the Estimation of Avian Population Trends.* U.s. Fish and Wildlife Serv., Biol. Rep. 90(1).

BIRDS

BIBLIOGRAPHY

Gelvin-Innvaer, L.A. 1990. Personal communications. Delaware Department of Natural Resources, Div. of Fish and Wildlife.

Gelvin-Innvaer, L.A. 1991a. *Reproduction and Survival of the Osprey in Delaware's Lower Bays.* Delaware Department of Natural Resources, Division of Fish and Wildlife.

Gelvin-Innvaer, L.A. 1991b. *Studies of the Nesting Biology of Bald Eagles.* Project E-1-13. Delaware Department of Natural Resources, Division of Fish and Wildlife.

Lincoln, F.C. 1990. *The American Brant-Living Bird on Museum Piece.* Audubon Mag. 52:282-287.

Martin, F.W., Posphala, R.S. and J.D. Nichols. 1979. "Assessment of Population Management of North American Migratory Birds." In: J. Cairns, G.P. Patil and W.E. Waters (eds). *Environmental biomonitoring, Assessment, Prediction, and Management: Certain Case Studies and Related Quantitative Issues. Statistical Ecology II.* International Co-operative Publ. House, Fairland, MD.

Mellon, R. 1990. *An Ornithological History of the Delaware Valley Region.* Cassinia 63:36-55.

Newton, I. 1979. *Population Ecology of Raptors.* Buteo Books, Vermillion, SD.

Nichols, J.D. 1991. *Science, Population Ecology, and the Management of the American Black Duck.* J. Wildl. Manage. 55:790-790.

Robbins, C.S., Bystrak, D. and P.H. Geissler. 1986. *The Breeding Bird Survey: Its First Fifteen Years, 1965-1979.* U.S. Fish Wildl. Serv. Resour. Publ. 157.

Rusch, D.G., Ankney, C.D., Boyd H., Longcore, J.R., Montalbano III, F., Ringelman, J.K. and V.D. Stotts. 1989. *Population Ecology and Harvest of the American Black Duck: A Review.* Wildl. Soc. Bull 17:379-406.

Sanderson, G.C. 1976. "Conservation of Waterfowl." In: F.C. Bellrose. *Ducks, Geese and Swans of North America.* Stackpole Books, Harrisburg, PA.

Sauer, J.R. and S. Droege. 1990. *Survey Designs and Statistical Methods for the Estimation of Avian Population Trends.* U.S. Fish & Wildl. Serv., biol. Rep. 90(1).

Stone, W. 1937. *Bird Studies in Old Cape May. An Ornithology of Coastal New Jersey.* The Academy of Natural Sciences of Philadelphia, Philadelphia, PA.

APPENDIX 4.8-A (Continued)
BIRDS
BIBLIOGRAPHY

U.S. Fish and Wildlife Service, 1984.

U.S. Fish and Wildlife Service, 1990.

Whitman, W.R. and R.V. Cole. 1988. "Waterfowl and Wetland Management in the Delaware River Basin." In: S.K. Majumdan, E.W. Miller and L.E. Sage (eds.). *Ecology and Restoration of the Delaware River Basin.* The Pennsylvania Academy of Science.

Whittendale, T.W. 1992. Delaware waterfowl survey data: 1975-1992. Delaware Depart. Nat. Resource, Division of Fish and Wildlife.

Whittendale, T.W. 1990. Personal communications. Delaware Dept. Nat. Resource, Division of Fish and Wildlife.

SECTION 4.9
MAMMALS

In general, Delaware's two large obligate wetland mammals, the beaver and the river otter suffered severe population declines since the arrival of European man, reflecting the effects of overharvesting and habitat loss and degradation. The following summaries are quoted from Kirkland and Serfass (1989). No references on mammals were found in the annotated bibliography and no accessible data were available during preparation of the report.

Beaver - In pre-Columbian times the beaver occurred in aquatic habitats throughout forested regions of North America (Genoways 1986). Extensive exploitation of beaver for their fur during the 1700s and 1800s led to the extirpation of this species from much of its original range. (Genoways 1986). During this century, beavers have been restored to many parts of their original range through restocking programs carried out by individual state wildlife agencies (Hill 1982). Today, descendents of reintroduced beavers occur in suitable habitats throughout Delaware. Highest population levels are sustained in the diverse aquatic habitats where conflicts with man sometimes occur as a result of the tree-cutting activities of beaver and flooding they cause.

Beavers prefer low gradient streams and rivers, small lakes, ponds, and marshes bordered by stands of preferred trees, such as aspen, willow, birch, maple, alder, cherry, and poplar (Klepinger and Norton 1983). Beavers cut trees close to the water's edge to forage on bark and twigs and for use in construction of dams and lodges.

Construction of dams by beavers influences the structure and dynamics of stream ecosystems. Water stored in beaver ponds recharges ground water supplies and maintains stream flow during dry periods (Finley 1937). Beaver dams conserve topsoil and reduce stream turbidity by filtering silt and organic debris from streams (Hill 1982). Organic matter trapped in beaver ponds stimulates primary production.

Lush herbaceous openings in forests created by beaver impoundments provide habitat for herbivores, such as white-tailed deer (*Odocoileus virginianus*), cottontail rabbits (*Sylvilagus spp.*), and meadow voles. In response to the presence of abundant prey populations, upland predators (e.g., foxes, hawks, and owls) are attracted to such habitats. Likewise, river otters, raccoons, and herons exploit beaver ponds to feed on fish, frogs, turtles, snakes, and other prey. Dead trees in beaver impoundments provide perches, nesting cavities, and feeding stations for a variety of species of birds. Waterfowl use beaver ponds for nesting sites and stopovers during migration. Thus, not only do the activities of beavers serve to foster the habitats required by this obligate wetland species, but they promote the development of habitats which can be exploited by a broad spectrum of other obligate and facultative wetland species.

River Otter - Historically, the river otter occurred in every major watershed in Pennsylvania, New Jersey, and presumably Delaware (Rhoads 1903). However, due to unrestricted trapping and water pollution, otter population declined drastically during the 1800s and early 1900s. Secluded sections of shoreline are repeatedly used by otters to congregate, feed, and defecate. River otter dens usually are located in riparian cover near the water's edge. In riverine habitats, otters use root systems in eroded stream banks and burrows constructed by muskrats and beavers as dens (Serfass *et al.* 1986). In lakes, marshes, and backwater sloughs along streams and rivers, abandoned muskrat and beaver lodges serve as dens for otters.

River otters feed almost exclusively on prey captured from aquatic habitats. Fish and crayfish are the most common prey species of river otters (Serfass 1984, Serfass *et al.*1986). Fishes such as suckers (Catastomidae), sunfishes (Centrarchidae), and minnows (Cyprinidae), which are numerous and slow moving, are taken most frequently by river otters. Depending upon habitat and season, river otters may supplement their diet with amphibians, freshwater mussels, aquatic insects, small mammals, and birds.

Small Mammals

The rice rat (*Oryzomys palustris*) inhabits salt marshes bordering Delaware Bay in southern New Jersey (Van Gelder 1984) and is common in the coastal marshes of the Delmarva Peninsula (Kirkland, unpublished data).

Star-nosed Mole - The star-nosed mole (*Condylura cristata*) is closely associated with water. This species prefers to construct its burrows in or near marshy areas or streams (Petersen and Yates 1980). It is an excellent swimmer and forages in water, feeding extensively on aquatic annelids and insects (Hamilton 1931). Thus on the basis of its ecological distribution, food habits, and adaptations for a semi-aquatic existence, the star-nosed mole is designated herein as an obligate wetlands species.

Muskrat - Muskrats are common and widely distributed in aquatic habitats (Merritt 1987). They achieve their highest densities in marshlands and other standing water habitats where abundant stands of emergent herbaceous vegetation are available to provide food, shelter, and materials for construction of lodges (McCord & Stardom 1983). Consequently, the highest densities of muskrats occur in areas which are dotted with lakes, swamps, marshes, and associated wetlands. The greater abundance of muskrats in standing compared to flowing waters also has been documented. Muskrats generally prefer meandering streams and rivers having numerous backwater coves and suitable banks for the construction of burrows (Doutt *et al.* 1977, Brooks and Dodge 1986).

Unlike other obligate wetland mammals, muskrats are adaptable and often do well in aquatic habitats disturbed by man. For example, they occur at high population densities along waterways coursing through agricultural areas where deforested riparian habitats, overgrown with herbaceous vegetation, provide suitable habitat. Unfortunately, in agricultural areas, muskrats are subjected to a variety of herbicides and pesticides which wash into waterways from adjacent fields and orchards. Little is known about either the immediate or long-term effects that such chemicals may have on muskrat populations, and research in this area is needed. In addition to thriving in agricultural areas, muskrats do well in farm ponds, drainage ditches, earthen canals, and other aquatic habitats created by man's activities (McCord and Stardom 1983).

Some human-induced habitat changes are detrimental to muskrats, especially those associated with the drainage and filling of wetlands for housing, industrial, and other human development. Likewise, riprapping and concrete channelization of streams prevent plant growth and burrowing of muskrats.

4.9 A

Genoways, H.H. 1986 Causes for species of large mammals to become threatened or endangered. pp 234-251 In Endangered Species Programs in Pennsylvania and Other States, causes, issues and management. Penna. Acad. Sci. Easton, Pa. 519 p

Hill, E.P. 1982 Beaver. In Wild Animals of North America. Johns Hopkins Univ. Press, Baltimore, MD. 1147p

Klepinger, K.E. and N. Norton 1983 Beaver. In North American Furbearers. Int. Assoc. Fish and Wildlife Agencies, 223p

Finley, W.L. 1937 The beaver: conservor of soil and water. Trans North Amer. Wildlife Conf. 2:295-297.

Rhoads, S.N. 1903 The mammals of Pennsylvania and New Jersey. privately printed, Phila. 266p

Serfass, T.L. 1984 Ecology and feeding relationships of river otter. Masters Thesis. East Stroudsberg Univ. East Stroudsberg, Pa. 115p

Kirkland, G.L. and T.L. Serfass 1989 Wetland mammals of Pennsylvania. In Wetlands Ecology and Conservation Pennsylvania Acad. of Science, 396p

DELAWARE INLAND BAYS

SECTION 5

CHARACTERIZATION INTEGRATION

Submitted to University of Delaware

by

ROY F. WESTON, INC.

March 1993

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SECTION 5

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5.1 INTRODUCTION

Major elements of the history of the Inland Bays are summarized in Figure 5.1. Early in their history, the watersheds were exploited for timber, charcoal, and bog iron. Over 40 mills operated along the creeks. Once the land was cleared (and drained, if necessary), subsistence farming began. Without modern agricultural practices, the soils were exhausted and abandoned. Sedimentation increased in the Bays as a result of erosion. By the civil war, most of the land that was suitable for farming had been cleared. Today, two crops are usually planted in these same fields using state-of-the-art practices (irrigation, fertilizer and pest control) to yield exceptional production. A huge poultry industry has developed in the watersheds during the last 50 years. The population of the watershed increased to about 30,000 by 1810, and took over 100 years to double to 60,000 in 1930. Then, it doubled again by 1990. The tourist industry has developed near the water and the summertime population may triple the resident population. Indian clam and oyster middens are abundant. Early navigators encountered problems navigating Indian River Inlet which was shallow, narrow and occasionally closed. Navigation of the inlet was especially troublesome in the 18th century and from 1900 to 1940. In the "History of the State of Delaware" (1870), Francis Vincent states:

> "This inlet rarely ever contains more than three feet of water, and after a great easterly storm its mouth is generally stopped up by sand washed into it from the working of the ocean, after which the waters of the bays again tear themselves a passage and wash the sand which has filled up the inlet into the ocean... The small depth of water at the Indian River Inlet creates the necessity of forcing the shallops over the bar by kedging."

We have no scientific measurements of water quality in the Inland Bays before 1950 and

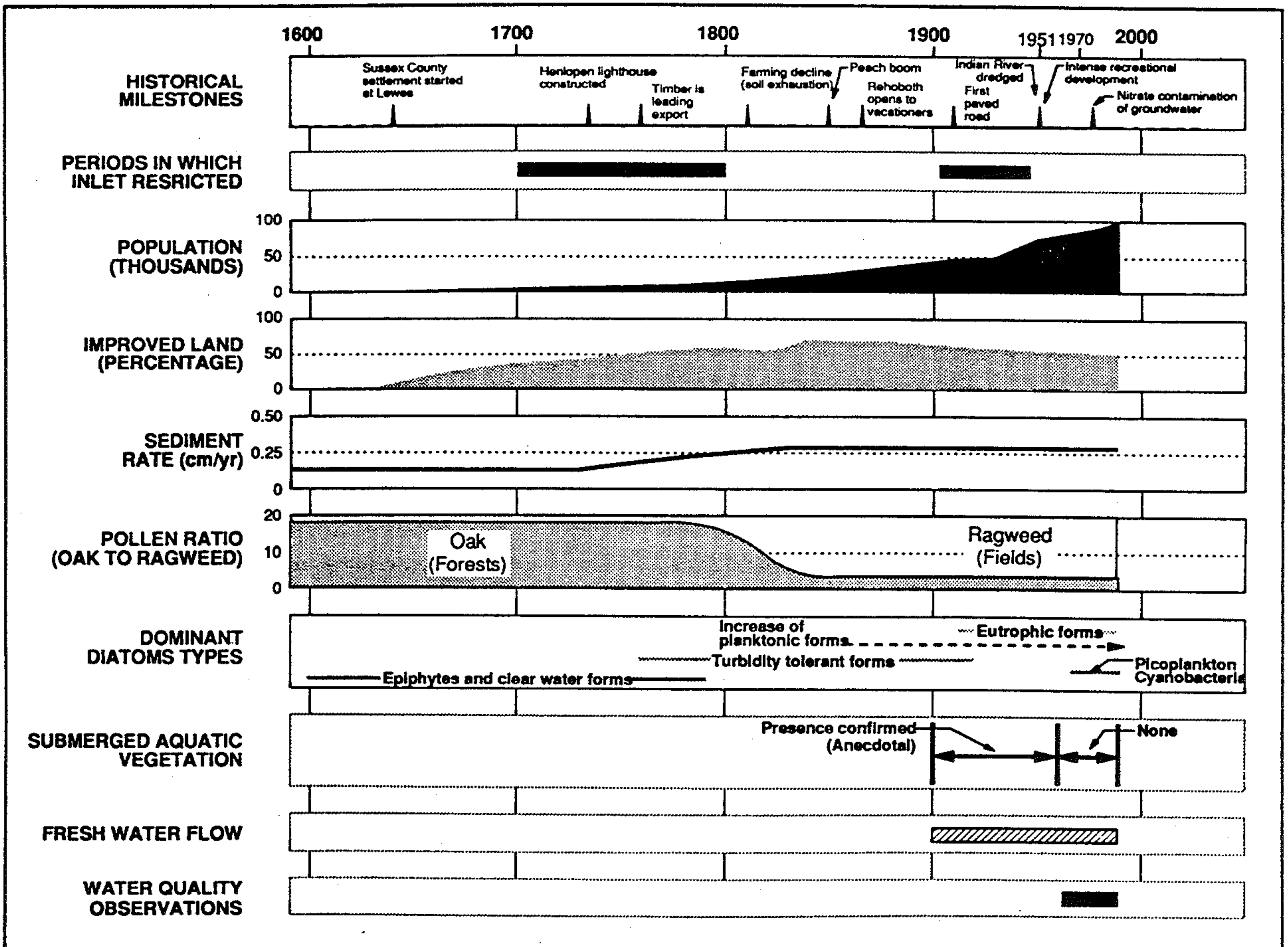


FIGURE 1 HISTORICAL TREND COMPARISON

must rely on anecdotal information to infer the character of the systems. Beasley (1987) analyzed the pollen and the diatoms from a sediment core in Rehoboth Bay. Oak pollen indicate forests, ragweed pollen indicate fields. Based on radiometric dating of samples from the core, a chronology of land use and water quality was developed for the period 1600-1950, for which we have no other data. During the late 18th century, timber was the leading export, the sedimentation rate doubled in the Bays and the dominant pollen switched from oak to ragweed. The dominant diatoms in Rehoboth changed during that time from epiphytes and clear water forms to turbidity tolerant forms. The latter half of the 19th and the 20th centuries are characterized by the increasing abundance of eutrophic forms of diatoms concurrent with the application of modern inorganic fertilizers, the development of a major poultry industry and a significant summer tourist industry.

Delaware's Inland Bays have a drainage area of about 300 square miles, a water surface area of 32 square miles, a marsh area of 9 square miles, a mean low water volume of 4 billion cubic feet and a fresh water discharge of 300 cubic feet per second. Almost 30 square miles of the Inland Bays are classified as shellfish waters, of which 19 square miles are approved for shellfishing. There are about 126 people per square mile of watershed and land is about 10% urban and 46% agriculture.

The Bays are beset with a series of problems similar to other mid-Atlantic estuaries. The Delaware Inland Bays Management Committee had identified several major problems that require immediate attention. These include circulation and flushing, sea level rise, eutrophication, sedimentation, habitat loss or modification, and pathogens. Our purpose in this document is to examine the inter-relationships between water quality, habitat and living resources of the modern Inland Bays and to integrate the relations, where appropriate. The principal data sources that have been used include Dobroski (Section 4), Maurmeyer (Section 3), and Smullen (Section 2).

Historical accounts and the records preserved in sediment cores demonstrate a fragile link between the Inland Bays and the sea. The inlet has deepened and shoaled, temporarily closed, and migrated along the barrier system (Figure 5.2). For five years, 1935-39, there was no free connection between the Inland Bays and the ocean. Marine and estuarine organisms and habitats within the Bays were destroyed and replaced by fresh water organisms. Water levels in the Bays rose, flooding nearby fields, and freshwater mosquitoes became abundant. A new channel to the ocean, protected by jetties, was completed in 1940. The present Indian River Inlet provides the first stable connection between the upland and the sea, creating more or less permanent estuarine conditions.

5.2 CIRCULATION AND FLUSHING

The Inland Bays, as we know them, began in 1938-40 with stabilization of the inlet location by construction of rubble jetties. After the inlet was opened, it and the area immediately surrounding it began to change shape to equilibrate with the currents produced by the fresh water draining from the land and the tides and waves present in the

Figure 2 Indian River Inlet, 1931, viewed from the east. The dredged channel is 100 feet wide.

ocean. Sand in the surf zone along this coast is, on average, transported to the north. The south jetty and strong currents through the inlet obstructed its passage, and the beach south of the inlet began to grow seaward. The beach north of the inlet was starved of its supply of sand and began to erode. As the south beach grew seaward toward the tip of the south jetty, sand bypassed the jetty and was swept into the inlet on flooding tide, creating a flood tidal shoal in the bay beyond the inlet. On ebbing tide, the sand was swept seaward and deposited on the ocean bottom, creating an ebb tide shoal. The beach north of the inlet continued to erode due to a lack of sand.

At the same time that the sand flow along the ocean coast had been affected, the inlet itself was changing. The tidal range in the coastal ocean at the mouth of Indian River inlet varies between 4.0 feet (mean) and 4.7 feet (spring). The inlet serves as a channel through which this tidal wave propagates twice a day. If the channel is large the tidal wave passes through unattenuated, generating mild currents and the tidal range in the Bays is similar to the range in the ocean. If, however, the trench is small, a large head is created between the two water bodies, currents become strong, and the tidal wave is attenuated within the Bays. The inlet was dredged and the sides were armored with stone jetties, 500 feet apart fixing it in space. The only adjustment that the inlet could make was to erode its sandy bottom, increasing its depth. The average depth of the inlet was 13 feet in 1940, increased to 22 feet in 1950, 30 feet in 1967, and 42 feet in 1975. The sand eroded from the inlet bottom was swept into the bay or ocean and was added to the sand derived from the ocean beaches, further increasing the size of the ebb and flood tidal deltas. As soon as the jetties were completed, severe erosion began at their bayward ends. This flanking was probably caused by eddies scouring the bank as the flood tidal currents exited the jetties and by refraction of waves obliquely entering the inlet. The channel in the bay beyond the jetties widened almost 600 feet during the first 18 months that the inlet was open. Sheet-piles and rip-rap were placed along these rapidly eroding areas in 1943 and 1963, and the erosion was merely displaced landward (Raney, et al., 1990). The eroded sediment accumulated in the flood tide delta.

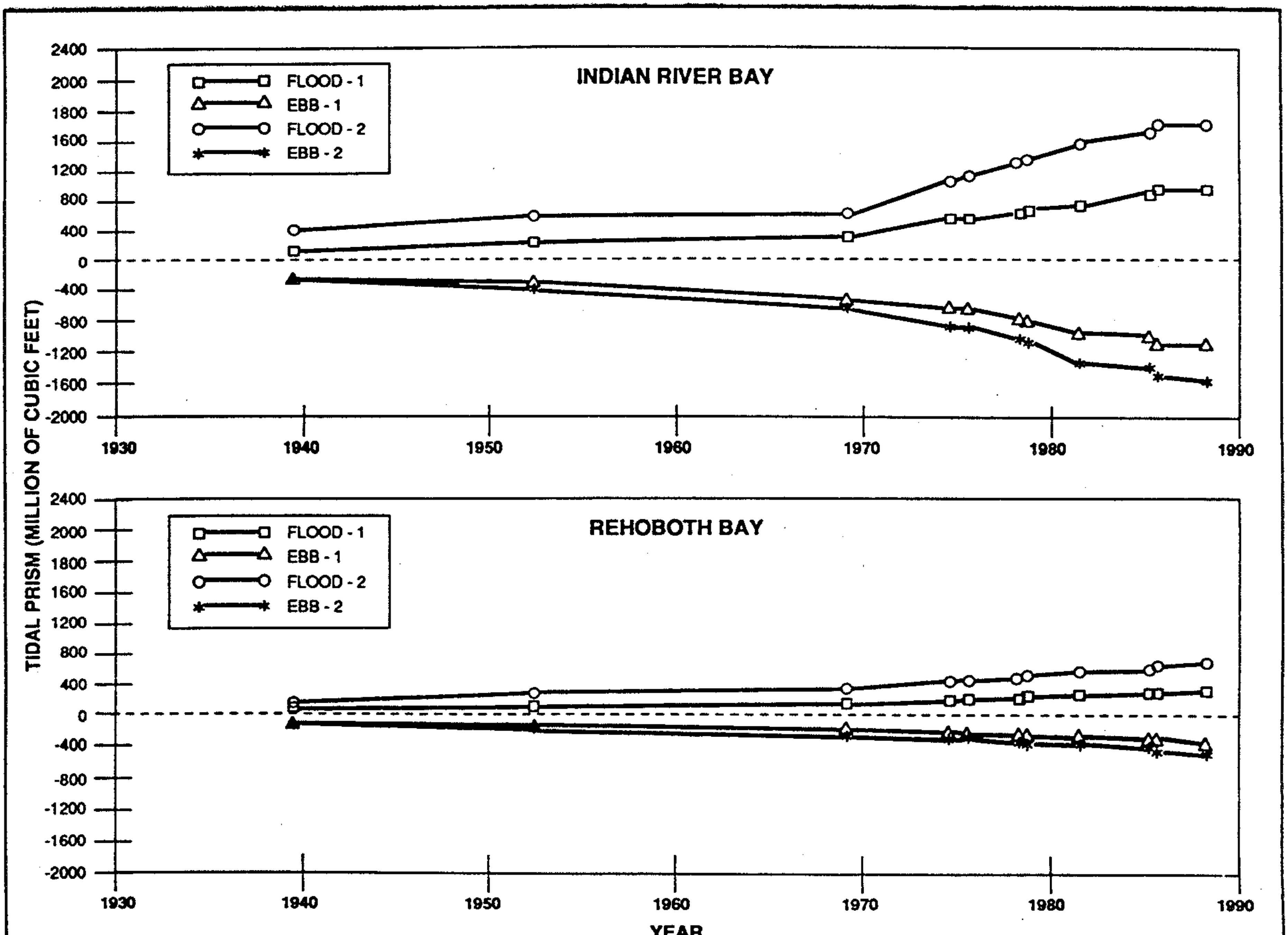
After only 12 years, the flood tide delta was sufficiently large that navigation was impeded. In 1951, over 1.1 million cubic yards of sand were removed to construct the channels from west of the inlet bridge, to the head of tide at Millsboro, as a navigation project" ...to keep the Inlet from forming an inner bar..." (Kaplovsky & Aulenbach, 1956). Over 3.2 million cubic yards of sand has been dredged from the channels around the inlet since the 1951 dredging. The sand has usually been pumped to the ocean beach to the north of the jetties in an attempt to reduce the severe beach erosion that continued to plague the area. Recently, a system has been installed to pass sand from the south beach to the north beach by way of a pipeline across the inlet. This system is designed to arrest the severe erosion problem north of the inlet.

As the tidal wave propagates through the inlet, it moves water into the Bays on flood tide and out of the Bays on ebb tide. The volume of water that is moved is called the tidal prism. On flood tides, in addition to water, substances such as salt and marine organisms are carried into the Bays; on ebb tides, some of these substances as well as estuarine organisms and substances from land drainage are lost to the sea.

In the Inland Bays, the amount of water that passes through the inlet has increased from 1940 to the present. The computed changes in tidal prism during the modern history of the Indian River Inlet are presented in Figure 5.3 for the Inlet and for Rehoboth Bay. The volume of salt water roughly tripled from 1939 to 1969, then almost doubled again from 1969 to 1988. Raney et al. (1990) find, in their model runs, that the inlet is likely to continue to deepen and increase the tidal prism in the future.

As the inlet has deepened and the cross-section has increased, the quantity of water passing through the inlet over 1 tidal cycle has increased from roughly 13,000 cubic feet per second (1939), to 37,000 cubic feet per second (1969) to 61,000 cubic feet per second (1988). These estimates are based on the model runs developed by Raney et al. (1990). In contrast to these increasing volumes of salt water flushing through the inlet, the fresh water discharge from the entire combined watersheds has remained constant and seldom exceeds 300 cubic feet per second, except during extreme events.

The changes in the tidal prism (4.5 times at Indian River Inlet and 3.8 times entering Rehoboth Bay) that have been calculated using the computer model, as well as the dredging (in 1951) of a channel 9 feet deep through Indian River Bay from the inlet to Old Landing and then 4 feet deep to the base of the dam at Millsboro have undoubtedly



Source: Adapted from Raney et al, 1990

FIGURE 3 VARIATION OF INDIAN RIVER BAY AND REHOBOTH BAY TIDAL PRISM

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increased the flushing of these bays. In addition, both processes have a tendency to increase the salinity, particularly in low salinity areas. It is possible to compute changes in the salinity in the Raney model, but this was not done in the 1990 study. We have collected and plotted the historical salinity data that are available. Since 1970, from all of the bays, we can find no seasonal or annual pattern of increase in salinity. This is not surprising for the areas near the ocean that already had high salinities. However, we would expect a trend of measurable salinity increase in the low salinity areas. A trend was not observed, though there are few sampling events. We do note that there has not been an observation of zero salinity in the spring at the first station downstream (about 600 yds) from Millsboro Pond since 1983 and that there have only been six zero salinities observed in the 18 years during which spring observations have been made.

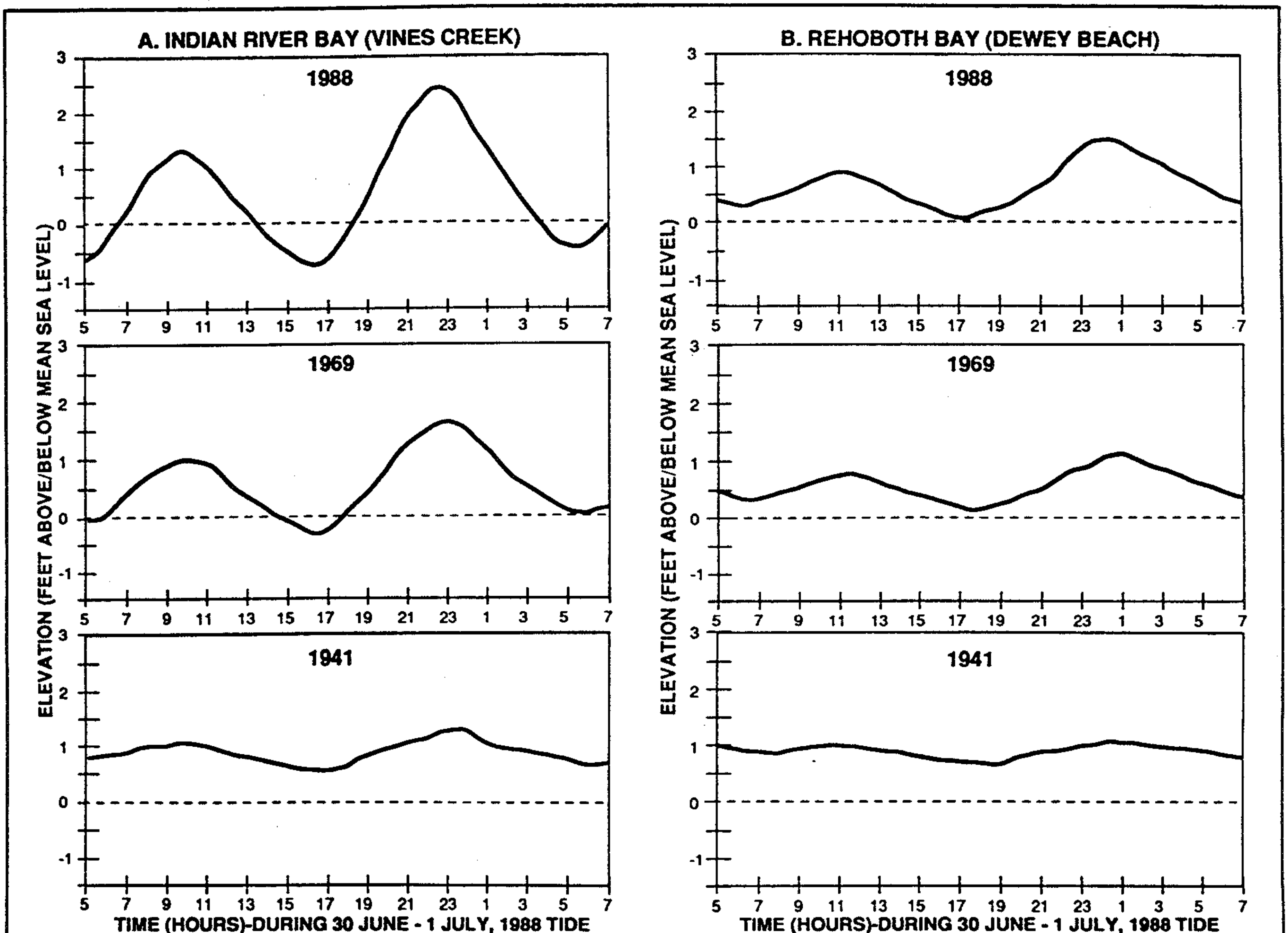
5.3 PRESENT SEA LEVEL RISE

The long-term rate of sea level rise is about 0.5 feet per century (.06 inches per year) along this coast (Kraft et al, 1973). The long-term average is subject to short-term fluctuations of large magnitude. Hicks (1972) reported a rise of 3 inches in 8 years during the 1960's (0.3 inches per year). Total sea level rise on the coast during the 50 years (1940-1990) since stabilization of the inlet is about 4 inches. Thus, if no other processes were operating, the Bays should be about 3 or 4 inches deeper now than in 1940. But other processes have been occurring to make the Bays shallower. The Inland Bays have been filling with sediment. Fine sediment generally comes from upland drainage and from shore erosion and is deposited in quiet areas (creeks, deep areas with low currents, and in marshes). The rate of sedimentation estimated by various authors (summarized in Maurmeyer) for these fine sediments is about 0.1 inches per year or 5 inches in the 50 years since 1940. In addition, great storms wash sand over the barrier beaches into the Inland Bays. The rate of accumulation of these sandy sediments, found principally along the barrier and near the inlet, is about double the sedimentation rate for the muds. Note that this sedimentation is episodic; all 10 inches of sand may be deposited in one 50-hour time period during the 50-year interval. In summary, there has been on average between 5 and 10 inches of sediment deposited in the Inland Bays and about 4 inches of sea level rise during the last 50 years. The Bays have shoaled relative to the computed mean bay water level between 1 and 6 inches, on average. Any local area may have shoaled more or less than this average.

In addition to shoaling of the Bays due to sedimentation, the tidal amplitude has also been modified. The cross-sectional area of the inlet has increased by 4 times since 1939, exclusively by increasing inlet depth so that now ..."there exists the possibility that the structural integrity of a major highway bridge over the inlet may be compromised" (Raney et al., 1990). As the cross section increased over time, the tidal wave passing through the inlet increased and was propagated through the Bays causing higher high tides and lower low tides. Raney, et al. (1990) developed and verified a model of the change in surface elevation in the Bays caused by the enlarging cross-section of the inlet. We have selected three (3) of the twelve model runs to demonstrate the spring tide levels at Vines Creek in Indian River Bay and at Dewey Beach in Rehoboth Bay (Figure 5.4). The same ocean tidal wave acting as the boundary condition and moving through the 1941, 1969 and 1988 inlet produces higher highs and lower lows with an enlarged inlet. In 1941, the spring tide range at the mouth of Vines Creek was 0.5 feet and increased to 3 feet in 1988. For Dewey Beach, the difference for the same time period was from 0.25 feet to 1.5 feet. This means that spring low tide elevations are lower (9 inches for Rehoboth and 12 inches for Indian River Bay) now than they were 50 years ago. Numerous anecdotal testimonials have been presented suggesting that the Bays are becoming more shallow. In addition to shoaling of the Bays caused by sedimentation, the water levels at low tide are lower at present than they were historically and the Bays are more shallow for about half of the time. In systems where the mean depth is only 3 feet, such changes in tidal range can dramatically affect whether one is ... "afloat or aground".

5.4 EUTROPHICATION

"...Eutrophic conditions typify the region;...High nutrient concentrations support high phytoplankton biomass;...Bloom forming blue-green algae were common in the (upper) Indian River stations..." (Sellner, 1988). Fish kills, described as massive (Tyler, 1989), occurred in the May-June periods of 1987 and 1988 in Indian River. The kills occurred during red tides, but neither a specific organism (toxic algae) or condition (low oxygen) could be shown to be the cause.



Source: Adapted from Raney et al, 1990

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FIGURE 4 COMPUTED CHANGES IN HISTORIC TIDE HEIGHTS FOR INDIAN RIVER BAY (A) AND REHOBOTH BAY (B)

Nutrient concentrations have declined substantially during the last twenty years in some regions of the Inland Bays. Middle Indian River Bay is an example of the change in nitrogen since 1970 (Figure 5.5). The sum of the two curves (Kjeldahl and Ammonia) is a reasonable approximation of total nitrogen because nitrate is almost always less than 0.1 ppm. While Kjeldahl N still exceeds 1 ppm, ammonia N has declined from 2 to 0.2 ppm from 1970 to 1990. Smullen (1992) has discussed potential explanations for the decrease in ammonia including analytical problems, source reductions, and process changes. We cannot distinguish among these possibilities. Kjeldahl nitrogen has remained relatively high in upper Indian River, yet there appears to be a decrease by a factor of two in Kjeldahl nitrogen in mid Indian River Bay. This decrease in nitrogen is coincident in magnitude and direction with a doubling of the tidal prism during the same time period and strongly suggests that dilution of the mesohaline and polyhaline waters of the Inland Bays with ocean water is a major cause of nutrient concentration reduction. Lacoutre and Sellner (1988) observed a statistical decrease in chlorophyll concentrations in these same areas at the same time, while not detecting measurable chlorophyll changes in upper Indian River. Beasley (1987) noted a decrease in nutrient favoring diatoms in the top of her core from central Rehoboth Bay. We conclude that improved water quality (N and chlorophyll) for the polyhaline and mesohaline areas of the Inland Bays has resulted from the increased flushing of these areas.

The balance between nutrient concentrations and estuarine resources has been developed in the Chesapeake and is generally applicable to the Inland Bays (Table 5.1-A). The

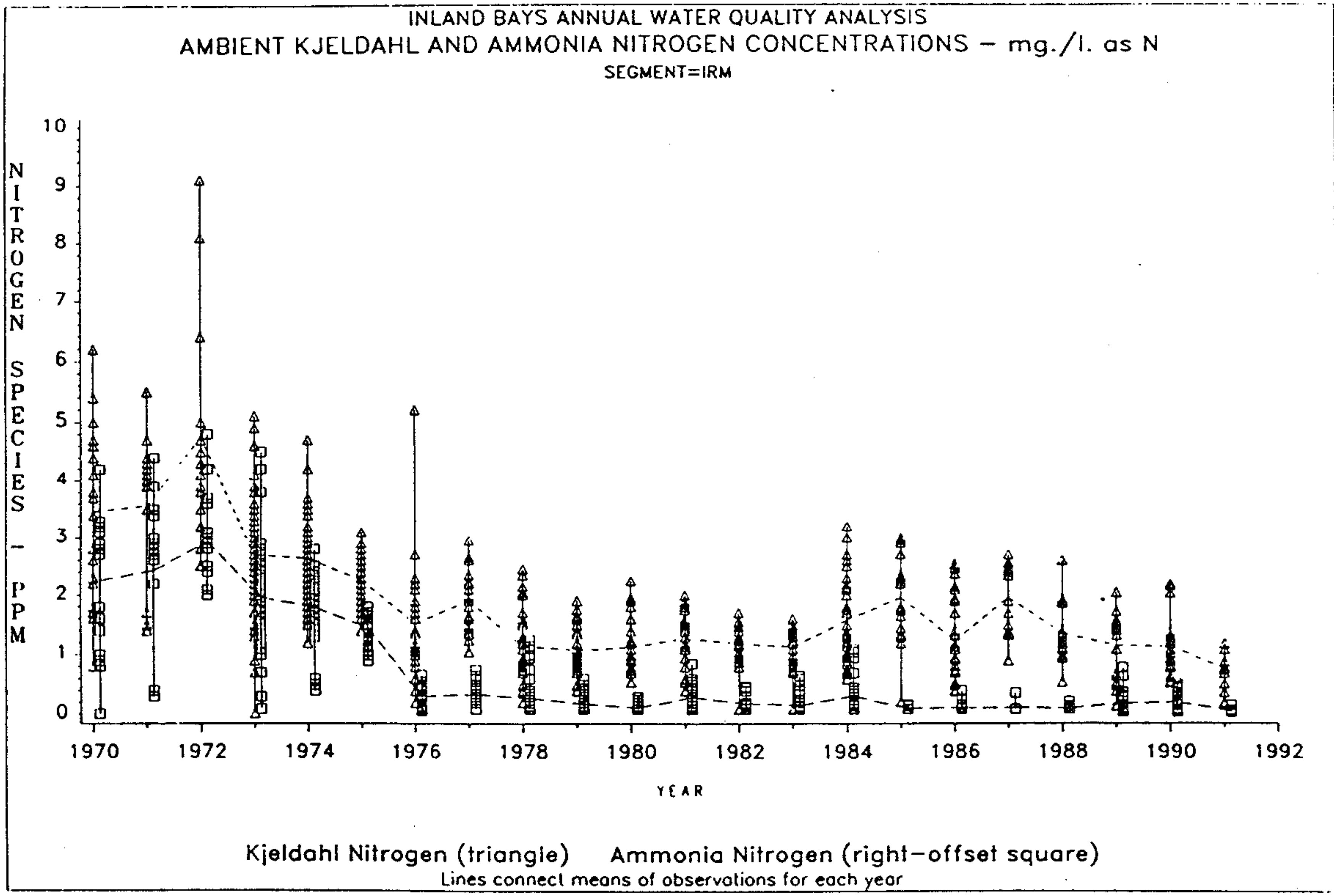

FIGURE 5 MIDDLE INDIAN RIVER BAY NITROGEN CONCENTRATION

attainment of certain water quality criteria do not necessarily ensure that environmental or resource objectives will be achieved. Inferior water quality will not support certain resources, but other environmental factors may prevent resource recovery even if water quality is improved. With the afore-mentioned caveats in mind, we have computed the status of nitrogen and phosphorus concentrations for the Bays and have applied the Chesapeake water quality measures. In general, we find that Rehoboth quality is healthy to fair, Assawoman and Indian River quality ranges from degraded to healthy. Further, the upstream two-thirds of Indian River Bay seems to be most degraded, especially because observed nutrient concentrations are exceptionally high for relatively saline portions of estuaries.

To assist managers to control or restore water quality in the Inland Bays, we have examined nitrogen and phosphorus concentrations to determine which might be the limiting nutrient, that is, the one by which phytoplankton growth is constrained. There are three methods for estimating whether nitrogen or phosphorus is limiting, the use of half-saturation constants, N/P ratios, and nutrient additions. Half-saturation constants were estimated for the Inland Bays by Lacoutre and Sellner (1986). They found that every measurement (136) that they made indicted that phosphorus was limiting. They and we used N/P ratios to estimate the limiting nutrient for the Inland Bays. Lacoutre and Sellner found that phosphorus was limiting almost all of the time during 1985-86. In Table 5.1-B, we have estimated the N/P ratio for all samples (103) in the database for 1990. For the mean values for all Inland Bays segments, the ratios exceed 20, an

TABLE 1-A

Inland Bays Environmental Quality Classification[a] Scheme

Class	Quality	Objectives	TN[b]	TP[b]
A	Healthy	Supports maximum diversity of benthic resources, SAV, and fisheries	<0.6	<0.08
B	Fair	Moderate resource diversity, reduced SAV, chlorophyll occasionally high	0.6-1.0	0.08-0.14
C	Poor	Significant reduction in resource diversity, loss of SAV, occasional algae blooms	1.1-1.8	0.15-0.20
D	Degraded	Limited pollution tolerant resources, massive, persistent blooms	>1.8	>0.20

[a] Based on Chesapeake classification scheme, USEPA, 1983
[b] TN and TP are total nitrogen and total phosphorus per liter

TABLE 1-B

Segment	TN[1]	TP[1]	Class[2]	N/P[3]
Rehoboth				
North	0.8	0.08	B	22
Middle	0.9	0.09	B	22
South	0.8	0.07	B-A	25
Masseys	0.7	0.08	B	19
Inlet	0.7	0.07	B-A	22
Assawoman				
North	1.6	0.11	C-B	32
Middle	1.9	0.09	D-B	46
South	1.1	0.06	C-A	40
Indian River				
Fresh	2.8	0.02	D-A	308
Upper	1.8	0.02	C-A	198
Middle	1.6	0.09	C-B	39
Lower	0.6	0.06	B-A	22

[1] Annual mean total nitrogen and phosphorus (mg/L^{-1}) for 1990.
[2] Class from Table 1-A, multiple measures may be used where N and P classes differ.
[3] N/P ratios (atomic) calculated from TN and TP values.

indication of phosphorus limitation. Recently, Ullman and Geider (personnel communication) have conducted nutrient enrichment experiments on phytoplankton populations in Rehoboth and Indian River Bays. They found that phosphorus was limiting in Indian River at the Delmarva Power Station, that nitrogen and phosphorus were co-limiting in eastern Indian River Bay and that although nitrogen and phosphorus were co-limiting in Rehoboth Bay, nitrogen was more limiting.

The sources of nutrients to the Inland Bays have been estimated by Ritter (1986) (Table 5.2). For Indian River and Assawoman Bays, the principal source of both nitrogen and phosphorus is agriculture through the application of inorganic fertilizers and manures. These practices, applied to the sandy, permeable soils of the watershed, have resulted in widespread contamination of the unconfined aquifer by nitrates. For Rehoboth, agriculture is the principal source for nitrogen but point sources are the major source of phosphorus, almost all of which originates from the Rehoboth Wastewater Treatment Plant.

The nitrates are transported to the Bays by way of groundwater discharge directly to the Bays, baseflow discharge to streams and direct runoff. Over 20% of the nitrates appear to be transported through direct groundwater discharge, though there is a question of whether the nitrates are connected to nitrogen gas as they pass through the bottom sediments of the Bays. Phosphorus, also applied as a fertilizer and manure, is fairly insoluble in fresh water and generally attaches to particles. The phosphorus concentration

TABLE 2

Annual Nitrogen and Phosphorus Loadings to the Inland Bays During a Normal Rainfall Year

Nutrient Sources	Indian River Bay		Rehoboth Bay		Little Assawoman Bay	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus
Boating	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Forest	11.0%	19.2%	7.4%	9.4%	6.7%	19.5%
Rainfall	6.2%	8.6%	8.8%	6.9%	12.8%	11.5%
Septic Tanks	16.0%	9.3%	11.2%	3.8%	14.6%	5.6%
Urban	9.8%	8.6%	11.7%	5.9%	11.2%	10.8%
Point Sources	12.5%	15.0%	27.3%	56.9%	0%	0%
Agriculture	44.6%	39.4%	33.0%	17.0%	54.7%	52.6%
Total Mass[1] Metric tons	843	38	457	36	125	8
Direct Groundwater Discharge[2]	250	NA	46	NA	NA	NA

[1] Data from Ritter (1986)
[2] Data from Andres (NA - not available)

in both fresh waters and estuaries seems to be fairly constant and controlled by a buffering mechanism, that is, the dissolved phosphorus is maintained at concentrations around 0.04 ppm by solution from particles or adsorption onto particles (Aston, 1980). Adsorption onto particles is at a maximum in the pH range of 3-7, so that phosphate removal is maximized in fresh and brackish waters. The general behavioral differences in the transport mechanism for nitrogen (primarily dissolved and non-point source) and for phosphorus (generally particulate or point source) lead to potential strategies for control. Inland Bays managers should examine strategies that keep soils and sediments on the land and remove as much phosphorus as possible from point sources, thus reducing, in the short term, the phosphorus input to the Bays. For nitrogen, an aggressive plan to control manure and fertilizer application is needed. A note of caution is warranted; the Chesapeake Program adopted a strategy to reduce nitrogen and phosphorus loads by 40% in a decade. While they are on schedule for phosphorus control, nitrogen loads have increased slightly, in spite of significant efforts at reduction. Recently, Houlahan et al., (1992) estimated the impact of Maryland's Critical Area Act on nutrient delivery to a tributary of the Chesapeake. The authors found that present nonpoint nutrient and sediment loadings could be reduced by 20-30%, through implementation of the Act, while preserving agricultural lands and allowing limited residential and urban development. Perhaps, there has been insufficient time for the benefits of the Act to be reflected in Bay-Wide loadings.

The seasonal density of phytoplankton cells in the Inland Bays is bimodal, with peaks in September and June. The peaks, up to 10^8 cells/L, are numerically dominated by picoplankton (0.2-2 μm) which constitute 90% by number. Lacoutre and Sellner (1988) report that these picoplankton consist mostly of cyanobacteria including Microcystis. During the cold months, total cell numbers decline and diatoms and flagellates dominate. Diatoms, in concentrations sufficient to cause red tides, were identified by Tyler (1989) to be mostly marine or coastal forms brought through the inlet into the nutrient rich Bays where they can readily multiply. The high phytoplankton cell density and high nitrogen, chlorophyll, and phosphorous concentrations all lead to the characterization of the system as eutrophic, even with the dramatically increased flushing caused by inlet changes.

The plankton form part of the materials suspended in the waters of the Bays. Non-living organic matter and inorganic minerals comprise the bulk of suspended matter. Portions of this material serve as a substrate for chemical and biologically mediated chemical reactions, as food for filter feeding organisms, and as contributors to the turbidity of the water column. The concentration of suspended matter varies from 3 ppm - >200 ppm on time scales of hours-years. Highest concentrations are usually observed during extreme events like very high freshwater discharges or high wind events. Gibbs (1988) found changes in suspended matter from 30 ppm to 85 ppm at one station during one afternoon and attributed the change to an increase in wind speed. Gibbs found that organic matter comprised about 30% of the material in suspension in Indian River Bay though, in summer, it could reach 50% of the total. There do not appear to be seasonal trends in the concentration of material in suspension. Rather, wind and freshwater discharge events seem to control suspended matter concentrations. There is a seasonal pattern in turbidity of the waters of the Inland Bays. Both anecdotal and technical observations verify clear waters in the winter and turbid waters in the summer, even though there are no parallel trends in suspended sediment concentration. This is probably due to the fact that water transparency is related to the size, composition, and concentration of suspended matter, not to concentration alone. The seasonal pattern of turbidity, as illustrated by Secchi disk measurements for southern Rehoboth Bay, is depicted in Figure 5.6. We have also plotted total suspended sediment and chlorophyll concentrations on the illustration. It is apparent that total suspended solids may be high or low when the water is clear, but the water is always turbid when chlorophyll is high during the summer. This pattern was also noted by Lacoutre and Sellner (1988). Associated with the chlorophyll, which may be concentrated in large plankton, are the picoplankton, the smallest individuals, with the largest surface area available for light absorption. The mean size of the phytoplankton of the Bays is about 10 μm, while the picoplankton are about 1μm. Spheres 1μm in diameter have 100 times the surface area of the same mass of 10μm particles. However, as calculated by Geider (personal communication), the quantity of chlorophyll observed in the Inland Bays is usually insufficient to account for more than 20% of the observed turbidity, even in summer. The calculation assumes that scattering within a cell suspension is offset by the "packaging effect" which can cause absorption of a cell suspension to be less than that of dissolved pigments.

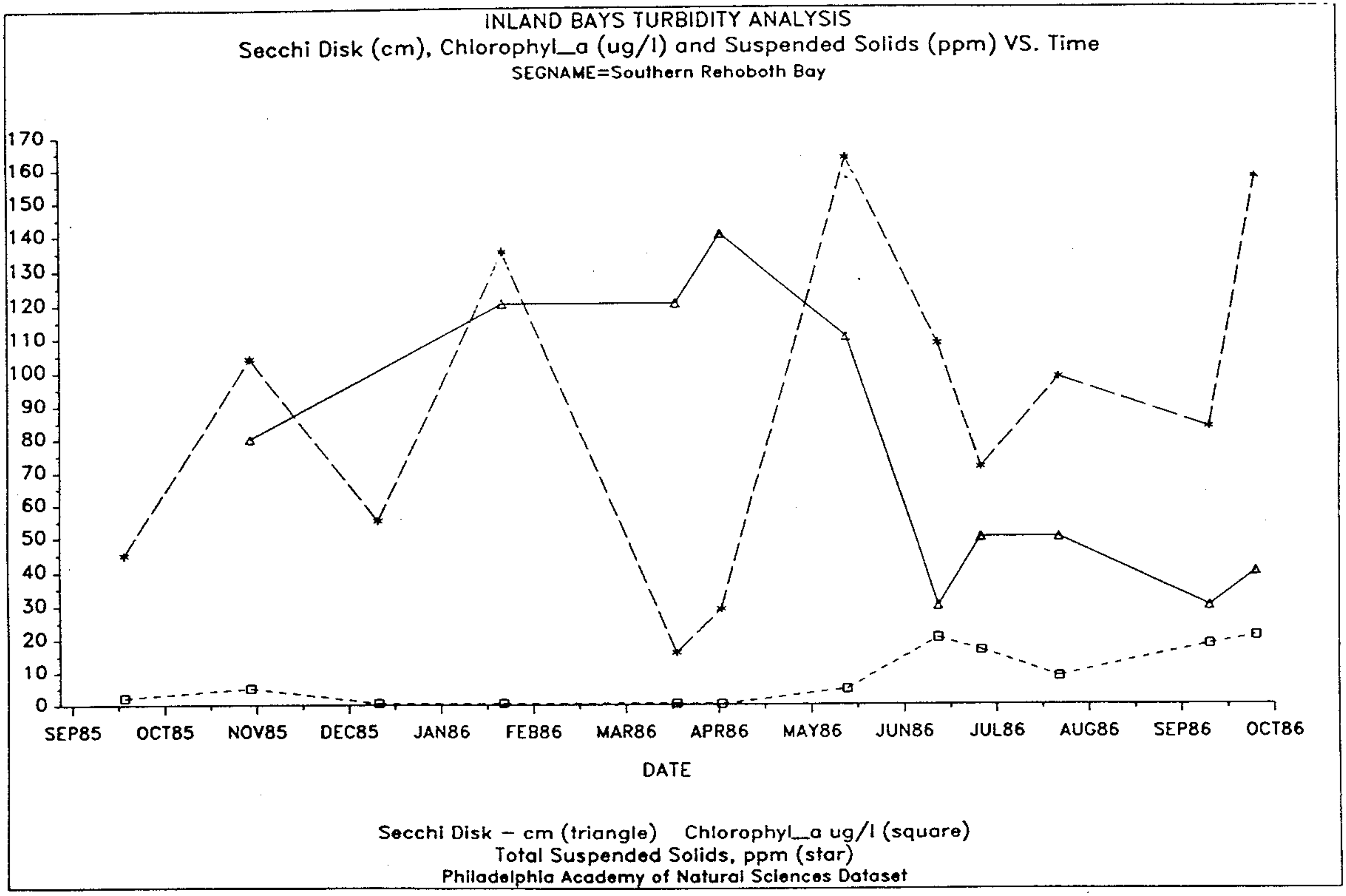

FIGURE 6 SEASONAL TURBIDITY IN SOUTHERN REHOBOTH BAY

In summary, we can say that the maximum annual turbidity of all three systems correlates with the summer chlorophyll maximum, that all three systems are characterized by the presence of large numbers of cyanobacteria (an order of magnitude larger in number than any other class of plankton) during the summer, and that the total concentration of material in suspension is variable and shows no correlation with seasonal turbidity. We suggest that, if management of turbidity is important to achieve ecological or recreational objectives, then further investigation of the causes of Inland Bays turbidity is warranted. Important local high turbidity may be induced by the turbulence caused by boat traffic, especially in high use and otherwise protected areas (Wright and Wagner, 1991).

A principal result of nutrient enrichment that is of great concern to managers is the oxygen demand created by the production of organic matter that has been stimulated by high nutrient concentrations. In shallow water, the dissolved oxygen concentration is affected by temperature (cold water holds more) and salinity (fresh water holds more) in the absence of organisms. When invertebrate animals are added, they consume dissolved oxygen in proportion to water temperature. When plants are added, they consume oxygen at night and produce oxygen in the presence of sunlight. Thus, the "worst" set of circumstances occurs when warm waters contain large quantities of phytoplankton and animals and all of these organisms have been respiring for the entire night. Dawn or early morning dissolved oxygen measurements are most sensitive to these conditions and have been aggregated by Inland Bay segment and examined for historical trends. The plot in Figure 5.7 shows both dissolved oxygen concentration and the dissolved oxygen

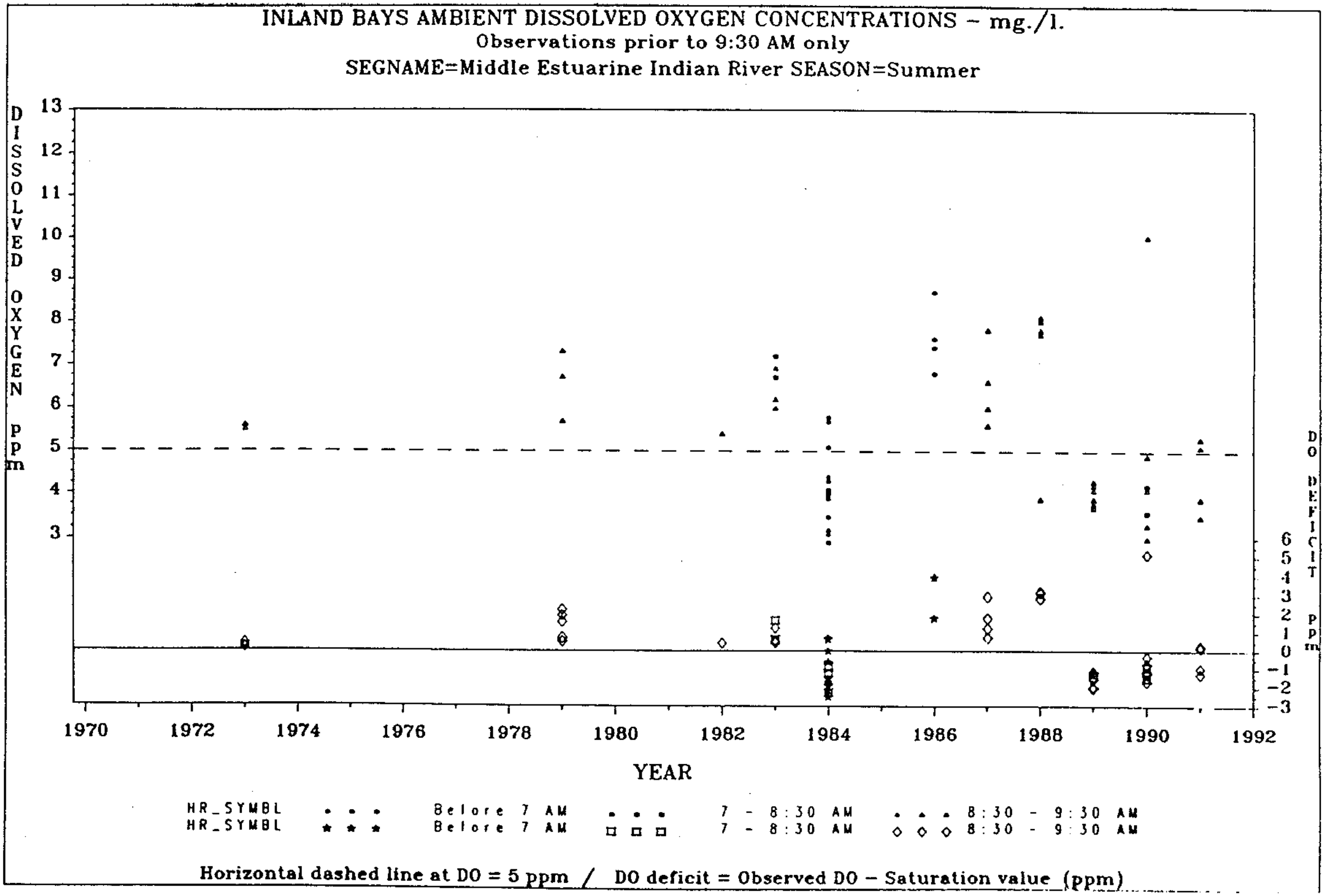

FIGURE 7 AMBIENT DISSOLVED OXYGEN CONCENTRATION

deficit (observed concentration - saturation value) for middle Indian River in summer for samples taken prior to 9:30 A.M. The 5 ppm water quality standard is shown as a dashed line. Numerous water quality violations occur. There is no statistical trend with time in these D.O. values, but in numerous segments, in spring and summer, we see a pattern of increasing deficits and water quality violations from 1986 to 1991. We urge that a monitoring program be established and continued to determine whether there is a temporal trend of declining D.O.'s in early morning.

5.5 HABITAT LOSS/MODIFICATION

After the inlet was opened in 1939-40, oysters were imported from nearby bays. By 1945, a packing house was opened at Oak Orchard. Oyster production virtually ceased in 1959 when the population was infected with MSX, a disease that killed large numbers of oysters from Long Island to the Chesapeake. Anecdotal information, from multiple sources, provides the principal data on the living resources of the Inland Bays prior to 1970. There were "...as many white perch as you wanted to catch in Indian River and Assawoman Bays till 1946..." Rockfish were abundant in the spring, especially in the early 1960's. There were notable herring and shad runs from 1940-62. These ended in 1968-69. From 1943-55 soft clams were abundant in Assawoman and Rehoboth Bays. Many testimonials have been presented suggesting an abundance of eelgrass beds near the Inlet and the presence of cabbage grass (Macroalgae) over wide areas of all of the bays.

Croakers, soft and hard crabs, sea bass, eels, spot and blowfish were abundant in the bays near the inlet.

The historical picture (1940-70) painted by anecdotal reports and based on the organisms found in the Bays is consistent with a traditional estuary; the presence of marine organisms that spend a portion of their lives in the Bays (seabass), the presence of anadromous organisms that require low salinity or fresh waters for portions of their development (shad) and the presence of estuarine organism that spend their entire lives in the Bays (white perch). The anecdotal history of the living resources of the Bays suggests that something changed that especially affected the abundance of estuarine and anadromous fishes. Fishes like shad, herring, and striped bass that leave the estuary after spawning can be affected by overfishing, predation, and other pressures in remote regions. Changes in their abundance may be unrelated to local conditions. White perch, though, live in the Bays for their entire lives and should be affected only by in-Bay processes. The white perch population in the Inland Bays, especially Indian River Bay, is low or absent. We hypothesize that the increase of salt water passing through the inlet coupled with dredging of creeks and channels has substantially reduced the limnetic and oligohaline habitats that are critical to anadromous fish survival in the Bays. We speculate that high salinity has increased the abundance of marine competitors and predators. Fresh water drainage from 1940 to the present shows no pattern to explain a possible salinity increase. Historical data on salinity and the organisms present in the Bays are not available to verify our hypothesis. We urge, though, that the mathematical model of the Bays be exercised to use historical Inlet dimensions to predict salinity distribution and test our hypothesis. We note, in passing, that the State has participated in the dredging or has permitted dredging by private interests of major tributaries to the Inland Bays including Love, White, Guinea, Herring, Wilson and Pepper Creeks. Each of these channel deepening activities can provide increased access by salt water to oligohaline and limnetic habitats.

Restoration of oligohaline and limnetic habitats (if the model confirms the anecdotal evidence) may be difficult to achieve. These environments are susceptible to blue-green algae blooms due to high nutrient loading, and the Lacoutre and Sellner (1988) study confirms the presence of blue-greens (cyanobacteria) in a degraded state, probably because of the high salinity throughout Indian River Bay. Under present circumstances, increasing fresh water flow will increase nutrient loads, while decreasing the cross-section of the inlet will reduce the dilution of nutrient loads by ocean water. Thus, restoration of anadromous or resident oligohaline fish populations may depend on restoration of both the quantity and quality of limnetic-oligohaline habitat.

Recreationally and commercially important fisheries are limited, at the present, to hard clams (residents of the Bays) and marine organisms that enter the Bays for portions of their life cycle. Some use the Bays as a nursery for larvae, while others enter as adults, using the Bays as seasonal feeding areas. These marine organisms are subject to population pressures beyond the Inland Bays or Delaware's ability to manage them.

Support for the State's interest through active participation in fisheries management plans developed by the Mid-Atlantic Fisheries Council is critical to maintaining and enhancing the populations of marine fisheries in the Inland Bays. Continued enhancements and enforcement activities focused on hard clams management are entirely within Delaware's span of control.

During the period 1938-73, over 2000 acres of wetlands were lost in the Inland Bays, mostly to dredge and fill for development, and mostly during the 1950's and 60's. Adoption of the Delaware Wetlands Act of 1976 sharply reduced the loss of tidal wetlands so that losses now are almost entirely caused by shore erosion. Total wetland losses since 1976 decreased to 5% to 10% of pre-regulation levels in the state. We suspected that the rate of shore erosion, and wetlands erosion in particular, would be modified by the enhanced tidal range predicted by a larger inlet. Examination of the data on Rehoboth shore erosion (Swisher, 1982) does not yield a trend during the period 1938-81 in spite of the increase in tidal range. Historical data on the types of marsh vegetation present on marsh surfaces are inadequate to determine whether measurable changes have occurred in any of the Inland Bays.

Submerged aquatic vegetation serves as habitat, helps prevent erosion of the bottom and thus reduces turbidity, and serves as food. There is abundant, reliable, anecdotal evidence for the presence of such vegetation in Indian River Bay near the Inlet and along the eastern edge of Rehoboth until the early 1970's. After that time, submerged aquatic vegetation has not been reported. Both widgeongrass and eelgrass are abundant on the Chesapeake side of Delmarva, in Chincoteague Bay and in Barnegat Bay to the west, south and north, respectively. Orth and Moore (1988) have analyzed the historical distribution of submerged aquatic vegetation in the Inland Bays and concluded that the high levels of suspended chlorophyll, turbidity, and dissolved nutrients suggest...that it is unlikely that SAV species ... would be able to survive in the bay system." We are confident that chlorophyll and turbidity are the result of high nutrient concentrations. We are reasonably certain that phosphorus can be controlled, because a large point source for Rehoboth can be controlled, and because non-point controls can be effective. However, the Chesapeake experience suggests that high dissolved nitrogen may limit submerged aquatic vegetation through the growth of epiphytes. Further, recent mesocosm experiments (Burkholder et al., 1992) suggest that nitrate enrichment can cause a decline of eelgrass as a direct physiological effect, especially under high temperatures. Even if management practices can be instituted that will increase water clarity, we have serious concern that submerged aquatic vegetation can be re-established without significant reduction in total nitrogen, except in those areas very near to the inlet.

5.6 REFERENCES

Andres, S., 1993. *Personal Communication.*

Aston, S.R., 1980. "Nutrients, Dissolved Gasses and General Biogeochemistry of Estuaries." In: *Chem and Biogeochem of Estuaries*, Olausson and Cato, eds. p. 233-262.

Beasley, E.L., 1987. *Change in the Diatom Assemblage of Rehoboth Bay, Delaware and the Environmental Implications.* Master's Thesis, University of Delaware, May 1987, 205 p.

Gibbs, R.J., 1988. *Turbidity of Indian River Bay.* Report to Delaware Department of Natural Resources and Environmental Control, 32 p.

Hicks, S.D., 1972. "Sea Level Rise." *American Geol. Inst. Report* 5(1).

Houlahan, J., W.A. Marcus and A. Shirmohammad, 1992. "Estimating Maryland Critical Area Act's Impact on Future Nonpoint Pollution." *Water Res. Bull.* 28:3, 553-567.

Kaplovsky, A.J. and D.B. Aulenbach, 1956. "A Comprehensive Study of Pollution on the Waters Within the Indian River Drainage Basin." State of Delaware Water Pollution Commission, 207 p.

Kraft, J. C., R. B. Biggs and S. D. Halsey, 1973. "Morphology and Vertical Sedimentary Sequences in Holocene Transgressive Barrier Systems." *Coastal Geomorphology,* p. 321 -354. Ed: D.R. Coates, 404 p.

Lacoutre, R.V. and Sellner, K.G., 1988. *Phytoplankton and Nutrients in Delaware's Inland Bays.* Report to Delaware Department of Natural Resources and Environmental Control, 140 p.

Orth, R.J. and Moore, K.A., 1988. *Submerged Aquatic Vegetation in Delaware's Inland Bays.* Academy of Natural Sciences of Philadelphia, 36 p.

Raney, D.C., Doughty, J.O., and Livings J., 1990. "Tidal Prism Numerical Model Investigation of the Indian Inlet River Scour Study." *Bureau of Engineering Research Report* 500-13, University of Alabama. Two volumes.

Ritter, W.F., 1986. *Nutrient Budgets of the Inland Bays.* Report to the Delaware Department of Natural Resources and Environmental Control.

Sellner, K. G., 1988. *Executive Summary in Phytoplankton, Nutrients, Macroalgae, and Submerged Aquatic Vegetation in Delaware's Inland Bays.* Report to Delaware Department of Natural Resources and Environmental Control, 140 p.

Swisher, M.L., 1982. *The Rates and Causes of Shore Erosion Around a Transgressive Coastal Lagoon.* M.S. Thesis, University of Delaware, Newark, Delaware, 210 p.

Tyler, M., 1989. *Inland Bays Phytoplankton Monitoring Study.* Report to Delaware Department of Natural Resources and Environmental Control, 12 pp. + Appendix.

USEPA, 1983. *Chesapeake Bay, A Framework for Action.* USEPA, Region III, 186 p.

Vincent, F., 1870. *The History of the State of Delaware.* Delaware Archives, 220 p.

Wright, D.O. and Wagner, K.J., 1991. "Power Boats on Shallow Lakes." *Lake Line,* (11)4, p. 8-12.

APPENDIX 5.1

FINDINGS OF THE STUDY SUMMARIZED BY CHAPTER

FINDINGS - Section 2 - Water Quality

Salinity	There are no systematic differences in salinity within the segments of Rehoboth Bay, Lower Indian River, or Masseys Ditch. Limnetic conditions occur only 20 percent of the springtimes in the uppermost reaches of Indian River Bay. There are no discernable interannual trends in salinity.
Temperature	Upper and middle Indian River segments are generally warmer in spring than either the freshwater or ocean segments. All segments for which data are adequate show a 2°-5°C springtime warming after 1980 compared to years before 1980. No such pattern has been identified for other seasons.
Nutrients	Total N concentration declined by a factor of 2 in all mid- and high salinity segments of all of the bays, beginning in the mid-1970's. Kjeldahl nitrogen and particularly ammonia concentrations were principally responsible for the decline, which coincided with a dramatic increase in flushing due to inlet scouring. There are no discernable trends in phosphorus concentrations. Phosphorus is the limiting nutrient in upper and middle Indian River, while phosphorus and nitrogen colimit primary production in other segments where data are available.
Salinity/Nutrients	Salinity/property plots for nutrients are uninformative for Rehoboth and Little Assawoman Bays because neither of these systems exhibit a wide salinity range. In Indian River Bay, there is a clear upstream springtime source of nitrate while total N behaves conservatively. Salinity/property plots segregated before 1975 and after 1986 show that Kjeldahl and ammonia nitrogen have decreased dramatically.
Nutrient Loadings	Ritter's estimate, as modified by Andres, represents the best available nutrient loading measure. Attempts to verify that model through historic flow and concentration data were unsuccessful. Direct groundwater discharge may be an

important source of nitrates to the Inland Bays. Currently funded research on the role played by bottom sediments to degrade nitrates to nitrogen gas may help in understanding the importance of this potential source.

Chlorophyll/Turbidity

Chlorophyll is usually highest in summer and lowest in winter. Annual average concentrations in upper and middle Indian River are indicators of eutrophic conditions. Suspended sediment concentrations vary from 3 ppm to 200 ppm on time scales from hours to years. Wind events, fresh water discharge, boat traffic and tidal currents all contribute to sediment resuspension. Turbidity is highest in summer and lowest in winter. It correlates with the annual chlorophyll cycle but not with suspended sediments.

Eutrophication

Two measures of enrichment were applied to the average annual concentrations of nitrogen, phosphorus, chlorophyll and turbidity. Both measures (one developed by NOAA comparing all major U.S. estuaries and one developed by EPA for the Chesapeake) show that upper and middle Indian River are eutrophic and that most other segments are enriched or highly enriched.

FINDINGS - Section 3 - Habitats

Estuarine Wetlands

Over 2000 acres (24%) of the estuarine wetlands in the Inland Bays have been lost, primarily due to dredging and development prior to 1976. Since that time minor losses have occurred due to natural erosion processes. Seventy-five percent of the estuarine wetlands of the Inland Bays have been ditched causing ecological and habitat changes.

Freshwater Wetlands

Due to extensive channelization and development activities, over 42% of freshwater streams have poor habitat quality and only 24% have good habitat value. As much as 62% of the palustrine wetlands have been lost due to channelization and ditching from 1950 to the present.

Bottom Sediments

Most areas of the bays have shoaled at rates from 0.3 cm - 1.0 cm/year due to sedimentation. In addition, due to an increased tidal range, large areas of the bays are alternately shallower and deeper than was the historical case. Muddy sediments are found in the western sections of the bays with sandier sediments to the east. Fifty to 75% of the sediments of each bay are sand dominated.

Dredging and Spoil Disposal

Approximately 6.7 million cubic yards of sediment have been dredged in the Inland Bays. Ninety-one percent of this material was dredged from Indian River Bay, mostly near the inlet while 8% percent was dredged from Rehoboth and 1% was dredged from Little Assawoman. Prior to 1970 most of the spoil was deposited overboard. Since that time, material dredged from near the inlet has been pumped to the ocean beaches north of the inlet while spoil from other areas has been deposited in upland sites. Lagoons have been dredged for residential and commercial development. The habitats within the lagoons are generally stressed as characterized by poor water quality, high sedimentation rate and poor circulation.

Littoral Environments

Over 90% of Rehoboth shoreline is marsh, with 6% sandy pocket beaches and 4% artificial structures. No data are available for Indian River shorelines. Little Assawoman shorelines are dominated (79%) by marsh with 4% sandy beaches and 17% artificial structures.

Evolution of Indian River Inlet

Tidal range and tidal prism have increased in Indian River and Rehoboth Bays as a result of a dramatic increase in the cross-section of the inlet between its stabilization in 1940 and the present.

FINDINGS - Section 4 - Living Resources

Chlorophyll

Highest values occur in summer in upper and middle Indian River with lowest values near the Inlet. Little Assawoman Bay has higher annual chlorophyll concentrations than does Rehoboth but both are lower than middle and upper Indian River.

There has been a significant decrease in the annual chlorophyll concentration from 1974-75 to 1985 in middle and upper Indian River.

Primary Productivity

Primary productivity is highest in middle and upper Indian River and lowest near the inlet. There is a strong seasonal cycle with highest values in the summer and lowest in the winter.

Speciation

Picoplankton dominate the phytoplankton community during summer with blue green algae present in all 3 bays. Over the last 300 years the diatom community has shifted with alternate opening and restriction of the inlet. Probably as a result of anthropoganic activity in the watershed, there has been an almost continuous shift from clear water, low nutrient forms to turbidity tolerant nutrient favoring diatoms.

Zooplankton

There are insufficient data available to characterize the status of the zooplankton in the Inland Bays.

The 1974 mean density of microzooplankton (5200-6300/m^3) is similar to other nearby estuaries. The microzooplankton are dominated by acartia sp. while the macrozooplankton are dominated by neomysis sp., crab zoece and Paleomonetes sp., all ubiquitous species in mid-Atlantic estuarine systems.

Macroflora

Rehoboth Bay contains a significant population of macroalgae, dominated, during the last 30 years by a few stable species. Macroalgae abundance in Indian River Bay is lower and abundance and distribution in Assawoman Bay is poorly known.

There are no beds of rooted submerged aquatic vegetation in the Inland Bays though anecdotal evidence suggests that SAV's have been present historically. In nearby Barnegat and Chincoteague Bays, SAV's recovered (by the 50's) from massive declines that occurred in the 30's. If significant stands of such plants were present in the Inland Bays they have not recovered.

Benthos

The most recent benthic survey is 15 years old and the current status is not definitively known. In Indian River Bay, where there is a strong salinity gradient, and the benthos seem to be mostly controlled by the interplay of sediment type and salinity. In Little Assawoman and

Rehoboth Bays, where there is little salinity gradient, the benthic community seems to be dominated by sediment type. In general, the numbers and species present are similar to other east coastal areas, given the wide variety of sampling techniques employed.

Shellfish

Blue crab populations were estimated in 1970. Anecdotal information prior to that time indicates the presence of a significant commercial fishery for both hard and soft crabs. At the present time, the blue crab provides an important recreational resource but we have no data on the status of the resource.

Hard clam populations in Indian River and Rehoboth Bays have been stable for 30 years, averaging about 2 individuals per square meter. Catch per unit effort has remained constant at about 1000 clams per day. The recreational catch is estimated at 40%-60% of the total harvest. There are no hard clams in Little Assawoman Bay, probably because the salinity is too low.

Finfish

There is abundant historical data to indicate the presence of anadramores fishes including shad, striped bass, herring and white perch in Indian River Bay. All of these essentially disappeared by the late 60's and early 70's. Among the causes were recruitment, disease, predation and overfishing in areas remote from the Inland Bays as well as the apparent loss of limnetic habitats within the Inland Bays.

Shore zone species are commonly year round residents and are similar in all 3 bays. The open water community (anchovy, spot, weakfish, croaker represent 95% of the catch) consists of seasonal visitors whose abundance follows regional trends.

In Indian River Bay the catch of the commercial finfishery is dominated by weakfish, bluefish, and menhaden with a single (1991) occurrence of large landings of American shad.

Rehoboth Bay commercial fisheries are dominated by weakfish, bluefish, and spot.

Waterfowl

Long term population declines of most North American waterfowl are mirrored in the Inland Bays. A variety of changes, principally habitat modifications, and pollution, as well as natural phenomena like sea level rise and shore erosion are generally held to be principal causes.

In the Inland Bays, geese, black duck, mallard and brant use all three bays intensively.