SECTION 4.5
BENTHIC COMMUNITY

4.5.1 Introduction

Benthic invertebrates constitute a major biological component of the Delaware Inland Bays ecosystem. The benthic fauna serve as important forage sources for estuarine fish, waterfowl, and larger invertebrates that use the bays. As such, benthic invertebrates represent a principal link between the primary producers and higher level consumers. In addition, the benthos exert major influences on the flux of materials across the sediment-water interface, playing principal roles in nutrient recycling, sedimentation, sediment chemistry and oxygen dynamics.

Because of their limited mobility, benthic invertebrates are particularly vulnerable to local changes in water and sediment quality, as well as, modifications to habitat due to such activities as dredging. Because of this, the benthic community, when evaluated over time, represents an excellent indicator of the response of the system to these changes (Reish, 1960; Godfrey, 1978; Pearson and Rosenberg, 1978; Grizzle, 1984; and Warwick, et al, 1987).

The principal objectives of the *Benthic Community* section of the *"Living Resource"* characterization are several and include:

- The identification of studies that have been conducted of the benthic community of the bays and selection of those studies most appropriate to characterization;

- The definition of the status of the benthic community, as defined by such measures as species composition and relative abundance; and

- A description of the historical record and the identification of changes in benthic community over time, where data allow.

By way of background, the benthos of the estuary can be broadly classified by adult size into three principal classes, viz., the macrobenthos, the meiobenthos, and the microbenthos. By convention, macrobenthos include those species that are large enough to be retained on a sieving screen with a pore size of 500 um (0.5mm). The meibenthos are smaller than macrobenthos and include those species that are retained on a screen of a pore size of 67 or 44 um; and the microbenthos are smaller yet (Day et al., 1989).

For the purposes of this characterization, the discussion of the benthic invertebrate community is limited to the macrobenthos principally because most quantitative studies of the benthos of the Inland Bays have been conducted on this size class of invertebrates. As a result, typical infaunal organisms that would not be included in this analysis include some nematodes, the harpactacoid copepods, turbellaria and protozoa.

4.5.2 Previous Research

While the usefulness of the benthic community as an indicator of environmental stress is well-established, surprisingly few comprehensive benthic invertebrate studies of the Inland Bays have been conducted. Table 4.5-1 below provides a summary of some of the key studies conducted to date of the invertebrate fauna of the Inland Bays. In addition to these studies, a few isolated investigations have been conducted to assess very specific aspects of the benthic community including the potential impacts of dredged lagoons (Brenum, 1976), thermal discharges (Logan, 1972; Logan and Maurer, 1975), and benthic succession (Watling, 1976). Because these studies are restricted in objective and limited spatially and temporally, they were not used in the characterization of the benthic community of the Inland Bays.

Table 4.5-1 Summary of Some Key Studies of the Benthic Resources of the Delaware Inland Bays	
Maurer, D, 1977.	*Estuarine Benthic Invertebrates of Indian River and Rehoboth Bays.* 1968-1970.
Jones, D. et al.	*The Distribution of Benthic Invertebrates in the* Upper Indian River *Estuary.* (1968-1971).
Delmarva Power & Light Company, 1976	*Ecological Studies in the Vicinity of Indian River Power Plant:* A 316 a Demonstration (1976).
DNREC, 1990	*Macroinfaunal Analysis of Several Stations in Indian River and Rehoboth Bay* (1990).
DNREC, 1991	*Macroinfaunal Analysis of Several Stations in Little Assawoman Bay.*
USEPA, 1990	*Environmental Monitoring and Assessment Program.* Summary of Benthic Data Collected July/August. 1990.

The first quantitative benthic faunal survey of Rehoboth and Indian River Bays was conducted by Maurer (1977) between 1968 and 1970. The objectives of this study included, among others:

- A determination of the nature, distribution, and abundance of the benthic communities, and

- A comparison of the annual and seasonal fluctuation of these communities.

In this study, a total of 95 stations (52 in Rehoboth Bay and 43 in Indian River Bay) were sampled (Figure 4.5-1a and Figure 4.5-1b). With the exception of limited sampling (4 stations) conducted by DNREC (1990) and a very specialized study of benthic succession in Sally's Cove by Watling (1976), this study represents the only quantitative survey of the benthic assemblage of Rehoboth Bay to date. Because the data for Maurer's study is available only in the form of a journal publication (Leatham, personal communication), data are presented as summary results with little information with which to correlate findings with specific locations in either bay.
In addition to the comprehensive study of the benthic invertebrates by Maurer, three other studies of similar scale in the Indian River Estuary have been performed. From 1968 through 1971, Jones

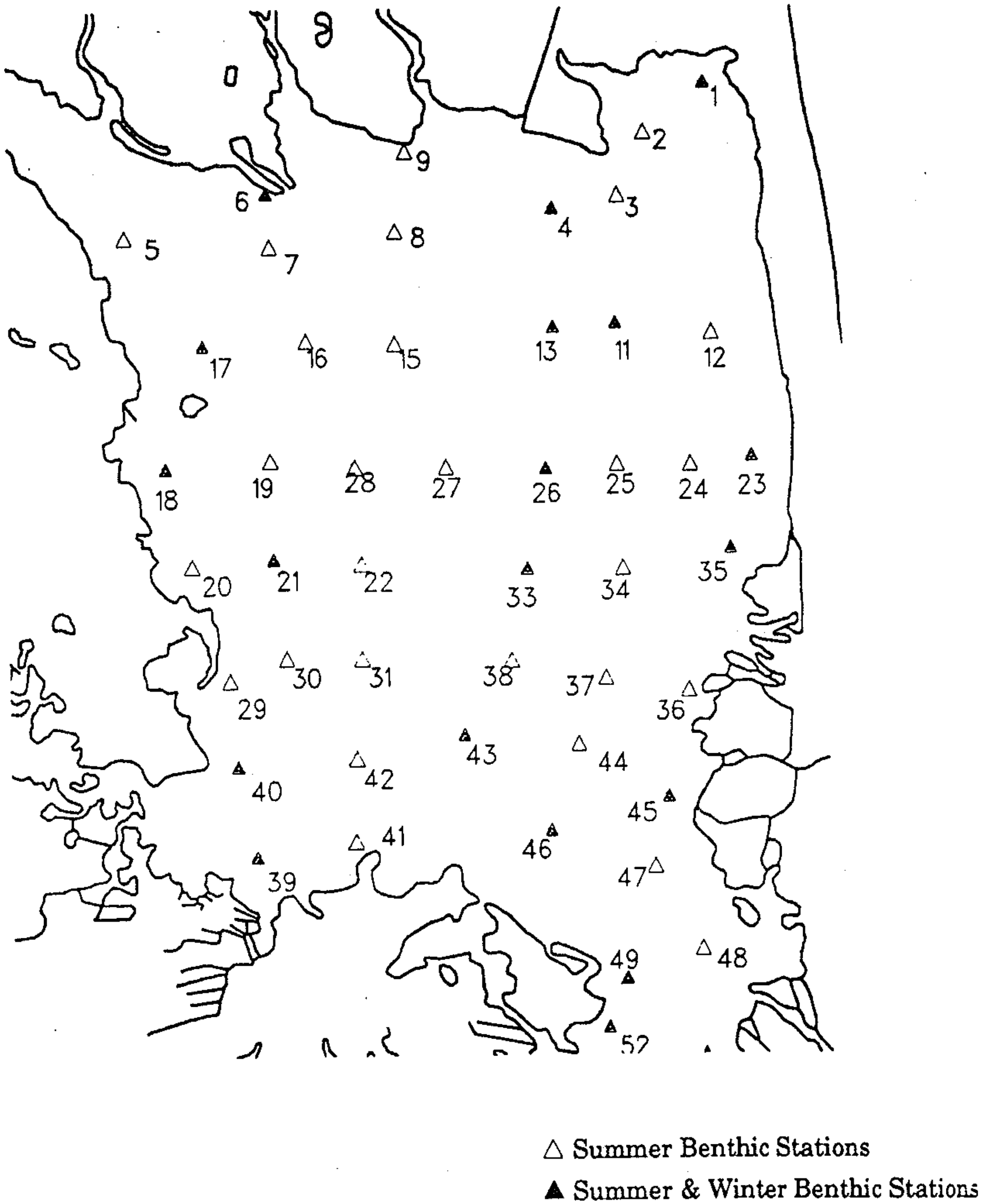

**Figure 4.5.1a
Location of
Benthic Sampling Stations in
Rehoboth Bay
(Maurer, 1977)**

Scale 1 Inch = 4000 Feet
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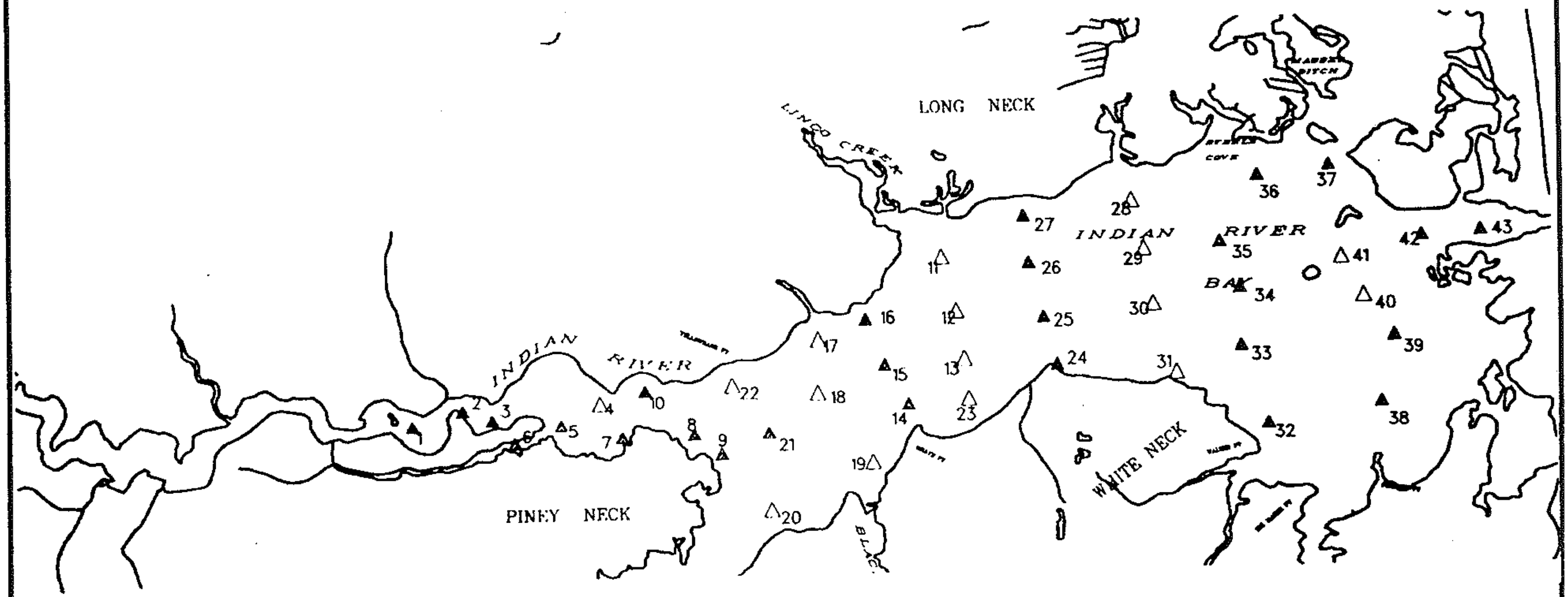


Figure 4.5.1b
Location of
Benthic Sampling Stations in
Indian River Bay
(Maurer, 1977)

et al (1973) evaluated the macrobenthic community at 19 stations located in the upper Indian River estuary (Figure 4.5-2). This study was limited to station locations from about Rock Point (in the vicinity of Buoy "2B") to the Millsboro Dam, and, therefore, is spatially limited to the oligohaline and the mesohaline segments of the Indian River estuary.

As part of a 316 demonstration (impingement/entrainment) for permitting its Indian River Power Plant, DP&L (1976) examined the seasonal composition of benthos at 21 stations located throughout the Indian River estuary between 1974 and 1976 (Figure 4.5-2). Because the DP&L study represents a more comprehensive coverage of the Indian River estuary, it was used as the critical data set for defining the historical record of the benthic community of the Indian River estuary. In addition, these data were also used to develop a general comparison with Jones et al. (1973) and Maurer's (1977) results.

Information regarding the benthic community of Little Assawoman Bay is limited to a small study conducted by DNREC in October, 1991. Three sets of samples, (3 replicates per location) were collected at three locations in Little Assawoman Bay (Figure 4.5-3). These data were used to describe what is known of the benthic community of Little Assawoman Bay.

In addition to these studies, a few more recent studies have investigated the benthic community of the Inland Bays. In 1987, DNREC's Division of Fish and Wildlife examined the invertebrate community of select tributaries of upper Indian River estuary and Little Assawoman Bay (Shirey, 1987). This study focused on the benthic communities of the tidal streams and did not include sampling of the bays proper. In 1990, DNREC looked at the benthic community of eight stations in Indian River Bay and adjacent deadend lagoons to compare the health of the benthic community in these areas with that of other areas on

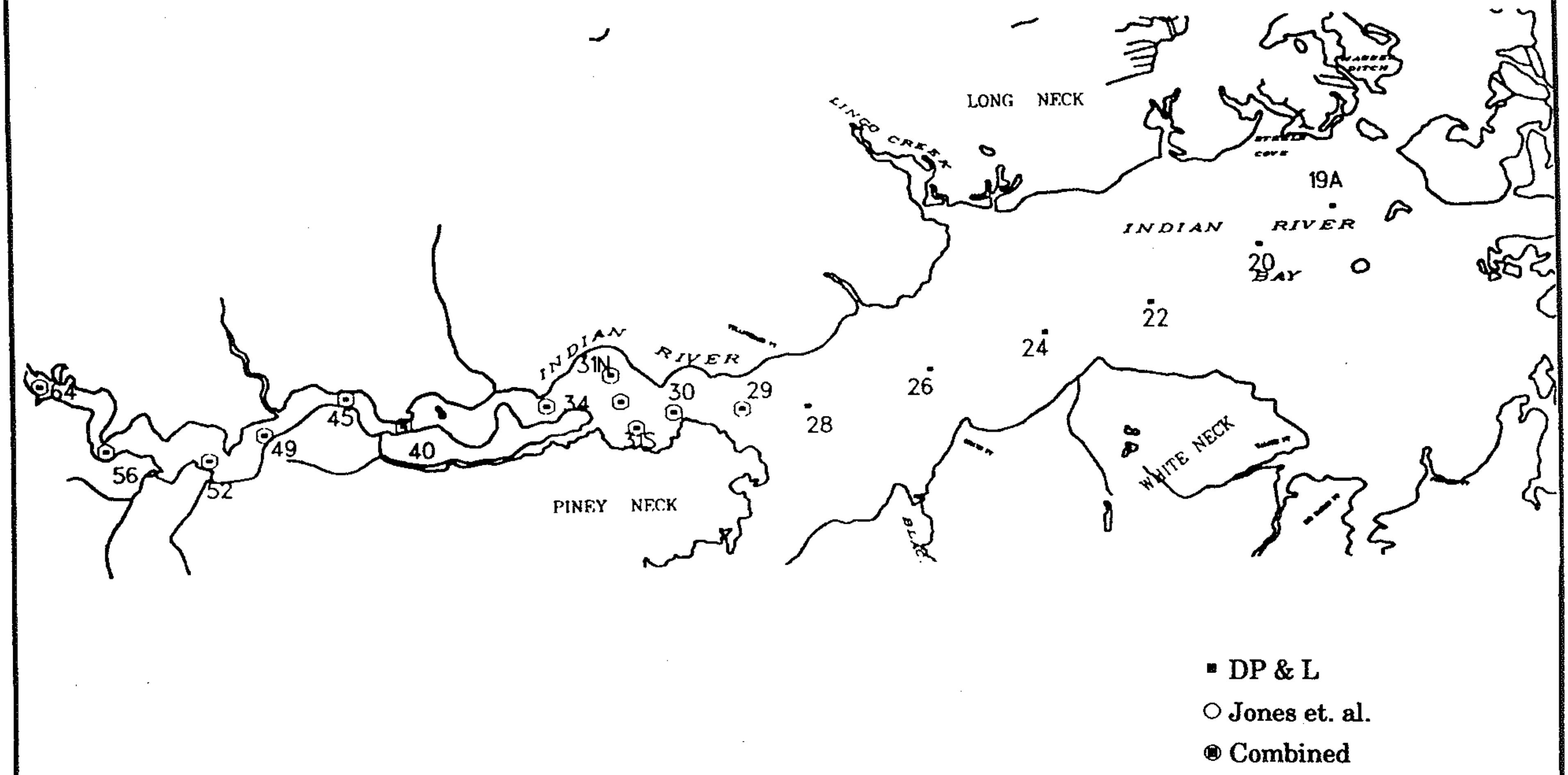
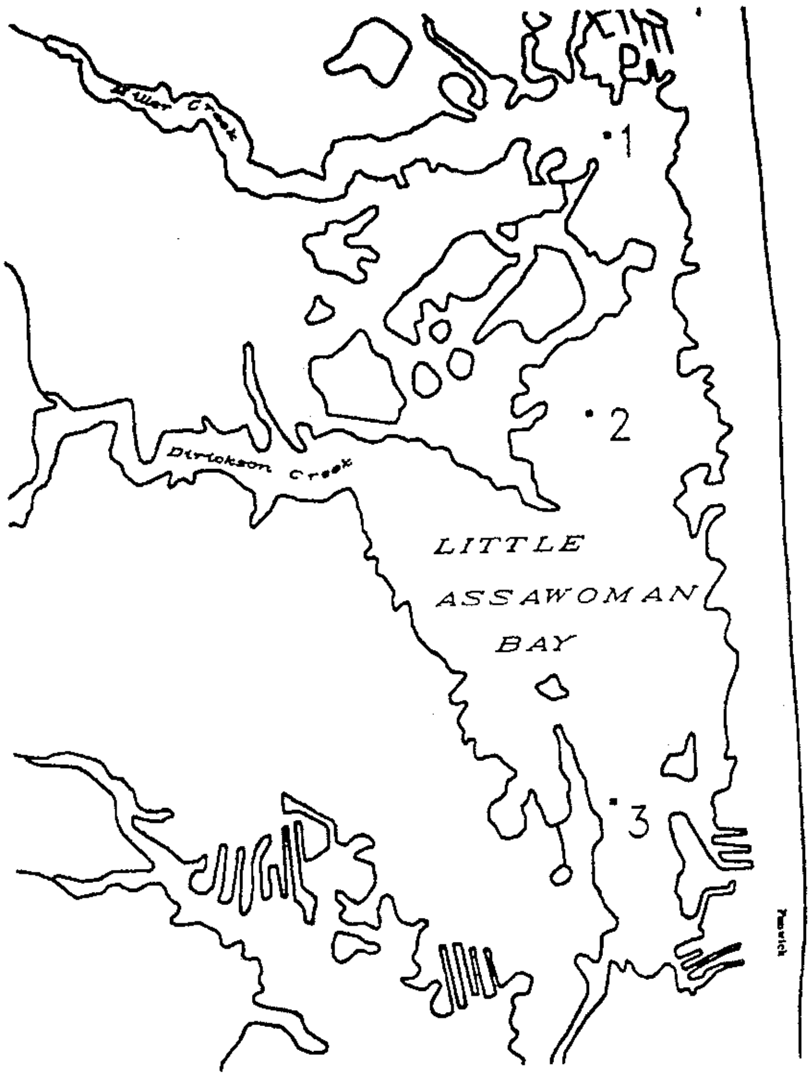


Figure 4.5-2
Locations of Benthic Sampling Stations
DP & L (1976), Jones et. al 1973

Note: Only those stations in the mainstem of the estuary are presented.



Source: DNREC 1991

Figure 4.5-3
Location of Sampling Stations in Little Assawoman Bay

Scale 1 Inch = 4000 Feet
2000 0 2000 4000

Indian River Bay. Because of the spatially and temporally limited scope of effort these studies were not evaluated here.

A third study included the collection and analysis of benthos at several stations located in the polyhaline segment of Indian River. These data were collected in 1990 as a part of a "demonstration project" conducted by EPA under its Environmental Monitoring and Assessment Program. The program is designed to assess the current condition and future change in a variety of environmental parameters, in this case changes in benthic abundance, biomass, and species composition in select estuarine and near-coastal locations. These data were not available for inclusion in this characterization. When these data are made available, their incorporation into this section would be useful in comparing the status of the benthic community in lower Indian River estuary with data collected by DP&L in the same area in 1974-1976.

Table 4.5-2 presents a summary of the sampling methods used in the key studies of the benthic resources.

4.5.3 Status of the Benthic Community

The most recent comprehensive survey of the benthic community of the Delaware Inland Bays was conducted more than fifteen years ago (1974 to 1976) in the Indian River Estuary (DP&L, 1976). Moreover, the only comprehensive benthic survey of Rehoboth Bay was performed from 1968 to 1970 (Maurer, 1977). As noted, only a single, limited study of the macroinvertebrates of Little Assawoman Bay has been performed. Although a number of specialized studies at various locations throughout the bays have been conducted in the interim they provide little insight into the benthic community of the estuary as a whole, because of large spatial and temporal limitations. Consequently, the status of the benthic community of the Delaware Inland Bays is unknown.

Because of the significance of benthic status to the overall interpretation of conditions of

Table 4.5-2
A Summary of Methods Used in Several Key Studies to Evaluate the Macroinvertebrate Community of the Delaware Inland Bays

Study	Study Period	Number of Stations			Method	Sieve Size (mm)
		RB	IRB	LAB		
Maurer, 1977	1968 - 1970	52	43		Peterson Grab ($0.066 M^2$)	1.0
Jones, et. al., 1975	1968 - 1971		19		Peterson Grab ($0.058 M^2$) ($0.026 M^2$)	0.5
Del. P&L, 1976	1974 - 1976		21		Peterson Grab ($0.026 M^2$)	0.5
DNREC, 1990	1990	4			Box Corer ($0.1 M^2$)	0.5 and 1.0
US EPA, 1990	1990		5		Box Corer ($0.02 M^2$)	0.5
DNREC, 1991	1991			3	Box Corer ($0.02 M^2$)	0.5

the "living resources" of the bays, the absence of more current information represents a significant data gap in the characterization process.

4.5.4 Historical Record of The Benthic Community

Comprehensive analyses of the benthic community of the Inland Bays is temporally confined to an eight year period between 1968 and 1976. Because of this and the absence of current benthic data, an analysis of "status and trends" for the benthic communities of the bays was not possible. Nevertheless, to provide some insight into what the benthos was like historically, a descriptive characterization of the benthic community for the period of record is provided below.

4.5.4.1 Rehoboth Bay

Limited data exist for Rehoboth Bay. The most comprehensive set of data for Rehoboth Bay was collected by Maurer (1977). In addition to Maurer, a much more limited sampling effort was conducted by Delaware DNREC in Rehoboth Bay in 1990. This study was designed primarily to evaluate the use of a proposed benthic assessment procedure (Luckenbach, et al. 1988) to establish biocriteria for marine and estuarine waters in Delaware (Maxted, 1991). Four stations were evaluated and were located in assumed "stressed" and "non-stressed" areas of the bay. Because of the narrow focus and attendant effort these data have limited potential in characterizing what is known of the benthic community of Rehoboth Bay. Consequently, Maurer (1977) represents the critical data set for establishing the historical record of the benthic community of Rehoboth Bay.

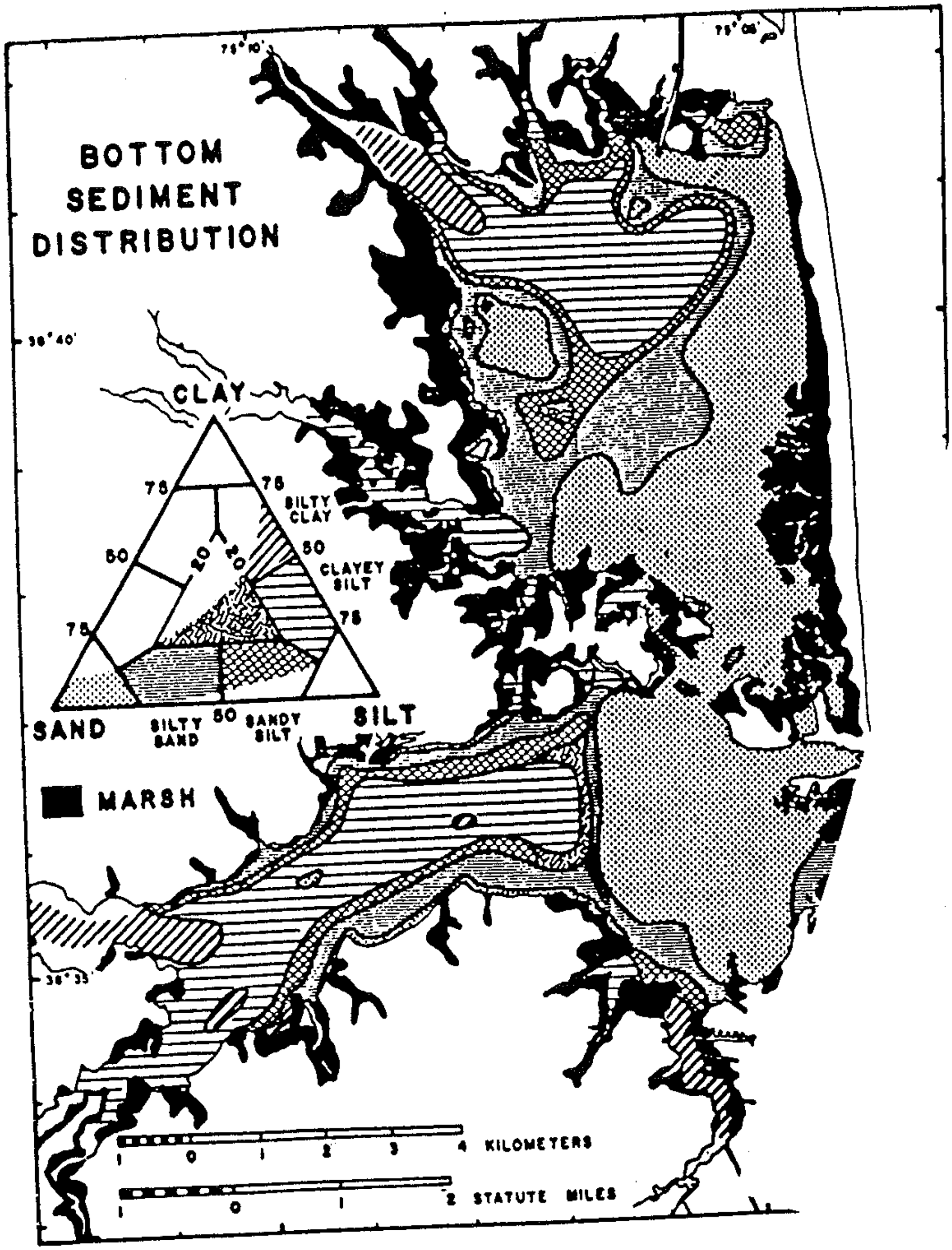
The distribution of the benthic fauna in estuaries is generally a function of several parameters, two of which are principal, namely, salinity and sediment type. As noted in Section 2, *Water Quality*, of this report, there is little spatial variability in the salinity of Rehoboth Bay. Data indicate that Rehoboth Bay is polyhaline with an annual salinity ranging from about 22 ppt to 30 ppt and a mean salinity of 28 ppt. As a consequence, salinity is not expected to play a major role in the differential distribution of benthic species in Rehoboth Bay. Thus the principal factor contributing to the heterogeneity of the benthic community in the Rehoboth Bay is probably sediment type.

A review of the sediment characterization of Rehoboth Bay shows that the bay can be broadly classified by three sediment types (Chrzastowski, 1986). Maurer describes these three principal sediment types in Rehoboth Bay based on the silt-clay content in sediment. They include "sand" defined by a silt-clay fraction of less than 20 percent; "muddy-sand" with a silt-clay content ranging from 20 percent to 80 percent and "mud" with a silt-clay fraction greater than 80 percent. Along the eastern shore and southern segment of Rehoboth Bay, sediments are predominantly sand. In the deeper portions of the bay and along the western shore muddy-sand dominates, while along the northern portion, mud-type sediment is characteristic. Silty-clay or mud sediments also occur at the mouth of Love Creek and clayey silt at the mouth of Herring Creek, (Figure 4.5-4). For a more complete discussion of sediment distribution, see Section 3 *Habitat Characterization.*

From 1968 to 1970, Maurer collected a total of 62,825 individuals at 52 stations in Rehoboth Bay. The average density of benthic organisms collected in Rehoboth Bay was 4,200 individuals/m^2, which varied seasonally with a somewhat higher abundance in summer (4,500/m^2) than that found in winter (3,700/m^2) due principally to a decline of amphipods in the winter. The average density of organisms collected in Rehoboth Bay was influenced by sediment type with the mean density of invertebrates in sands of 5,625 individuals/m^2; in muddy-sands 4,086 individuals/m^2; and in muds 3,260 individuals/m^2.

The average biomass of benthic invertebrates collected during Maurer's survey of Rehoboth Bay was 107.2 g wet weight/m^2 (17.5 g dry/m^2). The average macroinvertebrate biomass measured at three stations of varying sediment type also indicated differences in faunal composition:

	Polychaeta	Amphipoda	Mollusca	Total
Mud	22.5	5.4	3.8	31.7
Muddy-Sand	14.1	5.5	50.8	70.4



Source of Data: Chrzastowski, 1986

Figure 4.5-4
Bottom Sediment Characteristics and Spatial Distribution, Rehoboth Bay and Indian River Bay

Sand	2.5	0.3	2.4	5.2
(g wet weight/m^2)				

These data show that, while the largest number of organisms were found in sand sediments, they nevertheless comprised the least biomass.

Of the benthos collected in Rehoboth Bay, 126 species were represented. Figure 4.5-5 presents the composition of major taxa as a percent of the total number of individuals collected. These classifications, i.e., polychaetes, amphipods, and other arthropods, pelecypods and gastropods represent more than 99 percent of the total number of organisms collected. Of these, amphipods and pelecypods comprised more than 85 percent of the total number of individuals.

Of all classes of benthos collected, fifteen species representing fourteen families comprised more than 95 percent of the total number of individuals collected in Rehoboth Bay. Figure 4.5-6 presents the percent composition by family of the top fifteen species dominating the benthos of Rehoboth Bay in 1968 to 1970.

A summary of the principal taxa dominating each of the major classes or orders of benthos collected in Rehoboth Bay follows.

- **Polychaetes**

From 1968 to 1970, polychaetes represented the most diverse class of benthos collected in Rehoboth Bay. Thirty-one species representing nineteen families were collected. Nevertheless, polychaetes accounted for little more than six percent of the total number of organisms collected with an average density of about 150 individuals/m^2. Distribution of polychaete density was largely determined by substrate type and ranged from three percent of the total community density in sands to twelve percent in muds (Figure 4.5-7). Polychaete biomass was also a reflection of sediment type, with the average wet biomass of polychaetes of 2.5g wet weight/m^2 in sands; 14.1g wet weight/m^2 in muddy sands and 22.5g wet weight/m^2 in muds.

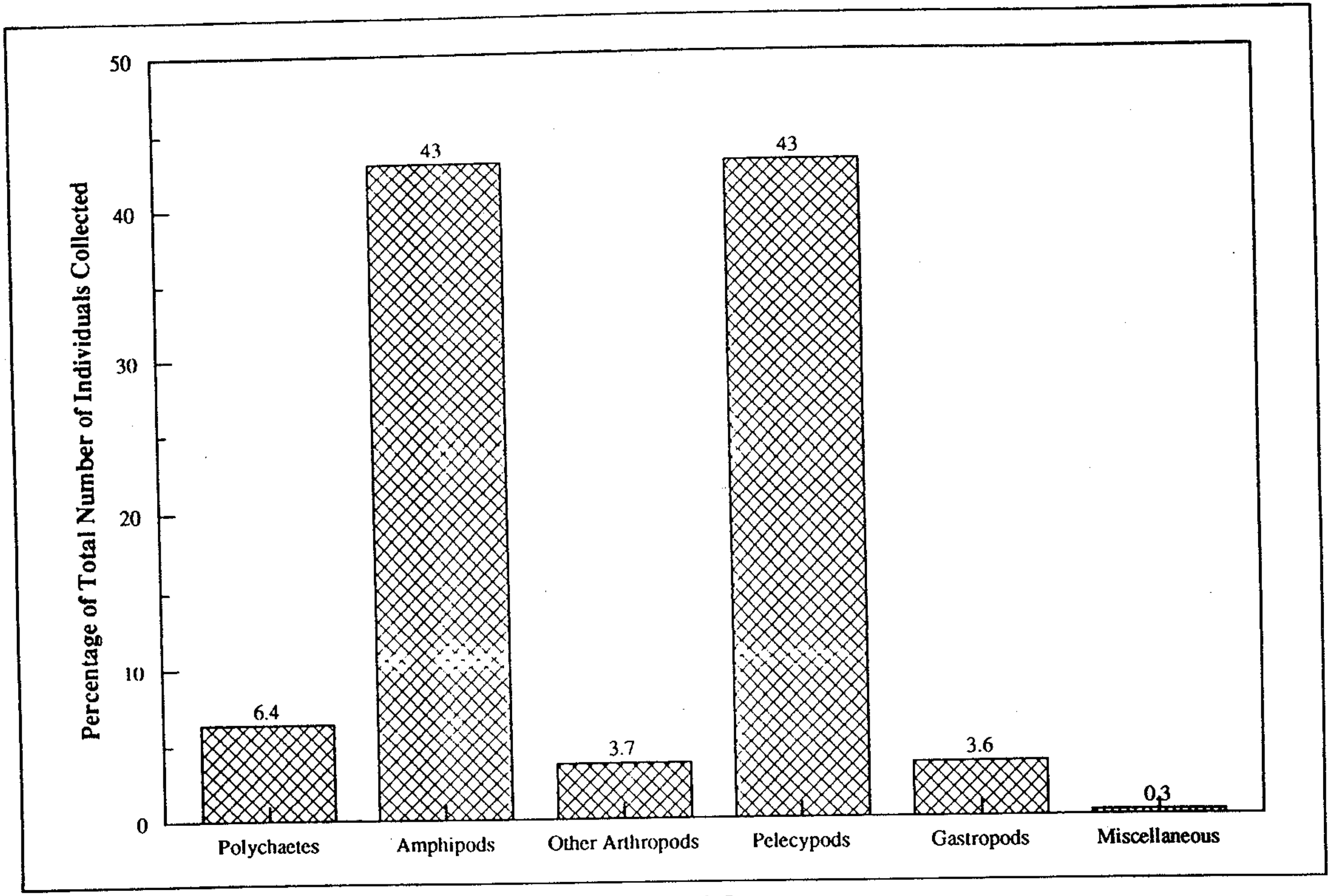


Figure 4.5-5
Composition of Major Taxa as Percent of
Number of Individuals Collected in Rehoboth Bay from 1968 - 1970
Source of Data: Maurer, 1977

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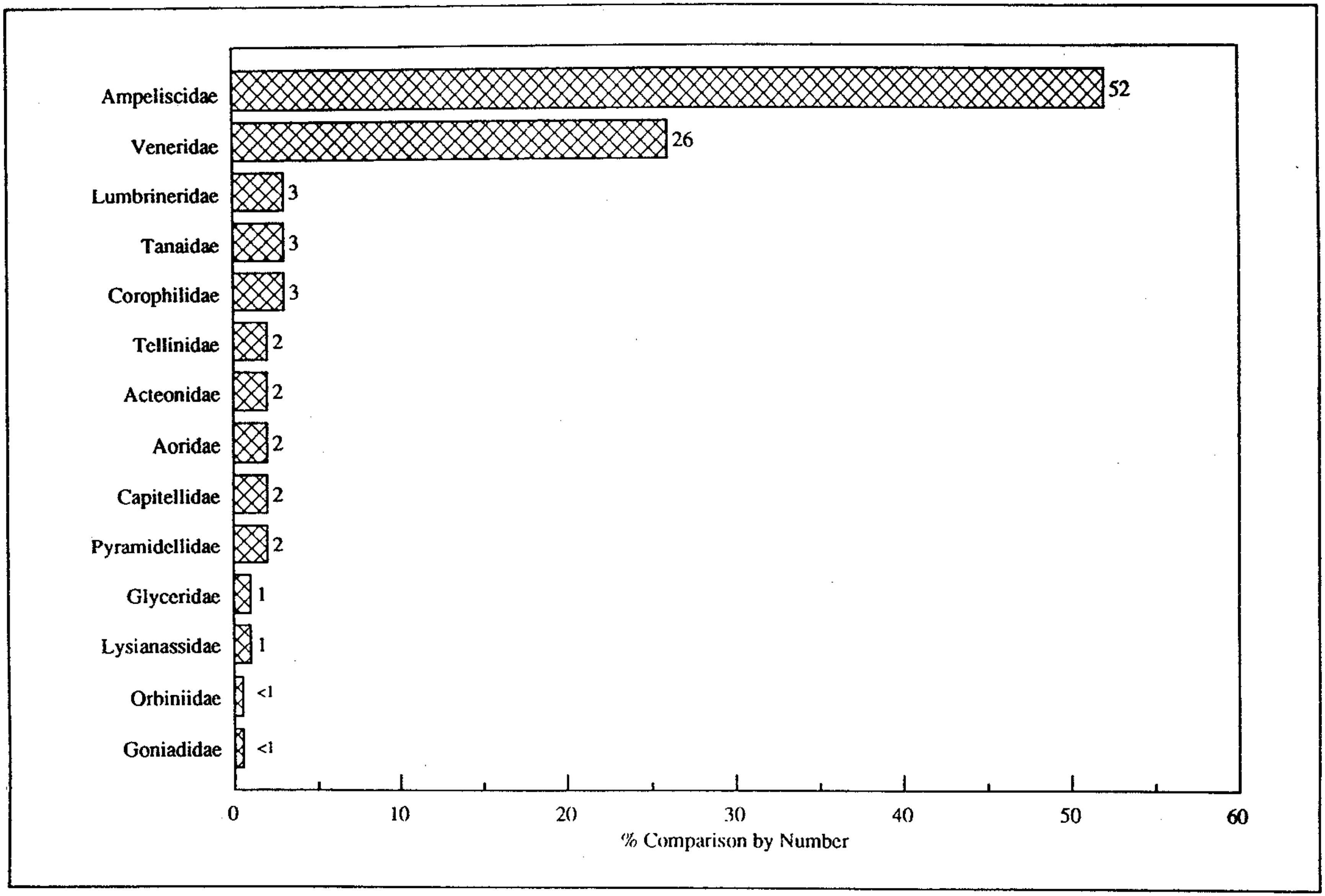

Figure 4.5-6
Percent Composition of Families Representing
Top 15 Species of the Benthic Community of Rehoboth Bay
Source of Data: Maurer, 1977

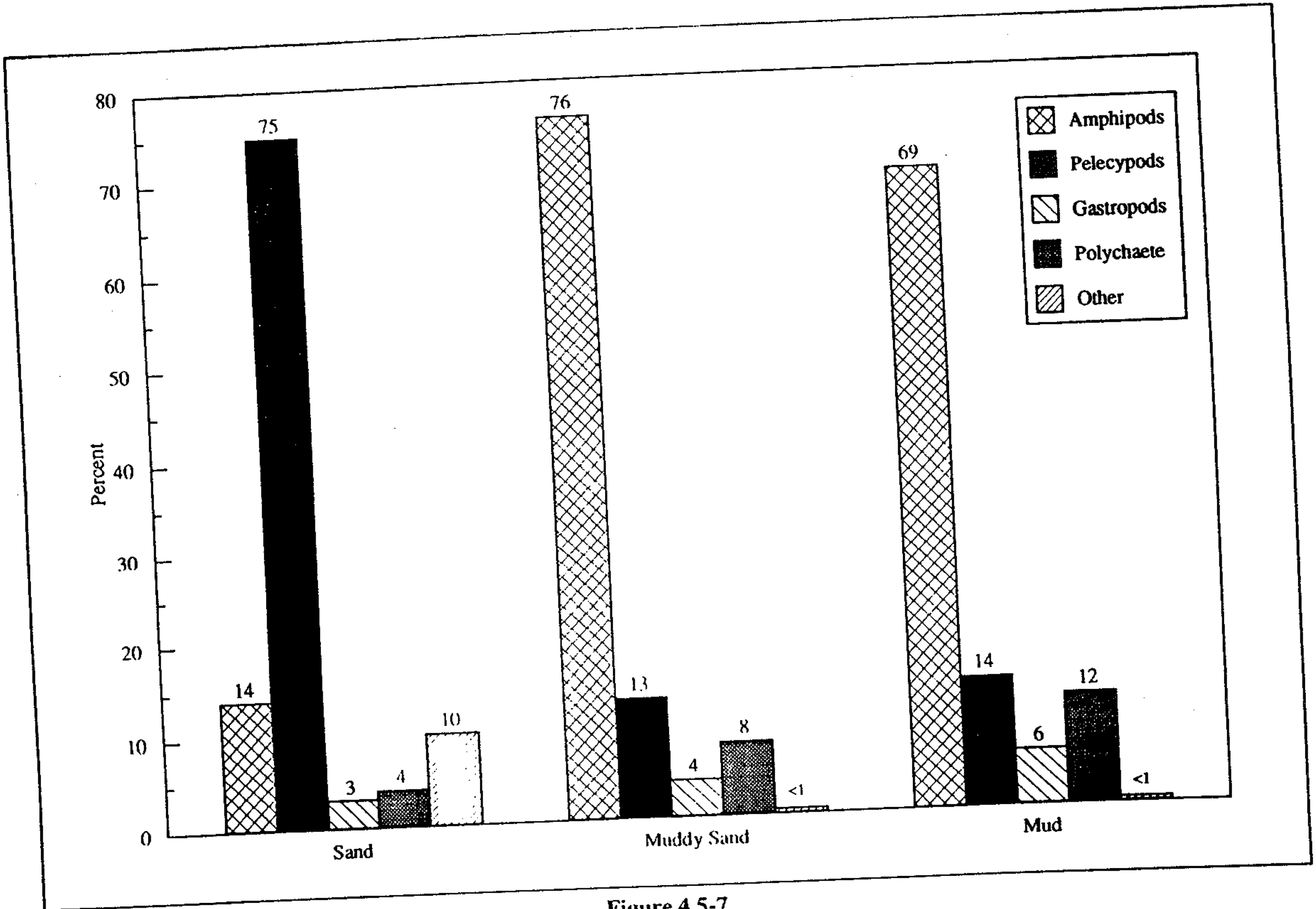

Figure 4.5-7

Composition of Relative Abundance of Organism Density of Major Taxa within Three Sediment Types of Rehoboth Bay

Source of Data: Maurer, 1977

The most common families of polychaetes and dominant species within those families collected in Rehoboth Bay during the 1968 to 1970 sampling period included:

- *Lumbrineridae*
    - *Lumbrineris tenuis*
- *Orbiniidae*
    - *Scoloplis fragilis*
- *Glyceridae*
    - *Glycera americana*
- *Goniadidae*
    - *Glycinde solitaria*
- *Capitellidae*
    - *Heteromastus filiformis*
- *Pectinariidae*
    - *Pectinaria gouldii*

Of the polychaetes, the dominant species in Rehoboth Bay from 1968 to 1970 was the lumbrinerid thread worm, *Lumbrineris tenuis*, which ranged in density from 40 to almost 200 individuals/m^2. The distribution of *L. tenuis* appeared to be fairly evenly distributed throughout the varying sediment types in the bay (Table 4.5-3).

- **Amphipods**

Twenty-five species of amphipods representing ten families were collected in Rehoboth Bay from 1968 through 1970. Amphipods comprised about 43 percent of the total number of benthic invertebrates collected with an average density of 1,800 individuals/m^2 (Figure 4.5-5). Distribution of amphipods by sediment type indicated a significant preference for mud- and muddy-sand (Figure 4.5-7). Average biomass of amphipods by substrate type was 5.4, 5.5 and 0.3 g(wet)/m^2 for muds, muddy-sands and sand, respectively.

Table 4.5-3

Average Density (no./m²) of Top 15 Species According to Percent Silt-Clay Rehoboth Bay

Species	% Silt-Clay				
	0.1-19.9	20-39.9	40-59.9	60-79.9	80-100
	Sand	Muddy Sand			Mud
Ampelisca abdita	123	2,958	457	4,182	1,788
Gemma gemma	3,244	446	335	309	374
Tellina agilis	125	170	74	22	11
Acteocina canaliculata	53	99	74	65	84
Lysianopsis alba	114	38	22	58	35
Lumbrineris tenuis	41	181	33	96	125
Microdeutopus gryllotalpa	86	98	104	35	95
Capitella capitata	21	57	86	139	136
Turbonilla interrupta	4	35	103	48	94
Glycinde solitaria	32	22	13	2	22
Scoloplos fragilis	33	10	27	8	5
Leptochelia savignyi	449	2	0	0	2
Corophium insidiosum	300	150	33	0	79
Glycera americana	7	32	25	11	38
Corophium tuberculatum	10	31	0	5	42

SOURCE OF DATA: Maurer, 1977

The most common families of amphipods and the dominant species within these families included:

- *Ampeliscidae*
    - *Ampelisca abdita*
- *Lysianassidae*
    - *Lysianopsis alba*
- *Corophidae*
    - *Coropohium insidiosum*
- *Melitidae*
    - *Elasmopus laevis*

Of the amphipods, *A. abdita* dominated the benthos with average densities ranging from about 125 individuals/m^2 to almost 4,200 organisms/m^2. Maximum densities of the amphipod were found in the muddy-sand sediments of Rehoboth Bay (Table 4.5-3).

- **Pelecypods**

Nineteen species of pelecypods were collected in Rehoboth Bay during the 1968-1970 sampling period. Represented by thirteen families, the bivalve molluscs comprised 43 percent of the total number of benthic invertebrates collected (Figure 4.5-5). The average density of the pelecypods in Rehoboth Bay at the time was about 500 individual/m^2. The distribution of pelecypods by sediment type indicated a strong preference for sand substrates where pelecypods comprised 70 percent of the benthos (Figure 4.5-7).

Common families of pelecypods and dominant species within those families included:

- *Veneridae*
    - *Gemma gemma*

Mercenaria mercenaria

- *Tellinidae*

  Tellina agilis

- *Solemycidae*

  Solemya velum

- *Mactridae*

  Mulinia lateralis

Of the bivalve molluscs, the gem clam, *G. gemma*, was the most abundant with average densities ranging from about 300 to 3,200 individuals/m^2 depending on sediment type (Table 4.5-3). Maximum densities were observed in the eastern and southern segments of the bay where sand dominates the sediment type (Figure 4.5-4).

- **Gastropods**

The gastropod molluscs represented a little less than four percent of the total number of benthic organisms collected in Rehoboth Bay from 1968 to 1970 (Figure 4.5-5). Seventeen species representing nine families of gastropods were collected. Dominant species by family include:

- *Scaphridae*

  Acteocina canaliculata

- *Pyramidellidae*

  Pyramidella fusca

  Turbonilla interrupta

- *Hydatinidae*

  Haminoea solitaria

The bubble snail *Acteocina canaliculata* dominated the gastropod community of Rehoboth Bay. Average densities for *A. canaliculata* ranged from about 50 to nearly 100/m^2. The distribution of this gastropod was fairly even throughout the sediment range with little significant sediment preference observed (Table 4.5-3).

- **Other Organisms of Note**

In addition to the four taxa groupings discussed above which represented a cumulative composition of 96 percent of the individuals collected, an additional taxon of note was the tanaid, *Leptochelia savignyi*, which represented about three percent of the benthic community of Rehoboth Bay by number. Found almost exclusively associated with sand, *L. savignyi* was collected at an average density of more than 400 individual/m^2 in these substrates (Table 4.5-3).

Distribution and Composition of Benthic Community by Sediment Type

As previously noted, in the absence of a strong salinity gradient, the heterogeneity of benthic faunal groups is largely a function of sediment type. Maurer describes three sediment types based on percent silt clay content in sediment and include "sand" - defined by a silt-clay content of less than 20 percent; "muddy-sand" with silt clay content ranging from 20 percent to 80 percent; and mud with a silt-clay fraction greater than 80 percent.

Figure 4.5-7 presents a comparison of the relative abundance, i.e., percent numerical composition, of the major taxa for each of the sediment types. In addition, Table 4.5-4 presents the average density and the relative distribution of principal families in the benthic community based on sediment type. The faunal assemblages associated with each are discussed briefly below.

- **Sand Fauna**

These fauna were collected in the sand substrate of Rehoboth Bay found predominantly in the eastern and southern segments of the bay. Again "sand" substrate is defined as sediments containing less than 20 percent silt-clay. Numerically dominant species in this sediment type included:

- *Gemma gemma* - the venerid clam accounted for more than 70 percent of the sand faunal assemblage by number. Average densities of this clam in sand assemblage measured

Table 4.5-4

Rank, Mean Density (No/m^2), and Percent of Total Density of Top Fourteen Families Collected in Rehoboth Bay According to Sediment Type (Source of Data: Maurer, 1977)

	Sand		Muddy-Sand		Mud	
	No./m^2	% of Total Density	No./m^2	% of Total Density	No./m^2	% of Total Density
Amphipoda						
Ampeliscidae	(5) 123	3	(1) 2,532	72	(1) 1,788	63
Lysianassidae	(6) 114	2	(8) 39	1	(7) 35	1
Aoridae	(7) 86	2	(6) 79	2	(5) 95	3
Corophidae	(3) 310	7	(9) 36	1	(6) 44	2
Pelecypoda						
Veneridae	(1) 3,244	70	(2) 363	10	(2) 374	13
Tellinidae	(4) 125	3	(5) 89	3	11	<1
Gastropoda						
Acteonidae	(8) 53	1	(6) 79	2	(5) 84	3
Pyramidellidae	(14) 4	<1	(7) 62	2	(5) 94	3
Polychaeta						
Lumbrineridae	(9) 41	1	(3) 103	3	(4) 125	4
Capitellidae	(12) 21	<1	(4) 94	3	(3) 136	5
Goniadidae	(11) 32	1	(12) 12	<1	22	1
Orbiniidae	(10) 33	1	(11) 15	<1	5	<1
Glyceridae	(13) 7	<1	(10) 23	1	(7) 38	1
Other						
Tanaidae	(2) 449	10	(13) 6	<1	2	<1

3,244 individuals/m^2.

- *Leptochelia savignyi* - a tanaid comprised about 10 percent of the sand faunal assemblage by number.

- *Corophium insidiosum* - the corophid amphipod accounted for about 7 percent of the sand fauna.

Collectively these three species accounted for almost 90 percent of the total number of benthic organisms collected from sand substrates.

- **Muddy-sand Fauna**

The widest ranging sediment classification, "muddy-sands" encompass sediments ranging in silty-clay content of 20 percent to 80 percent. These sediments are widely distributed in Rehoboth Bay and are found predominantly in the deeper central and the western portion of the bay. The fauna of this zone is dominated by suspension and deposit feeders occupying permanent tubes and burrows.

Numerically dominant species of the muddy-sand sediment assemblage included:

- *Ampelisca abdita* - the amplescid amphipod is a selective deposit feeder which comprises as much as 72 percent of the muddy-sand benthic community. Average densities of the amphipod for this assemblage measured about 2,500 individuals/m^2.

- *Gemma gemma* - the venerid clam was also a numerically dominant species representing approximately 10 percent of the muddy sand community.

- **"Mud" fauna**

Sediments characterized as "mud", i.e., having greater than 80 percent silt-clay content, are found in Rehoboth Bay, principally in the northern portion of Rehoboth Bay and at the mouths of Love Creek and Herring Creek. As with the muddy-sand faunal assemblage the amphipod, *A. abdita*, dominated the mud substrate. At an average density of almost 1,800 individuals/m^2, *A. abdita*, comprised about 63 percent of the benthic community by number of the "mud" sediments. The venerid clam, *G. gemma*, was the next most numerically dominant species contributing about 13 percent of the total number of organisms of this benthic community. In addition, the capitellid polychaete, *H. filiformis*, comprised five percent of the invertebrates collected in the "mud" community.

4.5.4.2 Indian River Estuary

Unlike Rehoboth Bay, the Indian River estuary exhibits a strong salinity gradient. Consequently, the distribution of benthic species in Indian River is not only controlled by sediment type but also by salinity. In a multiple correlation analysis of species distribution with salinity and sediment type, DP&L (1976) found that salinity was the major factor controlling benthic species distribution in the estuary. Three segments have been defined in the Indian River estuary based on a comparison of the annual average salinity distribution in Indian River estuary with the Venice salinity classification. For a more comprehensive discussion of the segmentation scheme for Indian River estuary, see Section 2, *Water Quality*. By way of review, the following segments and there characteristics have been defined:

- Oligohaline segment - ranging in salinity from .5 ppt to 5 ppt, this segment extends from Millsboro Dam seaward to the Indian River Power Plant (River Mile 9.2-13).

- Meshohaline segment - ranging in salinity from 5 ppt to 18 ppt, this segment extends from the IRPP to Greys Point on the south shore of Indian River Bay (River Miles 5.8 - 9.2).

- Polyhaline/Euhaline segment - ranging in salinity from 18 to 32 ppt, this segment includes Indian River Bay and extends from Grays Point to Indian River Inlet (River Miles 0 - 5.8).

Because of several factors discussed at length in Section 2, *Water Quality*, the tidal fresh segment of Indian River estuary is severely restricted. Historical records of salinity in uppermost Indian River demonstrate that limnetic conditions (<.5 ppt) occur infrequently and exist only briefly during periods of exceptionally high stream flows.

The following discusses the benthic invertebrate assemblages of each of the salinity segments. This discussion is based principally on the studies conducted by DP&L (1976) whose monitoring program encompassed each of the three segments and thereby allows for consistent comparison. In addition to the DP&L study, results are also compared with Jones et al (1973) for the oligohaline and mesohaline segments and with Maurer (1977) in general.

- **Oligohaline Segment**

From 1974 to 1976, DP&L collected a total of 102 samples at seven stations in the oligohaline segment of Indian River estuary. The average number of species and the average density of organisms collected at stations in the olighaline segment varied seasonally.

	Average # Species	Average Density (No./m^2)
Spring	14	4,851
Summer	13	3,044
Fall	14	4,377
Winter	11	4,139

Figure 4.5-8 presents a comparison of the relative abundance of individuals observed in the oligohaline by major taxa. Four taxa accounted for more than 90 percent of the standardized density (No./m^2) of individuals collected and included the polychaetes (41%), the oligochaetes (26%) the amphipods (16%) and the nematodes (8%).

Table 4.5-5 presents the average density (No./m^2) and percent of total density of the principal families and species collected by DP&L in each of the Indian River estuary segments. A summary of the principal families and species for each of the major taxa associated with the oligohaline segment is presented below.

- **Polychaetes**

From 1974 to 1976, polychaetes dominated the benthic community of the oligohaline segment of the Indian River estuary and accounted for more than 40 percent of the total number of individuals collected. The average density of polychaetes in this segment of the Indian River estuary from 1974 to 1976 was about 3,075 individuals/m^2. Individual families and species that contributed to more than one percent of the overall community density of the oligohaline segment included:

- *Spionidae*
  - *Streblospio benedicti*
- *Capitellidae*
  - *Heteromastus filiformis*

Of all benthic invertebrates collected in the oligohaline segment of Indian River estuary from 1974 to 1976, the spionid polychaete, *Streblospio benedicti*, numerically dominated the benthic community. With an average density of about 2,640 organisms/m^2, *S. benedicti* accounted for 33 percent of the total density of organisms in sediments of the oligohaline segment. *S. benedicti*

Table 4.5-[illegible]

Average Density (No./m²) and Percent of Total Density of Principal Benthic Species Collected by DP&L (1974-1976) for Each of the Indian River Estuary Segments

	Oligohaline Segment		Mesohaline Segment		Polyhaline Segment	
	No./m²	% of Total Density	No./m²	% of Total Density	No./m²	% of Total Density
POLYCHAETA		41.2		48.7		31.3
Spionidae	2640	34.3		40.0		10.8
Streblospio benedicti	2137	33.4	3102	37	354	6.3
Paraprionospio pinnata	15	0.2	180	2.1	165	3.0
Scolecolepides viridis	40	0.6				
Polydora ligni	8	.1	70.7	0.8	84.8	1.5
Goniadidae						
Glycinde solitaria	33	0.5	91.5	1.1	122	2.2
Nereidae						
Nereis succinea	30.3	0.5	66.0	0.8	133	0.2
Orbiniidae						
Scoloplos fragilis	0.9	0.01	13.3	.2	19.4	.4
Scoloplos spp	6.6	[illegible]	25.8	.3	45.4	.8
Phyllodocidae						
Eteone heteropoda	50.1	0.8	25.1	.3	2.4	.04
Capitellidae						
Heteromastus filiformis	241	3.5	372	4.4	559	10.0
Mediomastus ambiseta	.05	.01	1.8	.02	237	4.2
Capitella capitata	35	.6	1.1	.01	53.9	1.0
Hesionidae						
Gyptis vittata	7.6	0.1	11.5	0.1	15.8	0.3
Ampharetidae						
Hypaniola grayi	34.5	0.5	1.4	0.02	0	0
Lumbrineridae						
Lumbrineris tenuis	0.0		9.78	.1	3.6	.1
Unid Polychaeta	1.9	.03	118	1.4	70.9	1.3
UNID OLIGOCHAETA	**1635**	**25.6**	**15.4**	**.2**	**0**	**0**
AMPHIPODA		**15.6**		**34.1**		**29.1**
Ampeliscidae						
Ampelisca abdita	56.7	0.9	1071	12.7	990.6	[illegible]
Aoridae						
Leptocheirus plumulosis	919	14.4	1526	18.1	420	7.5
Corophidae		.16				
Corophium acherusicum	0.0	.1	30.9	.4	1.8	.03
Corophium tubellitalum	0.0		46.6	.6	29.7	.5
Corophium laccierre	3.8	0.06	3.2	.04	5.4	.1
Liljeborgiidae						
Listnella barnardi	5.2	.1	192	2.3	186	3.3
NEMERTEA						
Carinoma tremaphoros	67.1	1.0	8.6	.1	18.2	.3

Table 4.5-5 (cont'd.)

Average Density (No./m²) and Percent of Total Density of Principal Benthic Species Collected by DP&L (1974-1976) for Each of the Indian River Estuary Segments

	Oligohaline Segment		Mesohaline Segment		Polyhaline Segment	
	No./m²	% of Total Density	No./m²	% of Total Density	No./m²	% of Total Density
PELECYPODA		**2.2**		**3.4**		**27.2**
Mytilidae						
Mytilus edulis	1.9	.03	7.2	.1	1057	18.9
Mactridae						
Mulinia lateralis	14.7	.23	77.9	.92	12.7	.23
Tellinidae						
Macoma tenta	81	1.3	61	0.7	441	7.9
Venerida						
Gemma gemma	38	0.6	143	1.[illegible]	133	0.2
GASTROPODA		**.13**		**2.0**		**4.1**
Pyramidellidae						
Odostomia bisuteralis	.5	.01	47.0	.6	18.8	.34
Turbonilla interrupta	1.4	.02	41.6	.49	90.2	1.6
Acteonidae						
Acteocina canaliculata	9.5	.1	76.5	0.9	120	2.2
ISOPODA		**.46**		**.48**		[illegible]
Cyathura polita	13.2	.21	18.7	.22	[illegible]	[illegible]
Edotea triloba	16.1	.25	22.3	.26	[illegible]	[illegible]
CUMACEA						
Leucon americanus	160	2.5	249	3.0	38	[illegible]
Unid Foraminifera	142	2.2	109	1.3	72	1.3
Unid Nematoda	523	8.2	305	3.6	91	1.6
Other	46.4	.73	243	2.9	212	3.8

is a small burrowing polychaete that is euryhaline in its distribution in Indian River. In the Chesapeake, it is found throughout the mesohaline and polyhaline zones at densities generally less than 100/m^2. As a surface deposit feeder, it is subject to predation principally by crabs, but also by fish. The amphipod, *A. abdita* is considered a direct competitor of the polychaete where the feeding behavior and tubes of the amphipod interfere with the polychaete (Holland et al., 1979).

While not nearly as abundant, the capitellid, *Heteromastus filiformis*, was the next most abundant polychaete with an average density of about 250 organisms/m^2. Together the spionid and capitellid polychaetes accounted for about 38 percent of the density of the invertebrate community of the oligohaline segment of Indian River Estuary.

- **Oligochaetes**

The second most abundant taxon recorded in the oligohaline segment was the oligochaetes which accounted for 25 percent of the benthic community by number with an average density of 1,635 individuals/m^2. An analysis of the oligochaete population identified about 95 percent of the individuals to be the tubificid worm, *Limnodrilus*, an opportunistic species characterized by short life spans and high gamete production and found to dominate organically-rich sediments in other estuaries (Crumb, 1977, Diaz, 1979).

- **Amphipods**

Amphipods accounted for more than fifteen percent of the total organism density in the benthic community of the oligohaline segment with an average density of 985 individuals/m^2. Only a single species of amphipod contributed to more than one-percent of the total community density and included:

Aoridae

Leptocheirus plumulosis

Of the amphipods, the numerically dominant species, *Leptocheirus plumulosus*, was found at an average density of about 920 individuals/m^2.

- **Other Taxa**

In addition to the taxa noted above, other taxa contributing to more than one percent of the total invertebrate density in the oligohaline segment included:

Nematoda

Unidentified (8.2)

Nemertea

Carinoma tremaphoros (1.0)

Pelecypoda

Macoma tenta (1.3)

Cumacea

Leucon americanus (2.5)

In summary, Table 4.5-6 presents the benthic faunal assemblage characteristic of the oligohaline segment as well as the other segments of the Indian River Estuary for the period 1974 to 1976. Individually, these taxa contributed to more than one percent of the total organism density. In aggregate, these taxa accounted for more than 85 percent of numerical density of the benthic community of the oligohaline segment of the Indian River Estuary from 1974 to 1976.

Table 4.5-7 presents a comparison of the rank, mean density and percent mean density of the ten numerically dominant benthic species collected in three different studies of the oligohaline segment of Indian River estuary. Results of the DP&L study are compared with those of Jones et al., 1974 and Maurer, 1976. The results indicate that for the most part, the findings of DP&L

Table 4.5-6

Characteristic Assemblage of the Benthic Community of the Three Segments of Indian River Estuary in 1974-1976 Based on Numerical Dominance Source of Data: DP&L, 1976

Oligohaline	Mesohaline	Polyhaline
Polychaeta	*Polychaeta*	*Polychaeta*
Streblospio benedicti (Spionidae) *Heteromastus filiformis (Capitellidae)*	*Streblospio benedicti (Spionidae)* *Paraprionospio pinnata (Spionidae)* *Glycinde solitaria (Goniodidae)* *Heteromastus filiformis (Capitellidae)*	*Heteromastus filiformis (Capitellidae)* *Mediomastus ambiseta (Capitellidae)* *Capitella capitata (Capitellidae)* *Paraprionospio pinnata (Spionidae)* *Streblospio benedicti (Spionidae)* *Polydora ligni (Spionidae)* *Glycinde solitara (Goniadidae)*
Oligochaeta	*Amphipoda*	*Amphipoda*
tubificid worms (Limnodrilus)	*Ampelisca abdita (Ampeliscidae)* *Leptocheirus plumulosis (Aoridae)* *Lystriella barnardi (Lilljeborgidae)*	*Ampelisca abdita (Ampelscidae)* *Leptocheirus plumulosus (Aoridae)* *Lystriella barnardi (Lilljeborgidae)*
Amphipoda	*Pelecypoda*	*Pelecypoda*
Leptocheirus plumulosis (Aoridae)	*Gemma gemma (Veneridae)* *Mulina lateralis (Mactridae)*	*Mytilus edulis (Mytilidal)* *Macoma tenta (Tellinidae)*
Pelecypoda	*Gastropoda*	*Gastropoda*
Macoma tenta (Tellinidae)	*Acteocina canaliculata (Scaphandridae)*	*Turbonilla interrupta (Pycamidellidae)* *Acteocina canaliculata (Acteonidae)*
Nematoda		
Cumaea	*Cumacea*	
Leucon americanus	*Leucon americanus*	
Nemertea		
Carinoma tremaphoros		

Table 4.5-7

Rank, Mean Density and Percent of Mean Density of the Ten Numerically Dominant Species in the Oligohaline Segment of Indian River

Taxa	DP&L (1976)			Jones et al. (1973)			Maurer (1977)		
	Rank	Mean Density	Percent	Rank	Mean Density	Percent	Rank	Mean Density	Percent
Streblospio benedicti	(1)	2,137	33	(1)	3,195	33			
Class Oligochaeta	(2)	1,635	25	(2)	2,815	29			
Leptocheirus plumulosus	(3)	919	14	(3)	2,207	23			
Heteromastis filiformis	(4)	241	4						
Leucon americanus	(5)	160	3						
Macoma tenta	(6)	81	1						
Carinoma remophorus	(7)	67	1						
Ampelisca abdita	(8)	57	1	(4)	837	9	(1)	3,110	43
Eteone heteropoda	(9)	50	1	(5)	172	2			
Scolecolepides viridis	(10)	40	<1						
Oxyurostylis smithi				(6)	28	1			
Hypaniola grayi				(7)	108	1			
Nereis succinea				(8)	997	1			
Cyathura polita				(9)	61	<1			
Gemma gemma				(10)	57	<1	(2)	3,002	42
Corophium tuberculatum							(7)	123	2
Tellina agilis							(3)	307	4
Leptochelia savignyi							(5)	140	2
Mytilus edulis							(6)	129	2
Microdeutopus gryllotapa							(4)	240	3
Lysianopsis alba							(8)	66	>1
Polydora ligni							(9)	61	<1
Turbonilla interrupta							(10)	41	<1

and Jones et al. were similar with respect to numerically dominant species. In both studies, *S. benedicti*, the oligochaetes, and *L. plumulosis* were the three most abundant taxa collected. A comparison of mean densities of similar species indicate that Jones, et al., found somewhat higher numbers in the earlier study.

- **Mesohaline Segment**

From 1974 to 1976, DP&L collected a total of 96 benthic samples from six stations in the mesohaline segment of Indian River estuary. The average density of organisms, as well as the average number of species, varied seasonally:

	No. of Species	Average Density (No./m^2)
Spring	18	10,496
Summer	16	3,483
Fall	18	5,959
Winter	22	7,166

Figure 4.5-8 presents a comparison of the relative abundance of individuals observed in the mesohaline segment of Indian River estuary by major taxonomic group. The benthic community of the mesohaline segment was numerically dominated by the polychaetes (49%), and the amphipods (34%) which collectively comprised about 83% of the organism density of this segment.

A summary of the principal families and their associated species for each of the major taxa associated with the mesohaline segment is presented below. Table 4.5-5 presents the mean density (No./m^2) and percent mean density of the principal families and species collected by

DP&L in the mesohaline segment. Note that "principal" families and species refer to those invertebrate species which, in aggregate accounted for more than 98 percent of the benthic community by number.

- **Polychaetes**

Polychaetes dominated the benthic community of the mesohaline segment of the Indian River estuary accounting for almost one-half of the number of organisms of the mesohaline benthos. The average density of polychaetes in the sediments of this segment of the estuary was 4,090 individuals/m^2. Those families and species of polychaetes contributing greater than one percent of the overall organism density (No./m^2) included:

Spionidae
- *Streblospio benedicti*
- *Paraprionospio pinnata*

Capitellidae
- *Heteromastus filiformis*

Goniadidae
- *Glycinde solitaria*

As with the oligohaline community, the meshohaline community was dominated by the spionid, *S. benedict*, which accounted for about 37 percent of the benthic community by number. Average density of *S. benedict* was 3,102 organisms/m^2. In addition, the capitellid, *Heteromastus filiformis* was observed at densities of 372 individuals/m^2 which represented four percent of the benthic organism density of this segment.

- **Amphipods**

The amphipods contributed about 34 percent of the overall benthic density in the mesohaline segment of Indian River estuary with an average density of 2,870 individuals/m^2. Amphipod species contributing to more than one percent of the organism density of the mesohaline segment from 1974 to 1976 included:

- *Ampeliscidae*
  - *Ampelisca abdita*
- *Aoridae*
  - *Leptocheirus plumulosis*
- *Lilljeborgiidae*
  - *Lystriella barnardi*

Of the amphipods, the corophid species, *L. plumulosis* was numerically dominant and represented 18.1 percent of the benthic invertebrate density with an average density of 1,526 individuals/m^2. In addition, the ampeliscid *S. abdita*, accounted for almost 13 percent of the benthic invertebrate density of the mesohaline segment.

- **Pelecypods**

The pelecypods accounted for almost 3.5 percent of the benthic invertebrate community of the mesohaline segment (by number) with an average density of about 290 individuals/m^2. Dominant taxa of the bivalve molluscs in the mesohaline reach included:

- *Veneridae*
  - *Gemma gemma*
- *Mactridae*
  - *Mulinia lateralis*

G. gemma, the most abundant of the bivalves, represented 1.7 percent of the benthic invertebrate density with an average density of 145 individuals/m^2.

- **Other Taxa**

In addition to the above taxa other taxa contributing to more than one percent of the total invertebrate density in the mesohaline invertebrate community included:

- *Nematoda*
  - Unidentified species (3.6%)
- *Cumacea*
  - *Leucon americanus* (3.0%)
- *Gastropods* (2%)

In summary, Table 4.5-6 presents the benthic faunal assemblage characteristic of the mesohaline segment for the period 1974 to 1976. Individually, these taxa contributed to greater than one percent of the total organism density. In aggregate these taxa accounted for more than 85 percent of the benthic community of the mesohaline segment of the Indian River Estuary.

Table 4.5-8 compares the relative abundance of the ten numerically dominant species collected in several studies of the mesohaline segment of Indian River. As noted for the oligohaline segment, species dominance was similar for DP&L (1976) and Jones (1974) with *S. benedicti* representing the numerically dominant species in both studies. In addition, *A. abdita* also ranked within the top three numerically dominant species in both studies. However, *L. plumulosis*, which ranked second in the mesohaline community in 1974-1976 with a mean density of 1,526 individuals/m^2, was found at an average of less than 100 individuals/m^2 from 1968-1971. In addition, the amphipod *Leptochelia savignyi*, which ranked third in numerical abundance from 1968 to 1971 with a mean density of 837 individuals/m^2 was noticeably absent from the mesohaline benthos five years later. As found in the oligohaline reach, a comparison of mean densities for similar species indicated higher densities in the earlier study.

- **Polyhaline Segment**

Table 4.5-8

Rank, Mean Density and Percent Mean Density of the Ten Dominant Species Found in Several Studies of the Mesohaline Segment of Indian River Bay Estuary

Taxa	DP&L (1976)			Jones (1973)			Maurer (1971)*		
	Rank	Mean Density	Percent	Rank	Mean Density	Percent	Rank	Mean Density	Percent
Streblospio benedicti	(1)	3,102	37	(1)	5,928	43			
Leptocheirus plumulosus	(2)	1,526	18						
Ampelisca abdita	(3)	1,070	13	(2)	3,177	23	(1)	3,110	44
Heteromastus filiformis	(4)	372	4				(7)	123	2
Unid nematoda	(5)	305	4				(3)	307	4
Leucon americanus	(6)	249	3						
Listriella barnardi	(7)	192	2				(5)	140	2
Paraprionospio pinnata	(8)	180	2				(6)	129	2
Gemma gemma	(9)	145	2	(7)	525	4	(2)	3,002	43
Glycinde solitaria	(10)	92	1	(9)	255	2			
Leptochelia savignyi				(3)	837	6	(5)	140	2
Capitellidae				(4)	804	6			
Microdeutopus gryllotalpa				(5)	641	5			
Oxyurostylis smithi				(6)	614	5			
Eteone heteropoda				(8)	433	3			
Cyathura polita				(10)	212	2			
Polydora ligni				(11)	210	2	(9)	61	1
Tellina agilis							(3)	307	4
Mytilus edulis							(6)	129	2
Corophium tuberculatum							(7)	123	2
Lysianopsis alba							(8)	66	1
Turbonilla interrupta							(10)	41	1

*Note Maurer's data presented for the estuary as a whole

VR 026

From 1974 to 1976, DP&L collected a total of 56 samples from six stations in the polyhaline segment of Indian River Estuary. The number of species and the average density of benthic invertebrates collected in the polyhaline reach of the estuary varied seasonally:

	Number of Species	No./m^2
Spring	16	4,621
Summer	15	4,309
Fall	15	2,996
Winter	24	14,008

The benthic community of the polyhaline segment was dominated by three taxa. Figure 4.5-8 presents a comparison of the percent of mean density of organisms collected in the polyhaline segment of Indian River estuary by major taxonomic group. Three taxa accounted for 87 percent of the number of individuals collected in the benthic community and included the polychaetes (31%), amphipods (29%) and the pelecypods (27%).

Table 4.5-5 presents the mean density (No./m^2) and percent mean density of the principal families and species collected by DP&L in the polyhaline segment. Note that "principal" families and species refer to those invertebrate species which collectively accounted for more than 98 percent of the benthic community by number. A summary of the principal families and species for each of the major taxonomic groups associated with the polyhaline segment is presented below.

- **Polychaetes**

Polychaetes and amphipods dominated the benthic community of the polyhaline segment with polychaetes accounting for about 31 percent of the benthic community, by number. The average density of polychaetes in the polyhaline segment from 1974 to 1976 was 1,746 individuals/m^2.

Those families and species of polychaetes contributing greater than one percent of the overall community density (No./m^2) include:

- *Capitellidae*
  - *Heteromastus filiformis*
  - *Mediomastus ambiseta*
  - *Capitella capitata*
- *Spionidae*
  - *Streblospio benedicti*
  - *Paraprionospio pinnata*
  - *Polydora ligni*
- *Goniadidae*
  - *Glycinde solitaria*

Of the polychaetes, the capitellids dominated the benthos of the polyhaline segment contributing to about fifteen percent of the overall community density. The capitellid, *Heteromastus filiformis*, dominated the polychaetes with an average density of 560 individuals/m^2 and accounted for ten percent of invertebrate density.

The second most abundant polychaete, the spionid, *S.benedicti*, was found at a density of 345 individuals/m^2 and accounted for more than 6 percent of the total invertebrate density.

- **Amphipoda**

During the DP&L study, the amphipods accounted for 29 percent of the total density of macroinvertebrates in the sediments of the polyhaline segment of Indian River. Average density of amphipods in this segment at the time of the study was 1,634 organisms/m^2. Those amphipods contributing to greater than one percent of the overall invertebrate density included:

- *Ampeliscidae*

Ampelisca abdita

- *Soridae*

    Leptocheirus plumulosus

- *Lilljeborgiidae*

    Listriella barnardi

The ampeliscid, *A. abdita*, dominated the amphipod population accounting for almost 18 percent of the total number of benthic organisms collected. *A. abdita* was the second most numerically abundant species observed in the polyhaline segment. Average density of *A. abdita* measured 991 individuals/m^2.

In addition the aorid amphipod, *L. plumulosis*, represented 7.5 percent of the total benthic community density.

- **Pelecypods**

The third most abundant group of invertebrates observed, the pelecypods, accounted for almost 27 percent of the benthic community density. Dominant taxa of pelecypods included:

- *Mytilidae*

    Mytilus edulis

- *Tellinidae*

    Macoma tenta

The blue mussel, *M. edulis,* dominated not only the bivalve mollusc population but also represented the single most abundant species found in the invertebrate community of the polyhaline reach accounting for 19 percent of the total invertebrate density.

The average density of *M. edulis* observed in the sediments of the lower segment of the Indian River estuary was 1,057 individuals/m^2. The second most abundant bivalve was the tellin, *M. tenta* which represented almost 8 percent of the invertebrate community.

- **Other Taxa**

In addition to the polychaetes, amphipods and pelecypods, other taxa contributing significantly (>1.0%) to the overall invertebrate density included:

- *Gastropoda*
  - *Turbonilla interrupta*
  - *Acteocina canaliculata*,

- *Nematoda*

In summary, Table 4.5-6 presents the benthic faunal assemblage characteristic of sediments of the polyhaline segment of the Indian River estuary for the period 1974 to 1976. Individually, these taxa contributed greater than one percent of the total organism density.

In aggregate these taxa account for better than 90 percent of the total macroinvertebrate density of the polyhaline reach of Indian River.

4.5.4.3 Little Assawoman Bay

Information regarding the benthic community of Little Assawoman Bay is limited to a study conducted by DNREC in October, 1991. Three sets of samples (3 replicates/set, total coverage = 0.070 m^2) were collected at three locations in Little Assawoman Bay (Figure 4.5-3). All sediment samples were sieved with a 500 um sieve. The sediment type for each location was similar with Stations 1 and 2 characterized as silty-sand and Station 3 as muddy-sand.

The twenty-nine taxa were collected in Little Assawoman Bay. The average density of organisms collected in Little Assawoman Bay was 4,670 individuals/m^2 with an average biomass of 57 g wet weight/m^2 which was dominated primarily by the polychaetes:

	Polychaeta	**Arthropoda**	**Bivalve**	**Gastropod**	**Misc.**	**Total**
Station 1 (silty sand)	43.8[a]	0.04	0.06	0.0	.16	44.1
Station 2 (silty sand)	56.0	0.04	0.02	0.0	.04	56.1
Station 3 (muddy sand)	62.7	0.45	0.38	7.5	.13	71.2

[a]All biomass g(wet)/m^2

Figure 4.5-9 presents a comparison of the percent mean density of invertebrates collected by major taxonomic group. Polychaetes numerically dominated the benthic community accounting for more than 85% of the mean organism density. Of the polychaetes, the capitellid, *Mediomastus ambiseta*, accounted for more than 42 percent of the total invertebrate density (no./m^2) for the aggregate collection (Table 4.5-9).

Although fairly similar in hydrography, the benthic communities of Rehoboth and Little Assawoman Bay appear to be dissimilar. Note that the average salinity of Little Assawoman Bay is less than that of Rehoboth Bay (see Section 2, *Water Quality*). The average annual salinity in Rehoboth Bay is about 28 ppt and ranges from 22 to 30 ppt. By comparison, the average annual salinity in Little Assawoman Bay is 22 ppt and typically ranges from 17 ppt to 26 ppt. In sediments characterized as muddy-sand (Stations 1 and 2) dominant species in Little Assawoman Bay included the polychaetes, *M. ambiseta, C. torquata, G. solitaria, S. benedicti*. These species accounted for 84 percent of the total numerical density of organisms in the muddy-sand substrate of Little Assawoman Bay. In contrast in Rehoboth Bay in similar sediment types, polychaetes in aggregate, accounted for only eight percent of the organism density. Moreover, in 1968 to 1970 the amphipod *Ampelisca abdita* and the clam, *Gemma gemma* comprised 80 percent of the silty-sand fauna of Rehoboth Bay. These same species made up less than 0.1 percent of the total density of organisms for that sediment type in Little Assawoman Bay. In addition, while Rehoboth Bay has been shown to support a large population of hard clams

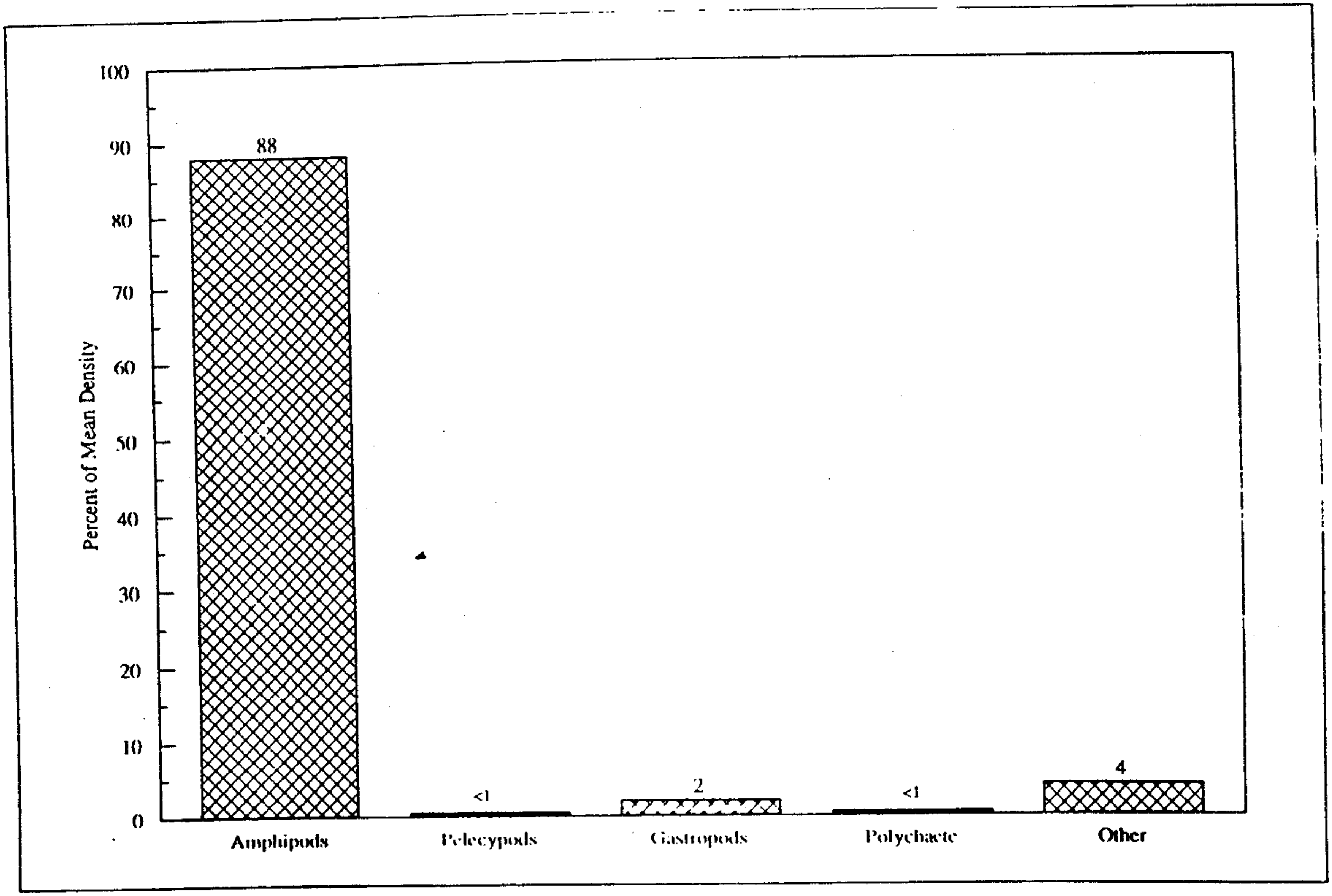

Figure 4.5-9

Percent Mean Density of Principal Taxonomic Groups Collected in Little Assawoman Bay in 1991

Source of Data: DNREC, 1991

Table 4.5-9

Rank, Mean Density (No./m²) of the Ten Numerically Dominant Species at Three Locations in Little Assawoman Bay (Source of Data: DNREC, 1991) (October 1991)

Taxa	Station 1		Station 2		Station 3	
	No./m²	% of Total Density	No./m²	% of Total Density	No./m²	% of Total Density
Polychaeta *Mediomastus ambiseta*	1,940	48.9 (1)	1,638	31.1 (1)	2,284	39.7 (1)
Clymenella torquata	560	14.1 (2)	1,466	34.1 (2)	1,149	20.0 (2)
Glycinde solitaria	316	8.0 (4)	316	7.4 (3)	776	13.5 (3)
Streblospio benedicti	431	10.9 (3)	230	5.4 (5)	230	4.0 (5)
Podarkeopsis levifuscina	287	7.2 (5)	144	3.4 (6)	230	4.0 (5)
Notomastus sp. A.	--	--	14	<1 (10)	172	3.0 (6)
Heteromastus filiformis	14	<1	--	--	86	1.5 (7)
Nemertea	129	3.2 (6)	259	6.0 (4)	417	7.3 (4)
Pelecypoda *Tellina agilis*	225	3.0 (7)	86	2.0 (7)	14	<1
Amphipoda *Lystriella barnardi*	86	2.2 (8)	57	1.3 (8)	29	1
Cumacea *Leucon americanus*	28	<1 (9)	--	--	--	--
Other		2.5		2.3		7.0
Mean Density (Total)	3,966		4,296		5,747	

Mercenaria mercenaria, Little Assawoman Bay appears to be lacking a hard clam population (Tinsman, 1991). Tinsman in his report speculated that lower salinities in Little Assawoman Bay may prohibit a sustained population of hard clams.

4.5.4.4 Comparison With Other Mid-Atlantic "Systems"

The benthic assemblage observed in the Inland Bays during the late 1960's and early 1970's was characteristic of estuarine soft-bottom benthic communities elsewhere along the Atlantic Coast during similar time periods.

A comparison of existing studies of coastal lagoonal systems like that for the Inland Bays shows a similarity in organism density throughout the mid-Atlantic region. Although the use of a variety of sieve sizes in collecting invertebrates precludes a direct comparison in many studies, it is clear that the macrofaunal density in Indian River, Rehoboth and Little Assawoman Bays lies well-within the range of densities reported for other estuaries of the Virginian Province (Table 4.5-10).

Numerically dominated by infaunal and epifaunal deposit feeders, such as *A. abdita, S. benedicti,* and *G. gemma* among others, similar community assemblages were observed in Barnestable Harbor (Sanders, 1962), Narragansett Bay, Great Bay, New Jersey (Durand and Nadeau, 1972), Moriches Bay (O'Connor, 1972) and Chincoteague Bay (Orth, 1973).

In a study of Chincoteague Bay, Orth (1973) reported the average density of invertebrates as approximately 4,500 indviduals/m^2. The benthos in this bay was dominated by the polychaetes, *S. benedicti*, and *H. filiformis* and the amphipod, *A. abdita.* In addition, the pelecypods *G. gemma* and *T. agilis*.

Dominant species reported for Moriches Bay in 1970 to 1971 included *Nereis succinea, G. americana, G. gemma, T. agilis, H. filiformis, C. capitata* and *A. cancliculata* and *H. solitaria* (O'Connor, 1972).

In his study of Indian River and Rehoboth Bay, Maurer noted that the occurrence of *G.gemma*, which next to *A. abdita*, was the single most abundant invertebrate of the benthic community of

Table 4.5-10
Comparison of Average Density (No.m^2) of Benthic Invertebrates Along Northeast Coast of U.S. (Loveland and Vouglitois, 1984; Jones, 1974; EA, 1976; Maurer, 1977)

Estuary	Sieve Size (mm)	Density Range (No./m^2)	Mean Density (No./m^2)	Source
Rehoboth Bay, DE	1.0	< 100-60,192	4,200	Maurer, 1977
Indian River Bay, DE	0.5			Jones, 1974
Indian River Bay, DE	0.5			DP&L, 1976
Indian River Bay, DE	1.0	< 100-106,871	7,400	Maurer, 1972
Little Assawoman Bay, DE	0.5	3,966 - 5,747	4,670	DE DNREC, 1991
Barnegat Bay, NJ	1.5	56-43,220	2,775	Loveland & Vouglitois, 1984
Hampton Roads, VA	1.0	520-8,865	2,571	Boesch, 1973
Mouth of Delaware Bay	1.0		100	Maurer, et al., 1974
Barnegat Bay, NJ			600	Phillips, 1967
Great Bay, NJ	1.1		≈5,000	Durand & Nadeau, 1972
Charlestown Pond, NJ	0.5		30,000	
Raritan River, NJ	1.5	15-14,245	2,586	Dean & Haskin, 1969
Cape Cod Bay	1.0	340-30,150	15,410	Young & Rhoads, 1976
Long Island Sound, NJ	1.0	5,566-46,404	16,446	Sanders, et al., 1956

Rehoboth Bay, was comparable to that found in other estuaries of the northeast United States with respect to organism density and frequency of occurrence.

As previously noted, the dominant benthos associated with the sand substrate of Rehoboth Bay was the venerid clam, *Gemma gemma*, which accounted for more than 70 percent of the sand fauna with an average density of 3,244/m^2. Similar assemblages have been observed for sand-fauna in the micro-lagoonal systems of the Woodshole area where pelecypods, and in particular, *G. gemma* dominated the invertebrate community at average densities of 4,500/m^2. In Charlestown Pond, a barrier beach lagoon in Rhode Island, *G. gemma* was also found to dominate the sand substrate at a density exceeding 10,000/m^2.

4.5.4.5 Summary

No current comprehensive data base is available by which to define the status of the benthic community of the Delaware Inland Bays. The last and only comprehensive survey of Rehoboth Bay was conducted over twenty years ago by Maurer. Likewise, a similar gap in data exists for Indian River estuary, as the last comprehensive survey there was conducted from 1974 to 1976. While data for Little Assawoman Bay are current, sampling was limited and, therefore, a conclusive indication of the status of the benthic community of Little Assawoman Bay is also not known. No historical benthic data exists for Little Assawoman Bay. As a consequence, data are unavailable for both defining the status and identifying trends in the macroinvertebrate community of the Inland Bays. The benthic community, when evaluated over time, represents an excellent indicator of the response of a system to changes in water and sediment quality. Because of the significance of the status and trend in the benthic community to the overall interpretation of conditions of the living "resources," the absence of more current information is a significant data gap in the Inland Bays characterization.

Consequently, we recommend that the Inland Bays program establish a baseline monitoring program by which future changes in the benthic community can be monitored. Moreover, this program should be integrated with whatever monitoring programs are conducted for "water quality" and "habitat modification" so that inferences of "cause and effect" can be more strongly supported.

APPENDIX 4.5-A
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SECTION 4.5-A

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SECTION 4.6
SHELLFISH

4.6.1 INTRODUCTION

Little has been recorded about the biota of the Inland Bays, including shellfish, prior to the early 1940's. Anecdotal information suggests that during prolonged openings of the inlet, the salinity regime of the bays became sufficiently stable to sustain populations of several shellfish species. In an article in *"Journal Every Evening,"* Higgins (1946) reported that the Reverend William Beckett, an Anglican missionary to Sussex County, wrote of "wonderful seafood found in [Rehoboth Bay and Indian River] in the 1730's and that colonial map-makers had noted the location of fabulous oyster beds." In *A Geographical Description of the States of Maryland and Delaware, 1807*, Scott (1807) noted that in the early 1800's, seafood from Indian River was becoming a prosperous business, however, for the most part, fish and shellfish caught in the bays was taken for personal consumption. Principal species included "shad, rock, trout, drums, sheepshead, oysters, clams and crabs" (as cited in Godfrey, 1953). In *Delaware: A Guide to the First State (Eckman*, 1955), describes the town of Millsboro as a center for shipping a variety of products including seafood. As late as 1915, local crabbers brought in thousands of soft-shell crabs from Rehoboth and Indian River Bays to Millsboro for shipment. Moreover, Godfrey (1953) reported that fish, crabs, oysters and clams were caught and sold in large numbers from the bays. In the early 1920's, crab shipments from the Inland Bays averaged 60,000 crabs per day at a market value of $5,000.

The intermittent closing of the inlet for extended periods, no doubt, seriously affected the shellfishery of the bays. Godfrey (1953) reported that the closing of the inlet in 1925 caused an estimated loss of one million dollars a year to the local seafood industry.

The stabilization of Indian River Inlet in 1939 resulted in the return of several shellfish species in the bays including the Eastern American oyster (*Crassostrea virginica*), the softshell clam (*Mya arenaria*), and the hard clam or northern quahog (*Mercenaria mercenaria*). Following the opening of the inlet, the soft shell clam was among the first shellfish to repopulate the Inland Bays, where they were clammed recreationally especially along Rehoboth Bay's east shore (Horn, 1957). However, the soft shell clam population underwent a marked decline in the early 1950's until it practically disappeared from the inland bays around 1955 (Lesser and Ritchie, 1979).

Prior to the onset of the hard clam industry in the mid- to late 1940's, large sections of Rehoboth and Indian River Bay were leased to individuals for oyster production. During the 1940's, Rehoboth and Indian River Bay served as major oyster plantation grounds for seed oysters obtained primarily from Delaware Bay (Humphries and Daiber, 1968).

In 1948, more than 3,164 acres or one-third (34 percent) of Rehoboth Bay was leased as oyster production grounds and 1,143 acres or about 13 percent of Indian River Bay was leased for similar purposes. Because of the oyster's commercial importance to the local seafood industry, the Delaware Commission of Shellfisheries promoted the use of the lower bays in the 1940's as "oyster production" areas almost to the exclusion of the hard clam industry (Lesser and Ritchie, 1979).

Beginning in 1956, the oyster population of the Inland Bays was decimated by *Haplosporidium nelsoni* (MSX). This oyster disease caused mass oyster mortalities along the entire east coast (Haskin and Ford, 1982). Attempts to re-establish the oyster population in the inland bays by using planting stock from natural oyster beds located in tributaries of the Delaware Bay failed on several occasions throughout the 1960's. Consequently, no significant oyster production in the inland bays has occurred since 1959 (Lesser and Ritchie, 1979).

In addition to producing oysters, the Indian River estuary was also used to depurate oysters taken from a number of beds from Delaware Bay and its tributaries. In 1966, only a single plantation ground in the vicinity of Oak Orchard/Pepper Creek was used to depurate oysters form the Mispillion and Murderkill Rivers. Depuration of oysters was intermittent throughout the 1960's and 1970's. DNREC records indicate that from 1966 to 1969, plantings decreased in Indian River from 6,474 bushels to 2,090 bushels of oysters. In 1978, 2,075 bushels of oysters were harvested from the Broadkill River and planted on oyster grounds in Indian River. The last planting was made in 1978 (Humphries and Daiber, 1968; Tinsman, personal communication).

In addition to soft shell clams and oysters, the Inland Bays supports or has supported several other potentially valuable shellfish populations including mussels, *Mytilus edulis*, surf clams, *Spisula solidissima*, and conchs, *Busycon spp*. In its *Draft Shellfisheries Management Plan*, DNREC, (1979) reports that all these species can be found in varying degrees of abundance in both bays. However, none of these species are currently exploited commercially or recreationally and little information exists for these species. In addition, Indian River and Rehoboth Bays also supports small populations of bay scallop, *Argopecten irradians*. The bay scallop was observed by Humphries and Daiber, (1968) in their survey of the hard clam of Indian River and Rehoboth Bays in 1965. In addition, Maurer (1977) observed bay scallops commonly associated with macroalgae of the bays. The presence of bay scallops in the shallows fringing the bays has also been mentioned ancedotally by several long-time residents of the bay area (Bryant, 1992). Because of its isolated distribution and rather small population, however, the bay scallop is neither of recreational nor commercial importance in the Inland Bays.

Finally and in summary, the hard clam (*Mercenaria mercenaria*) and the blue crab (*Callinectes sapidus*) are currently the only shellfish species of commercial or recreational importance in the Delaware Inland Bays. A review of existing information regarding the blue crab indicated that little substantive information on the blue crab population of the Inland Bays is available. In 1970, the University of Delaware, College of Marine Studies, initiated a blue crab survey of Indian River Bay. The general objectives of that study were to:

1. appraise the fluctuations in abundance of blue crabs by studying the relationship between adult and juvenile crabs; and

2. provide a long-term data base by which to make predictions and formulate models (Keck et al., 1973).

This project appears to have been discontinued around 1973. Although there are no recent data available, blue crabs are abundant in the Inland Bays and crabbing is an important recreational use of the bays (Greeley-Polhemus Group, 1987; Lesser, 1989). The following discussion of the status of the shellfish resource of the Inland Bays is limited to the hard clam.

4.6.2 Supporting Information for the Hard Clam Resource

Indian River and Rehoboth Bays have supported a commercial hard clam fishery since the early 1940's. Since that time a number of studies have been performed to assess various aspects of the hard clam resource of the inland bays. Table 4.6-1 presents a summary of the key hard clam studies conducted in the Inland Bays since the mid-1960's. In making comparisons between studies it is important to note the method used and gear employed to determine whether direct comparisons can be made. Table 4.6-2 provides a summary description of the study period, the number of stations, and collection methods used for each of the studies.

Table 4.6-1 Hard clam Studies of the Delaware Inland Bays	
Humphries & Daiber, 1968	*Shellfish Survey of Indian River Bay and Rehoboth Bay - Delaware.* (1967).
DNREC, Cole and Spence, 1976	*Hard Clam Survey Indian River - Rehoboth Bay.* (1975-1976)
Delmarva Power & Light Company, 1976	*Ecological Studies in the Vicinity of Indian River Power Plant.* 316 Demonstration 1974-1976.
DNREC, 1985-1990	Annual Reports: Technical Assistance to Commercial Fisheries
U.S. EPA, 1987	*Hard Clam Survey of Indian River Bay*

The first shellfish survey of the lower bays was performed by Humphries and Daiber (1968) during the summer of 1967. Conducted for the Northeast Marine Health Sciences Laboratory of the Public Health Service, the purpose of the survey was to evaluate the density of various shellfish including the hard clam relative to domestic pollution in the Rehoboth and Indian River Bays. A total of 196 stations in Rehoboth Bay and 196 stations in Indian River were sampled using commercial oyster tongs. Clams at each location were measured and classified according to eight commercial size categories. As part of this survey, the density distribution of hard clam in both bays was mapped by size class and the total standing crop for each bay was estimated.

A second study by Cole and Spence (1977) was conducted in 1975/1976 to determine the density distribution of hard clams in the Rehoboth and Indian River Bays. In this study, Cole and Spence surveyed similar stations to Humphries and Daiber (1968), using a more efficient sampling technique. In the earlier study, Humphries and Daiber used oyster tongs that were neither efficient in collecting clams below a depth of three to four inches nor were capable of collecting clams smaller than 1½ inches (3.8 cm). To obtain a better estimate of total hard clam density, Cole and Spence used a venturi-type hydraulic dredge and sampled one meter square

Table 4.6-2

A Summary of Key Studies of the Hard Clam Population

Researcher	Study Period	Number of of Stations		Methods
		RB	IRB	
Humphries and Daiber	1967	196	196	Tongs
Cole and Spence, 1976	1975	172	166	Clam Rake
DP&L 1976	1974-1976	31		Peterson Dredge
DNREC	1985	8	8	Hydraulic Dredge
DNREC	1986	8	8	Hydraulic Dredge
DNREC	1987	8	8	Hydraulic Dredge
DNREC	1988	8	8	Hydraulic Dredge
DNREC	1989	8	8	Hydraulic Dredge
US EPA	1987		165	Hydraulic Dredge

plots to a depth of one foot. The dredge was capable of sampling all size classes of clams from 2 mm to chowder size. As part of this survey, the density distribution of hard clams was mapped as well as size-frequency data generated.

Between 1974 and 1976, the Delmarva Power and Light Company, conducted a study of the benthos on the Indian River estuary as part of a comprehensive ecological program related to its Indian River Power Plant. To obtain information on hard clam populations, DP&L conducted two studies designed to supplement population data collected by Humphries and Daiber (1968) on clams living within the influence of the IRPP thermal plume. In June 1976, hard clams were sampled at 31 stations using a commercial clam rake. In August 1976, the same method was used to sample clams at eleven of the previously sampled stations.

As part of a program to provide technical assistance to commercial fisheries, Delaware's Division of Fish and Wildlife has been conducting a number of studies of the clam fishery of the Inland Bays since 1979. Studies have included recreational surveys in 1979, 1985 and 1987 and hard clam recruitment surveys between 1985 and 1989, as well as on-going commercial clamming surveys.

In addition to those studies described above, in the summer of 1987, the EPA (1987, unpublished data) conducted a study of Indian River Bay similar to those performed previously by Humphries and Daiber in 1967, and again by Cole and Spence in 1976. The EPA sampled 165 stations in Indian River Bay using a diver-operated suction dredge. A one-meter square bottom plot was sampled at each station. The results of the EPA study represent the most current estimate of the distribution of hard clam density in Indian River Bay. Consequently, the status of the quahog resource in Indian River Bay is probably best defined by the results of this study.

4.6.3 Stock Assessment of Hard Clam Resource

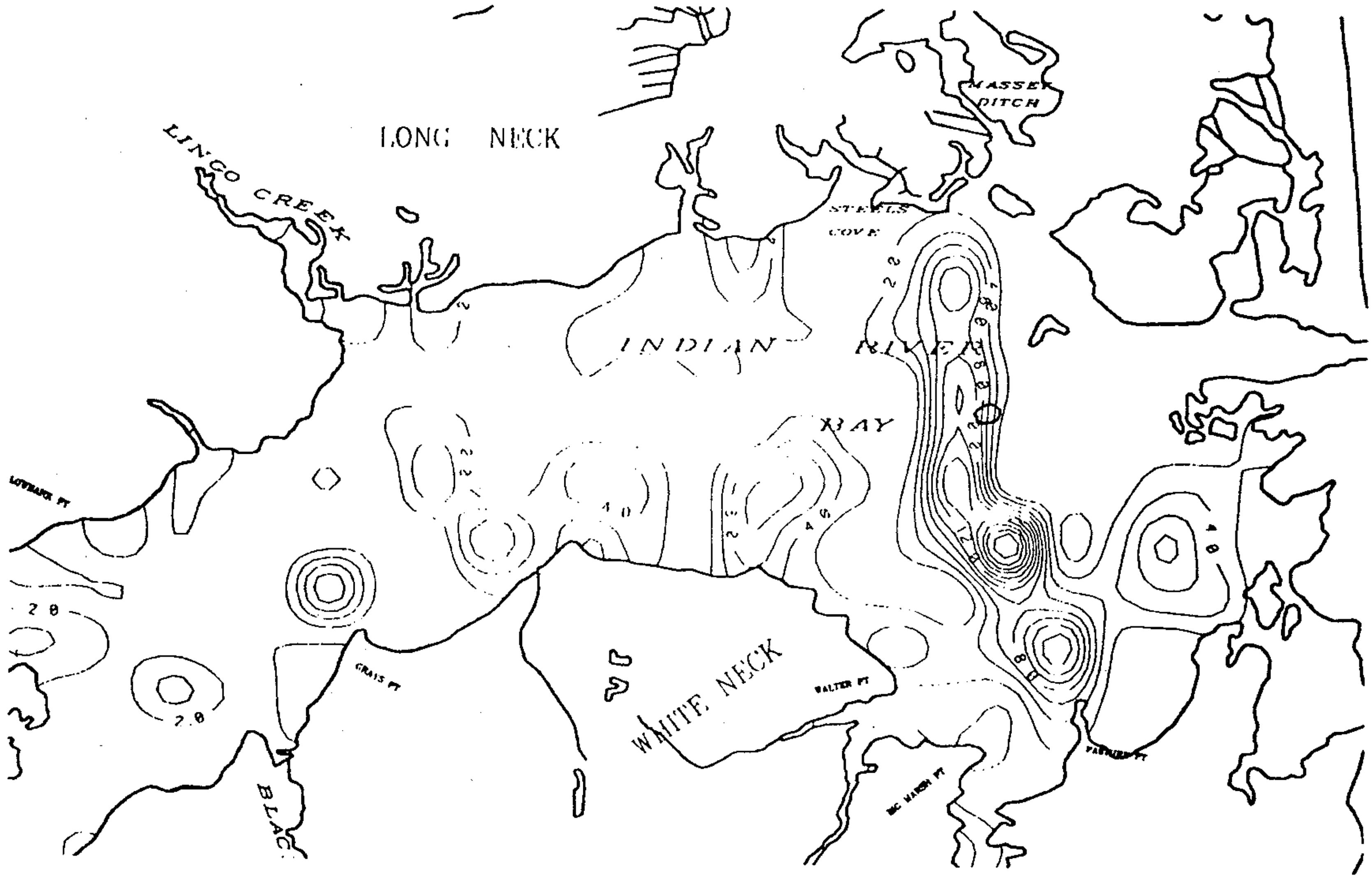
4.6.3.1 Status in Indian River Bay

The status of the hard clam resource in the Indian River Bay is best described by data collected by the EPA in 1987. As noted, the EPA (unpublished data) conducted an extensive survey of the hard clam resource in Indian River Bay during the summer of 1987. This study was performed to assess the distribution and density of the hard clam population in the estuary and to compare these data with the previous results of Cole and Spence (1977). Figure 4.6-1 presents the distribution of hard clam density (average number of clams per square meter) measured in 1987 at 165 stations in Indian River Bay. These stations were located on the same grid as that previously defined by Cole and Spence (Figure 4.6-2). The EPA found that hard clams were widely distributed throughout the estuary. In general, clam density increased towards the inlet with the most productive beds located mid-bay, south of Massey's ditch. Results of this study indicated an average clam density of 2.2 clams per square meter and a maximum density of 21 clams per square meter in Indian River Bay.

Figure 4.6-3 presents the length-frequency distribution for hard clams collected by EPA in Indian River Bay in 1987. The distribution indicates that during this time, there was an abundance of older clams in the 8 cm to 10 cm range. This size class comprised 45 percent of the total clams collected in Indian River Bay. The distribution also indicates that in 1987, the third most abundant size class was the 0.1 to 0.9 cm class, which represented 18 percent of the total clam density. The relatively high abundance in this size class suggested a successful recruitment of hard clams in Indian River Bay in 1986.

4.6.3.2 Historical Record of the Hard Clam Stock in Indian River Bay

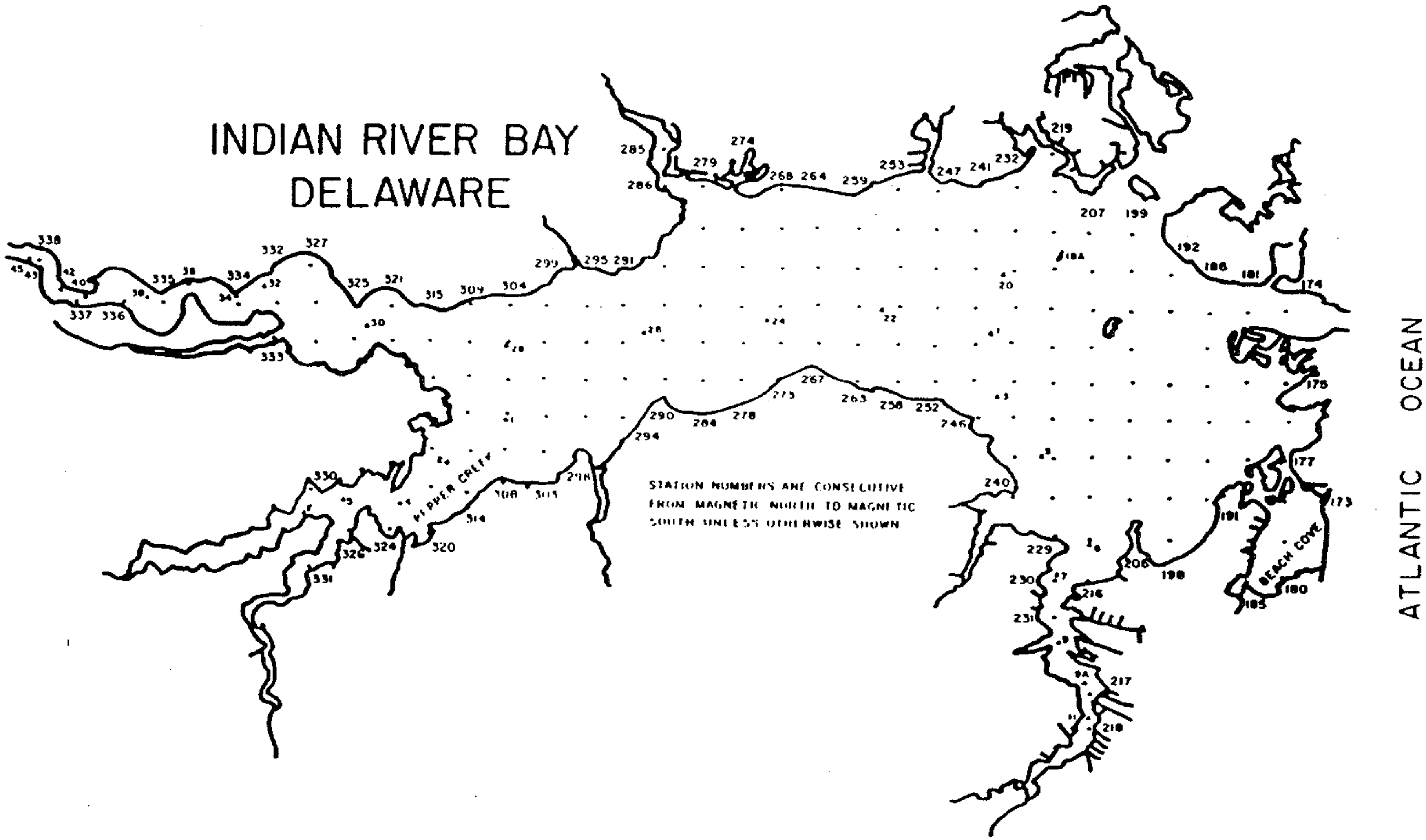
The inventory of hard clams, measured in 1975-1976 by Cole and Spence demonstrated a mean density of hard clams in Indian River Bay of approximately 2.1 clams per square meter. The distribution of hard clam density measured in Indian River Bay in 1975-1976 is provided in



Source of Data: EPA 1987

Figure 4.6-1
Distribution of Hard Clams Density (clams/m²)
in Indian River Bay - 1987

Scale 1 Inch = 4000 Feet
2000 0 2000 4000



Source of Data: Cole & Spence, 1977

Figure 4.6-2
Hard Clam Sampling Grid for Indian River Bay

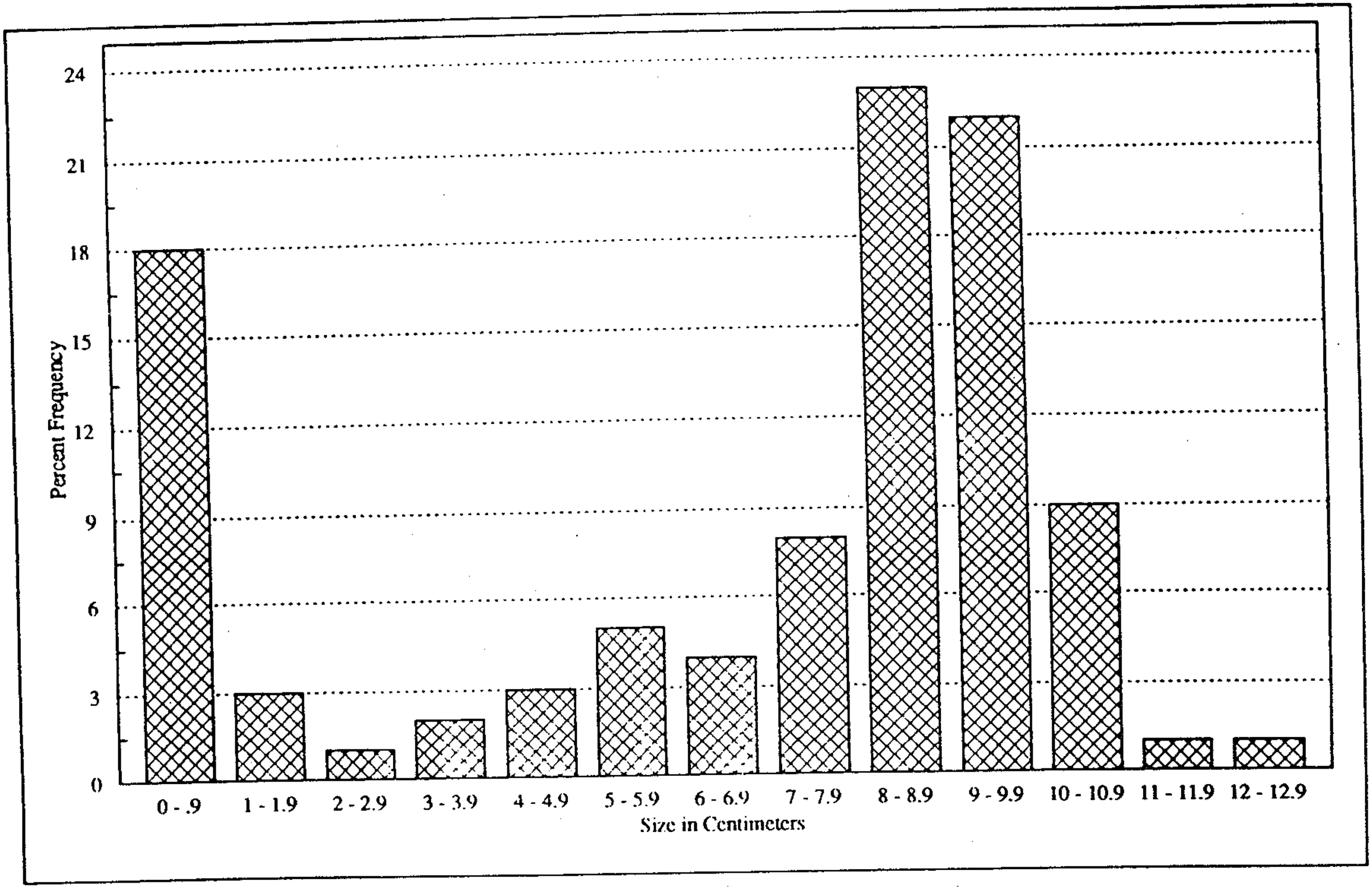


Figure 4.6-3

Length Frequency Distribution of Hard Clams Collected at 165 Stations in Indian River Bay in 1987

Source of Data: U.S. EPA, 1987

Fish10-D18

Figure 4.6-4. A mean density of 2.2 clams per square meter recorded in 1987 suggests little change in the overall average clam density of Indian River Bay in the eleven year interval between the two studies. Spatial differences in clam density distribution between 1976 and 1987 are provided graphically in Figure 4.6-5. The figure shows the change in clam density between 1976 and 1987. Areas of greatest change occur mid-bay south of Massey's ditch and north of Grays point.

In 1967, Humphries and Daiber also found hard clams to be widely distributed in Indian River Bay with mean density of 1.7 clams per square meter (Figure 4.6-6). A statistical comparison (students "t" test) of data collected in 1967 with that collected in 1976, using only data for clams larger than 1.5 inches (3.8 cm) to offset differences in efficiency of sampling gear, indicated no significant difference in mean clam density between the two studies. However, Cole and Spence argued that although clam stocks were similar, when sampling method efficiencies were taken into account, the clam stocks between 1967 and 1976 may have actually decreased. They reasoned that had the clam population truly remained similar, an improved sampling technique, like the hydraulic dredge, should have resulted in a significant increase in the mean density of clams collected.

Two explanations were offered for the "apparent decrease:"

1. Heavy commercial clamming pressure during the 1960's and 1970's; and,

2. The lack of optimum sediment type to support and produce higher densities.

Cole and Spence had shown that clam distributions were closely correlated with sediment types and that shell and sandy mud sediments contained statistically significant higher clam densities than any other sediment type. Muds had the lowest clam densities. Clam abundance in heterogeneous substrate mixture of sand or mud with gravel or shell has been shown elsewhere (Pratt, 1953; O'Connor, 1972). At the time of their study, Cole and Spence speculated that the reduction of oxygen, due to decomposition of organic sediments, may possibly limit their

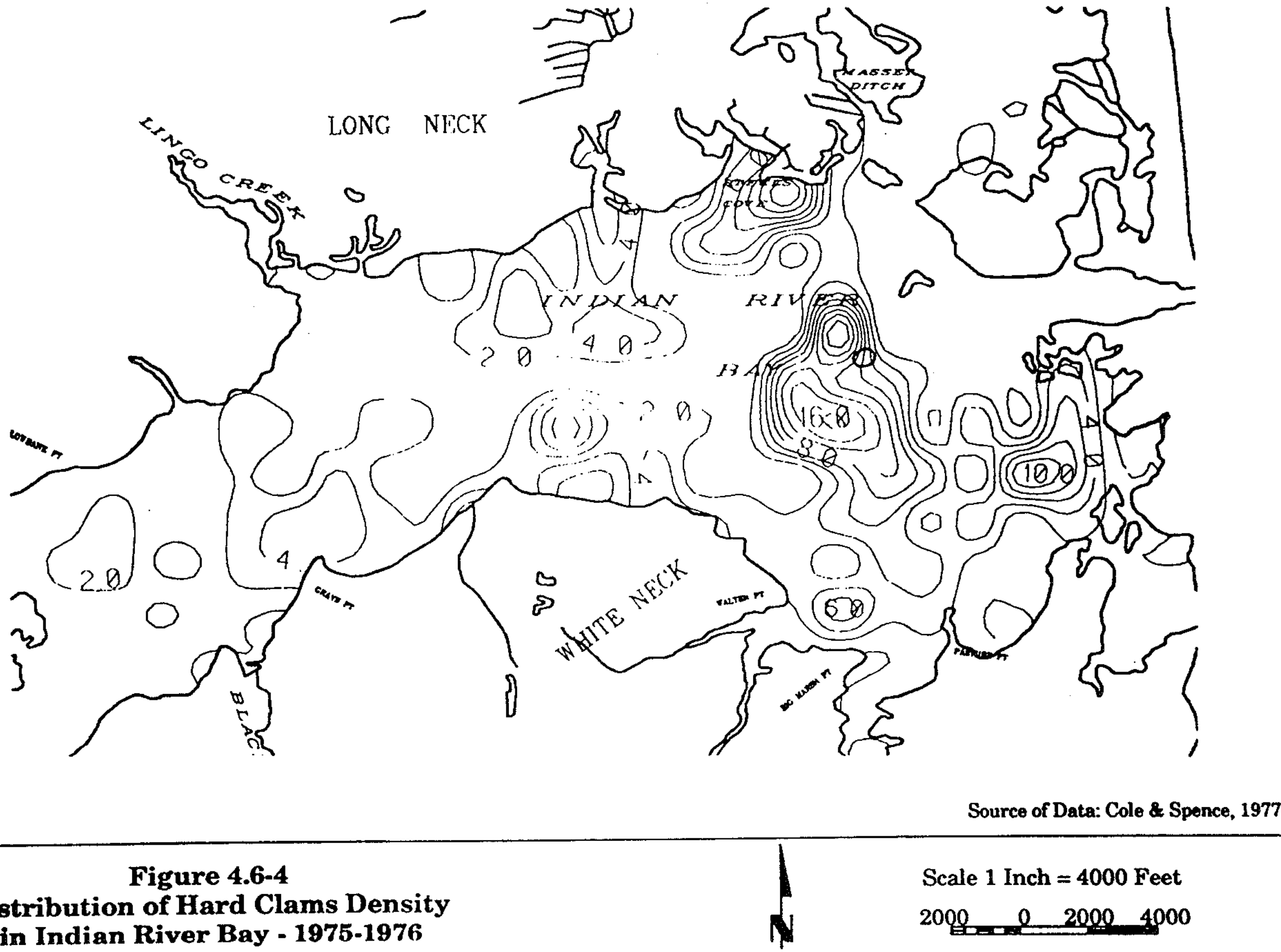
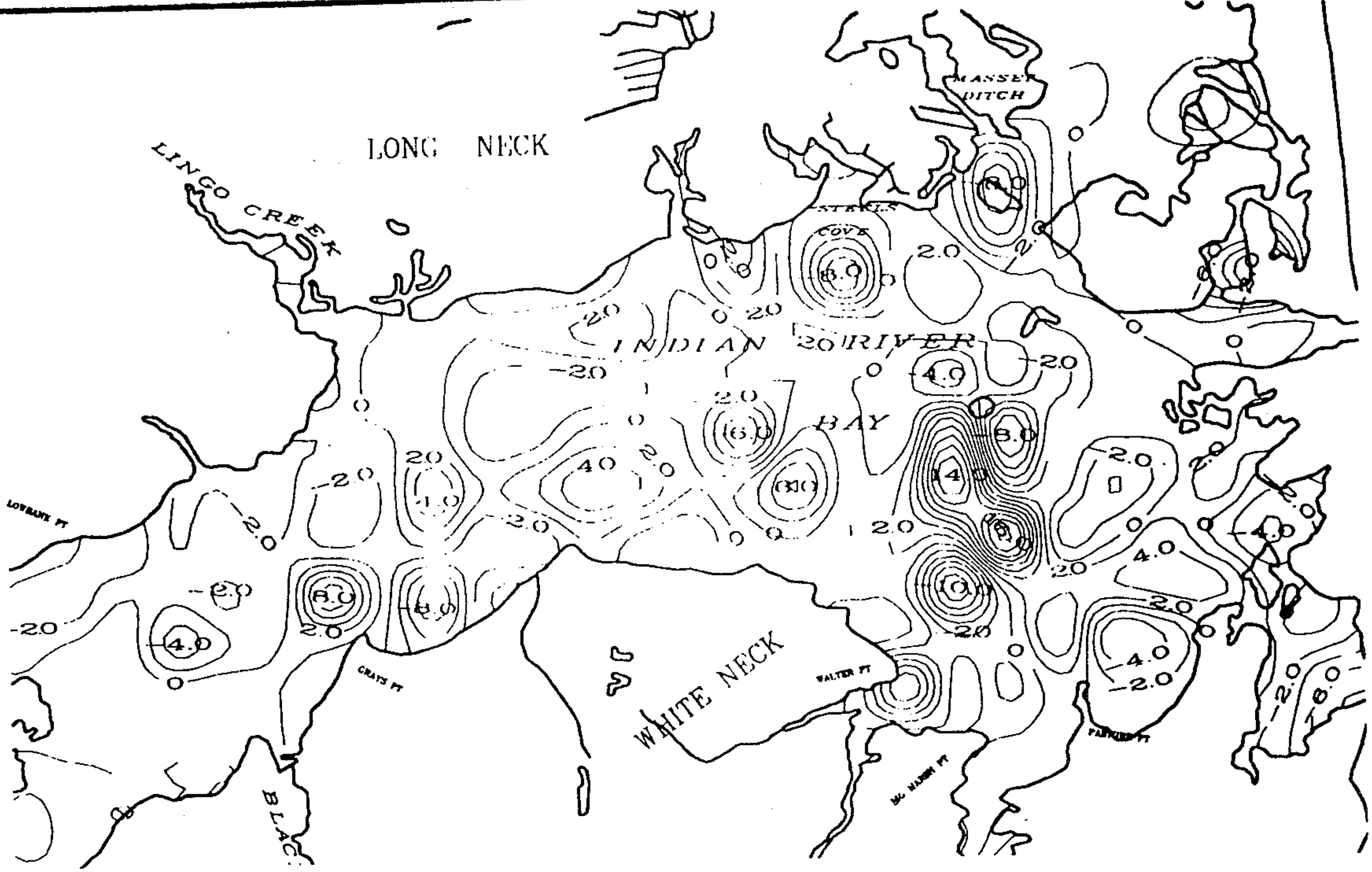


Figure 4.6-4
Distribution of Hard Clams Density in Indian River Bay - 1975-1976



Source of Data: EPA, 1982
Cole & Spence, 1977

Figure 4.6-5
Difference Map of Hard Clams Density (clams/m²)
in Indian River Bay
Between 1976 and 1987

Scale 1 Inch = 4000 Feet

2000 0 2000 4000

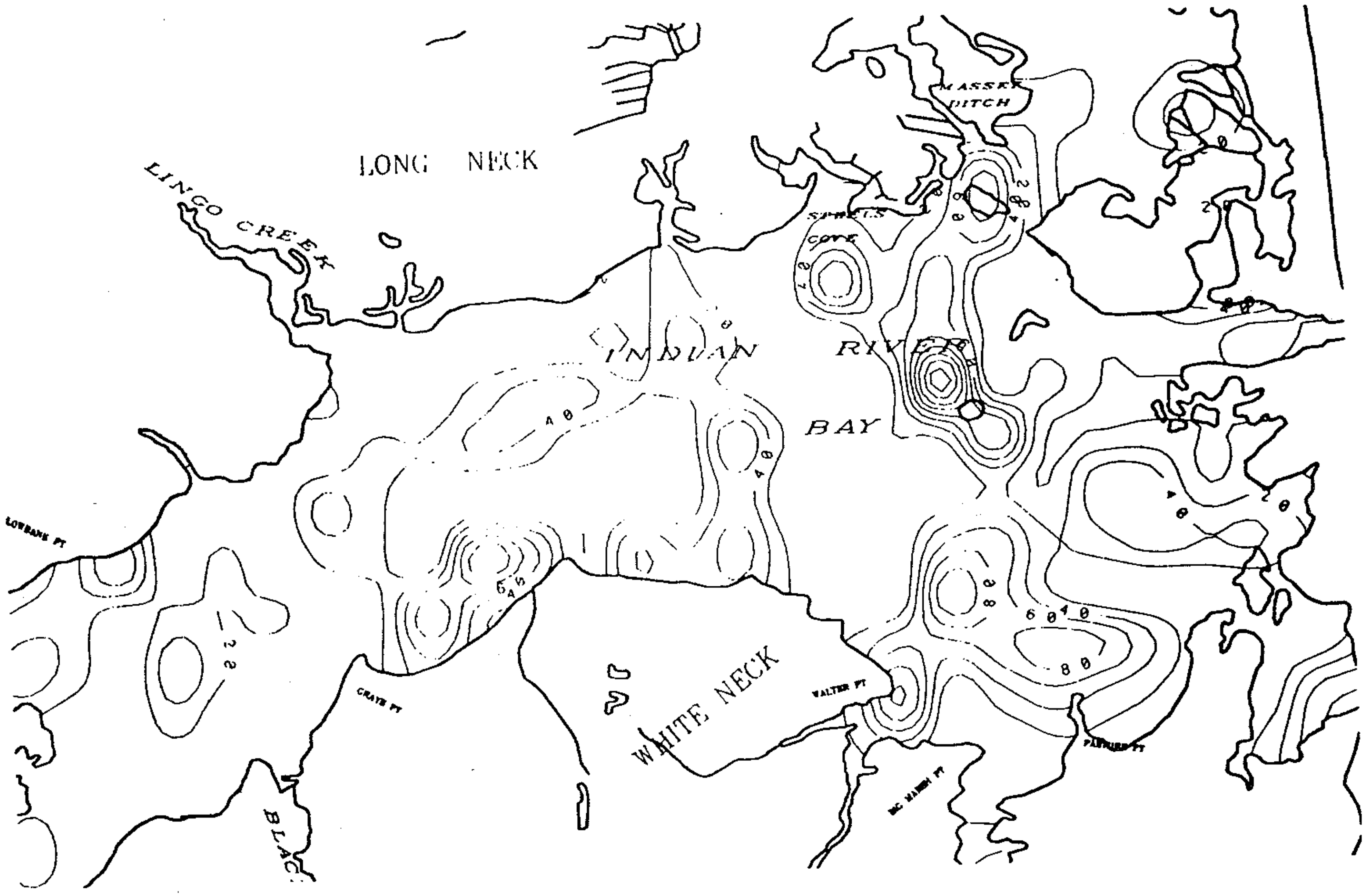


Figure 4.6-6
Distribution of Hard Clams Density in Indian River Bay - 1967

distribution in muds. Arnold (1983) suggests predation as the limiting factor with larger material such as shell offering spatial refuge from predation.

In addition to the comparison of clam density data, useful information on changes in the hard clam population are also obtained from a comparison of size-frequency distributions. Knowledge of the age-structure (as inferred from size distribution) is valuable in determining the status of recruitment in the population. Distribution in size class reflect varying success in recruitment stock. Typically, bimodal distributions reflect successful recent young year recruitment along with a large and older standing stock. The length-frequency distribution for hard clams collected in Indian River Bay in 1975-1976 is provided in Figure 4.6-7. Cole and Spence's data indicate that the dominant size class of hard clams collected in 1975-1976 was the 8.0 cm to 10.9 cm size class which represented approximately 54 percent of the total clams collected. The dominance of this size class in 1987 was comparable to that found previously in 1987, again representing about 54 percent of the total clams collected. However, there is one principal contrast in the length-frequency distributions seen in both studies. Figure 4.6-8 presents a sum-difference plot of the length frequency distributions for hard clams collected in 1976 and 1987 in Indian River Bay. The plot shows that the greatest change between 1976 and 1987 occurred in the 0.1 to 0.9 cm size class which increased its contribution to the population size by 15 percent, i.e., from 3 percent of the population in 1976 to 18 percent in 1987, supporting the notion of a successful recruitment year in 1986.

Based on earlier studies, this suggests the first highly successful recruitment of hard clams in Indian River Bay in twenty years. Prior to 1985, the hard clam population in Indian River Bay was dominated by larger, older clams. Cole and Spence suggested that these older clams were the result of a successful recruitment year in the early 1960's. In 1976, Cole and Spence, using growth data from Belding's study of hard clams in Massachusetts, speculated that 75 percent of hard clams collected in their study were set prior to 1971.
From these data, Lesser and Ritchie (1979) concluded that the dominant size class collected in 1975 and 1976 were survivors of a "massive" natural clam set in 1961-1962.

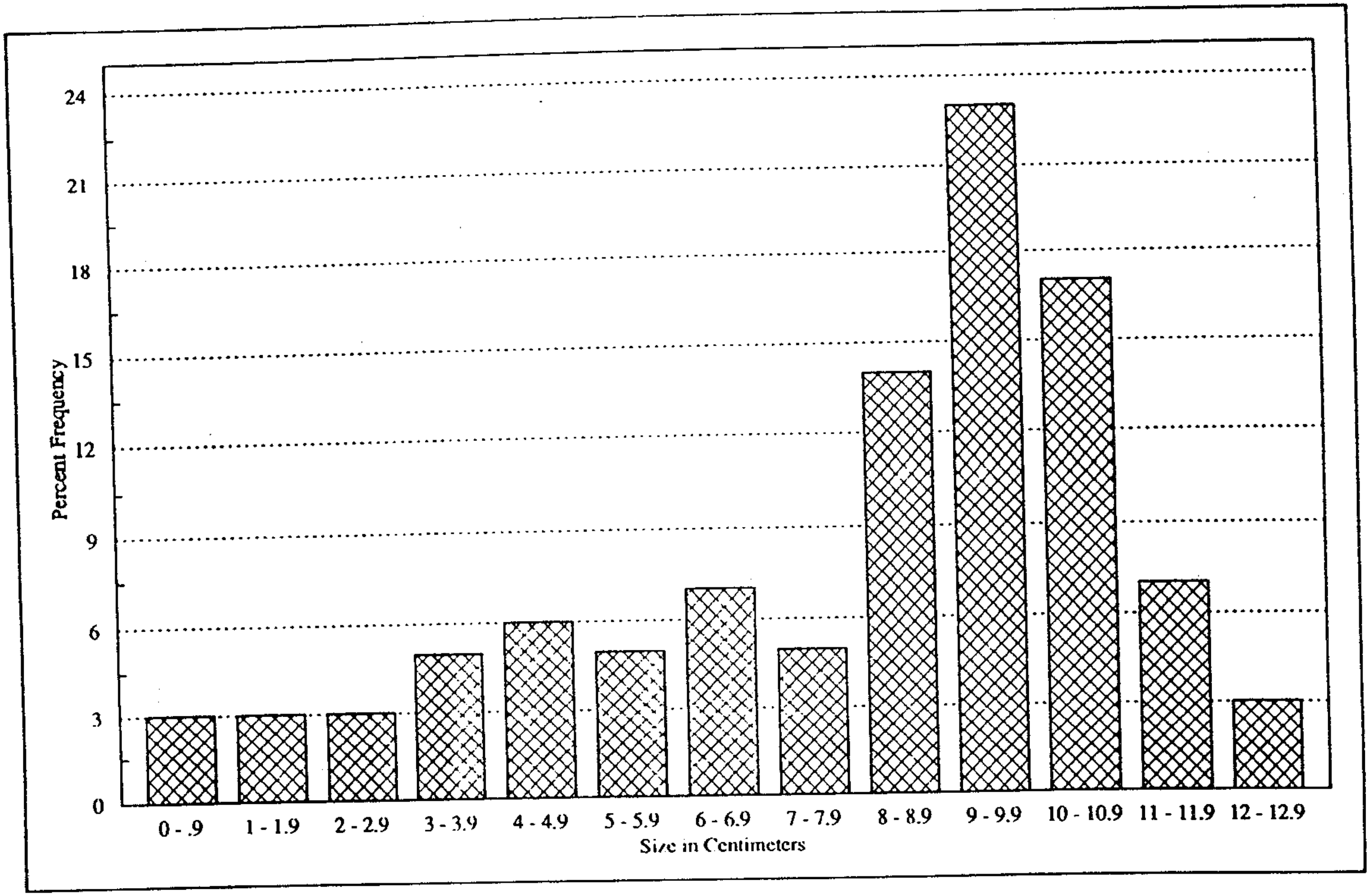


Figure 4.6-7
Length Frequency Distribution of Hard Clams
Collected from Indian River Bay in 1975 - 1976
Source of Data: Cole and Spence, 1977

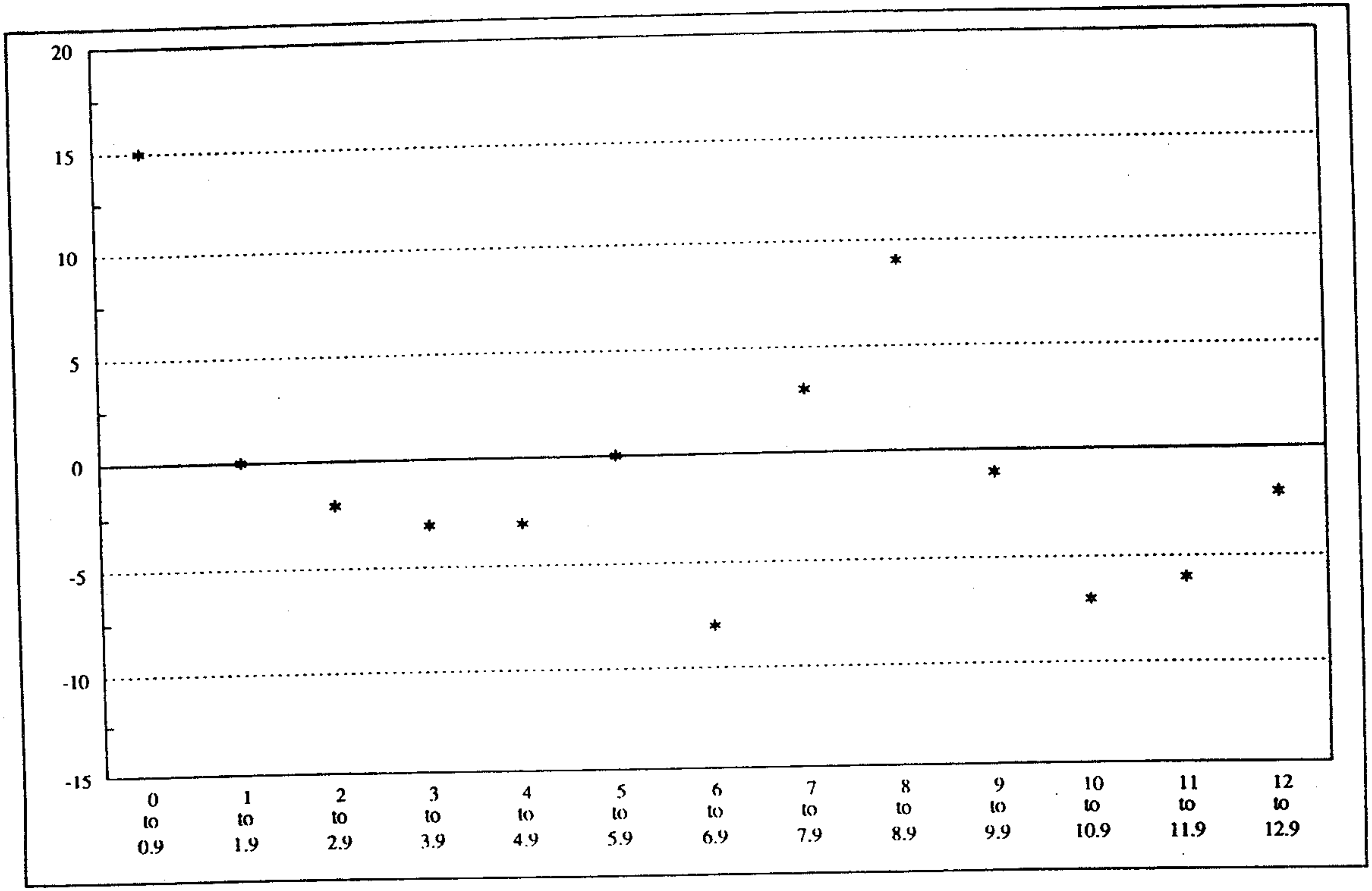


Figure 4.6-8
Percent Difference in Size Frequency Distribution for Hard Clams between in 1976 and 1987 in Indian River Bay
Source of Data: Cole and Spence, 1977

In addition to the length-frequency distributions obtained from the preceding studies, the Division of Fish and Wildlife monitored eight stations in Indian River Bay from 1985 to 1989 assess the annual recruitment of juvenile hard clams to the population. Figure 4.6-9 presents a description of length frequency for hard clams collected at these stations for the last two years of the survey, i.e., 1988 and 1989.

Based on these data, Cole et al., (1989) have suggested that recruitment of juveniles into the hard clam population in the last several years has been modest and that few young clams are being added to the bay on an annual basis. While successful sets do occur periodically, as in 1986, they may not be sufficient to maintain present population densities. The reasons for poor recruitment have been linked to a variety of factors including high larval mortality due to 1) predation, 2) low dissolved oxygen during critical veliger and early spat stage, and 3) potential toxicity from several contaminants, including tributyl tin. The extent to which any one of these factors plays a role in the hard clam population dynamics of Indian River Bay or Rehoboth Bay is unknown. Certainly predation is a principal factor in the natural control of hard clam density. Blue crabs are significant predators of juvenile hard clams as has been shown elsewhere (Gibbons, 1984). Other predators include cownose rays, horseshoe crabs and a variety of finfish including flounder.

Clams of all lifestages exhibit a marked tolerance to low dissolved oxygen. The minimum dissolved oxygen requirement for normal development is about 0.5 mg/L, although growth rates are greatly reduced below 4.2 mg/L, (Chesapeake Bay Program, 1983). The reported dissolved oxygen requirement for hard clams adopted by the Chesapeake Bay Program (1991) is 5.0 mg/L. Dissolved oxygen concentrations recorded in various Inland Bay segments have shown significant excursions below this threshold (see Section 3, Water Quality). There is currently insufficient information for ambient or contaminant levels in either bay with which to compare the existing water quality and hard clam habitat requirements.

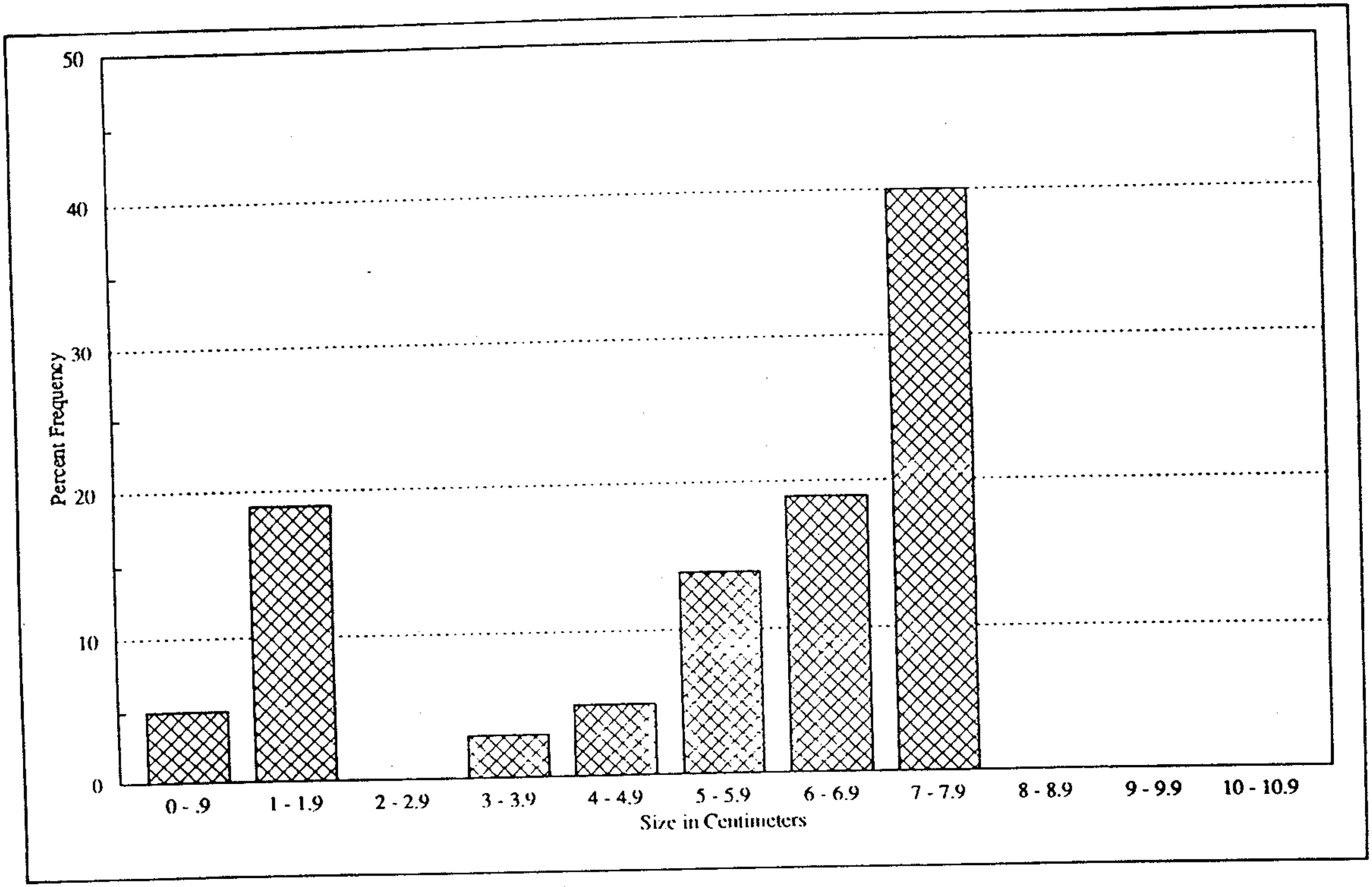


Figure 4.6-9
Length Frequency Distribution of Pooled Hard Clams Collected from Indian River Bay in 1988 - 1989
Source of Data: DNREC, 1989

Fish94-D19

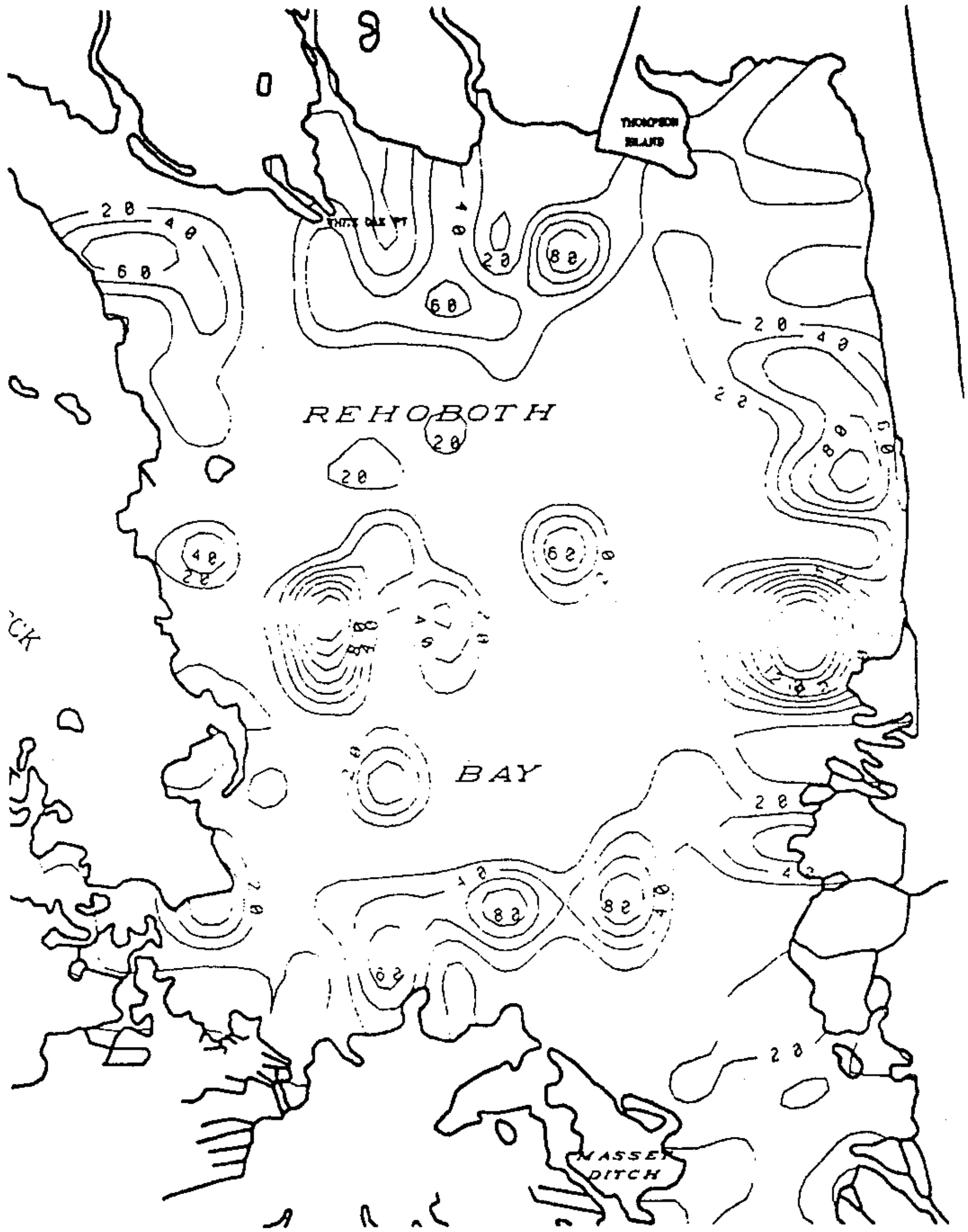
4.6.3.3 Status in Rehoboth Bay

The last comprehensive survey of the hard clam population of Rehoboth Bay was conducted in 1975-1976 (Cole and Spence, 1977). With the exception of the annual hard clam recruitment survey conducted by DNREC, no study of the hard clam population has been conducted since 1976. Consequently, the status of the hard clam resource in Rehoboth Bay is not known. This represents a significant data gap in the assessment of the status of "living resources" in the Delaware Inland Bays.

4.6.3.4 Historical Record of Hard Clams in Rehoboth Bay

As noted, the most recent study of the distribution and density of hard clams in Rehoboth Bay was conducted in 1975-1976. At that time, Cole and Spence (1977) demonstrated that hard clams were widely distributed in Rehoboth Bay and existed in denser and more extensive clam beds than those found in Indian River. An abundance of more suitable substrate (shell and sandy-mud) was offered as a possible explanation. The mean density of clams collected by Cole and Spence in 1975-1976 from Rehoboth Bay was 3.6 clams per square meter. Figure 4.6-10 presents the distribution of hard clams density (average number of clams per square meter) measured in 1975-1976 at 172 stations.

Previous to the 1975-1976 study, Humphries and Daiber (1968) conducted the first shellfish survey of the Inland Bays in 1967. Hard clam density reported in that study measured 1.9 clams per square meter. The use of oyster tongs to collect hard clams was thought to have underestimated the actual hard clam density. This component was not represented in the population estimate because oyster tongs were unable to sample sublegal (<1.5 inch) clams. Figure 4.6-11 presents the distribution of hard clam density (clams per square meter) found in Humphries and Daiber's study.



Source of Data: Humphries & Daiber 1968

Figure 4.6-11
Distribution of Hard Clams Density in Rehoboth Bay - 1976

Scale 1 Inch = 4000 Feet
2000 0 2000 4000

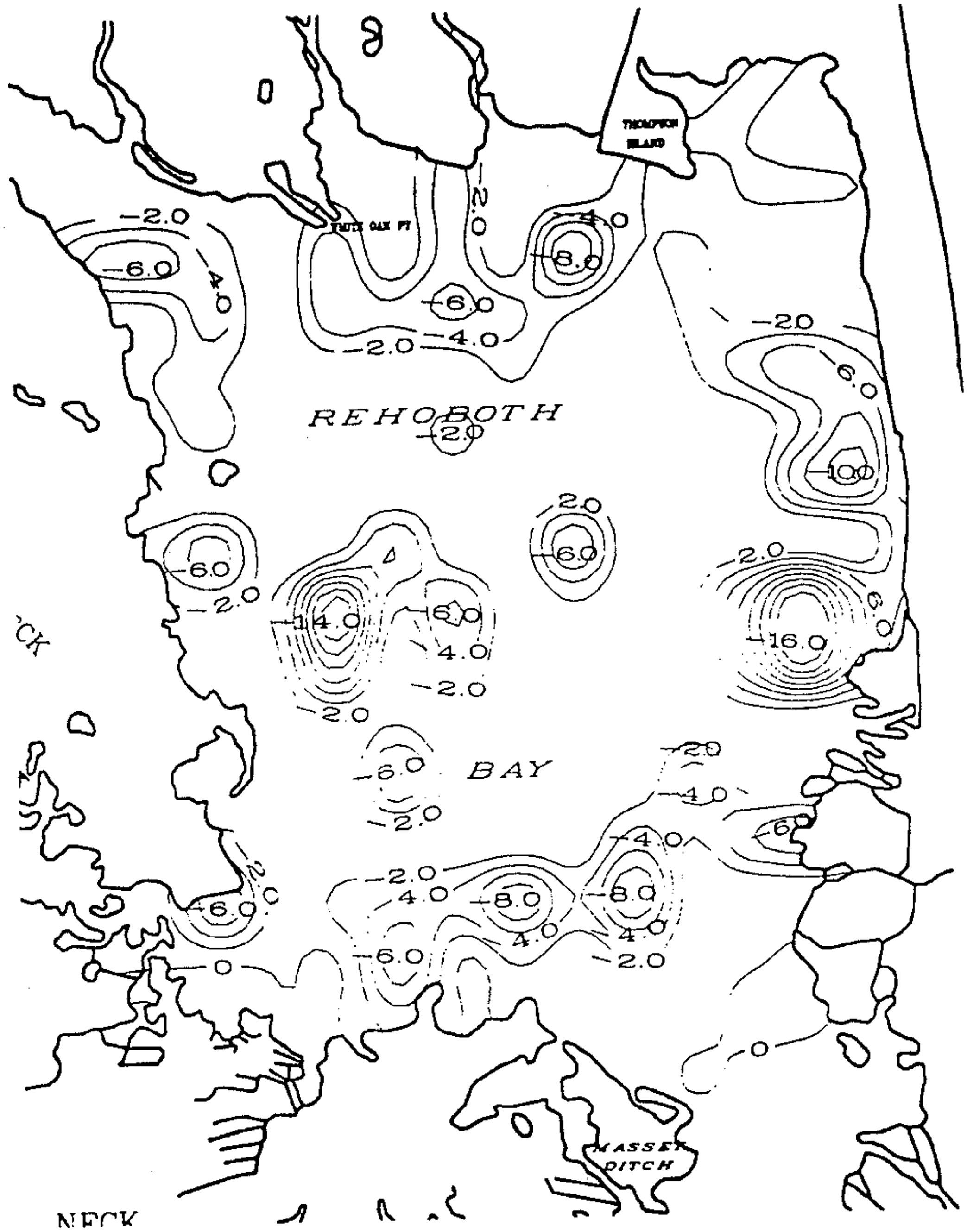
A statistical comparison (student's "t" test) of the hard clam density observed between 1976 and 1977 indicated that the 1976 study showed a significantly higher clam density than that found previously (Cole and Spence, 1977). Figure 4.6-12 shows the change in clam density between 1967 and 1976. Again, differences in collection gear may have been largely responsible for the changes observed.

Figure 4.6-13 presents the length-frequency distribution of hard clams collected in Rehoboth Bay in 1975-1976. Similar to the findings in Indian River Bay for the same years, the clam size was dominated by the 8-10.9 cm size class. Sixty-nine percent of all hard clams collected were these older and larger clams. Fewer than six percent of the hard clams were of recruitment size (<2 cm). While no data were available from Humphries and Daiber on sublegal size frequency, they nevertheless did report that the dominant size class found in Rehoboth Bay in 1967 was 5.5 cm to 9.9 cm, a size range similar to that found by Cole and Spence in 1975-1976.

More recently, the Division of Fish and Wildlife has sampled eight stations in Rehoboth Bay to assess annual recruitment of juvenile hard clams to the population. Figure 4.6-14 presents a description of the length-frequency distribution for hard clams collected at these stations since 1985.

4.6.3.5 Little Assawoman Bay

No formal survey of the hard clam population in Little Assawoman Bay has been conducted, therefore, the status of hard clam in Little Assawoman Bay is unknown. However, a qualitative survey of hard clams of Little Assawoman Bay was performed in 1991 (Tinsman, 1991). In this survey, Tinsman sampled thirteen stations in Little Assawoman Bay using a clam rake at shallow stations and a commercial bull rake otherwise. No hard clams were found. Tinsman speculated that the lower salinities of Little Assawoman Bay may prohibit a sustainable hard clam population. The salinity range for normal egg development is 20-35 ppt. Optimal salinity for growth and survival to settlement is 26-27 ppt. The larval metamorphosis is inhibited at salinities less than 17 ppt (Davis, 1958; Loosanoff and Davis, 1963; Davis and Calabrese, 1964).



Source of Data: Humphries & Daiber 1968
Cole & Spence, 1977

Figure 4.6-12
Difference Map of Hard Clams Density
in Rehoboth Bay
Between 1967 and 1976

Scale 1 Inch = 4000 Feet
2000 0 2000 4000

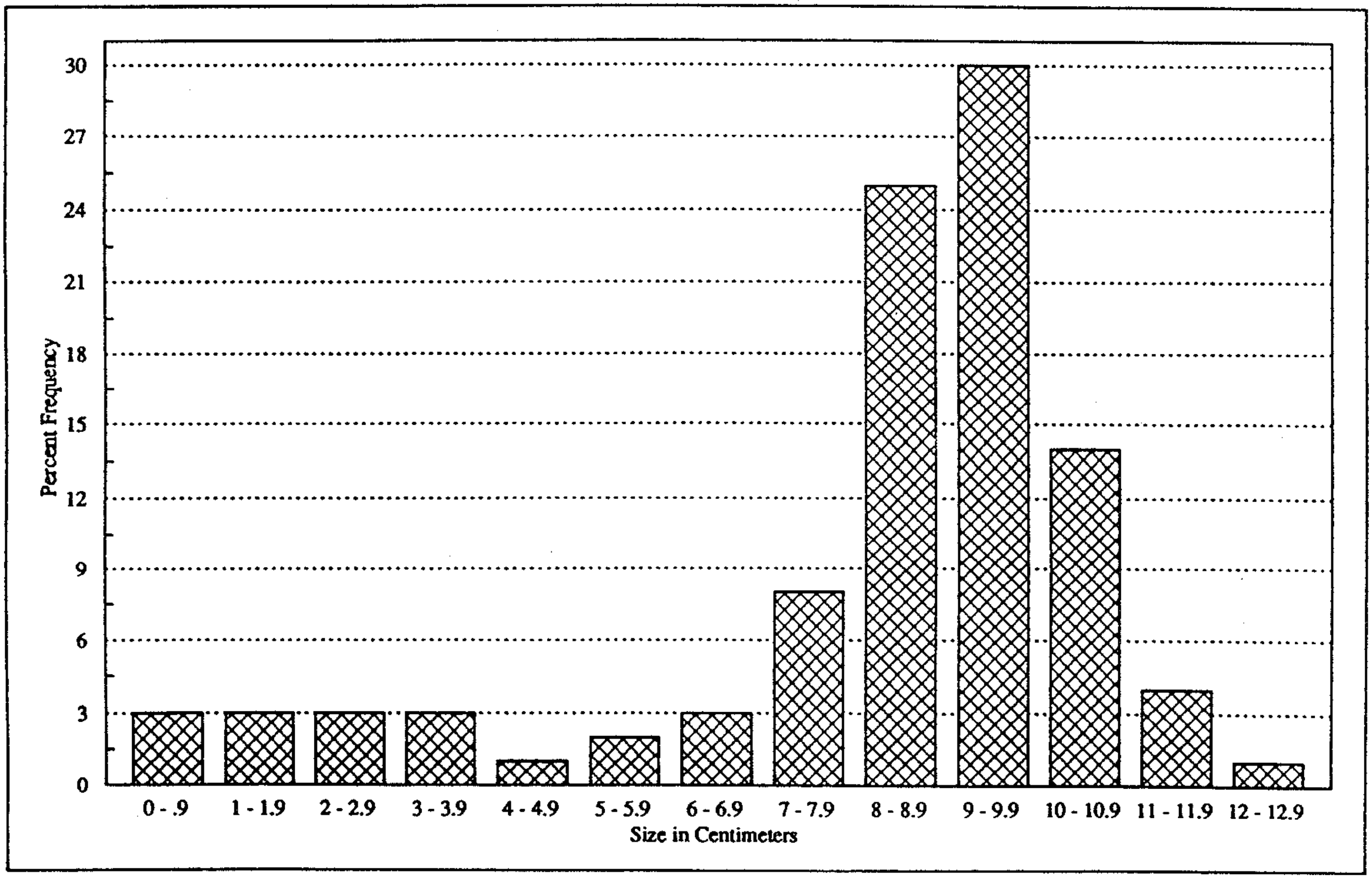


Figure 4.6-13
Length Frequency Distribution of Hard Clams
Collected from Rehoboth River
Source of Data: Cole and Spence, 1977

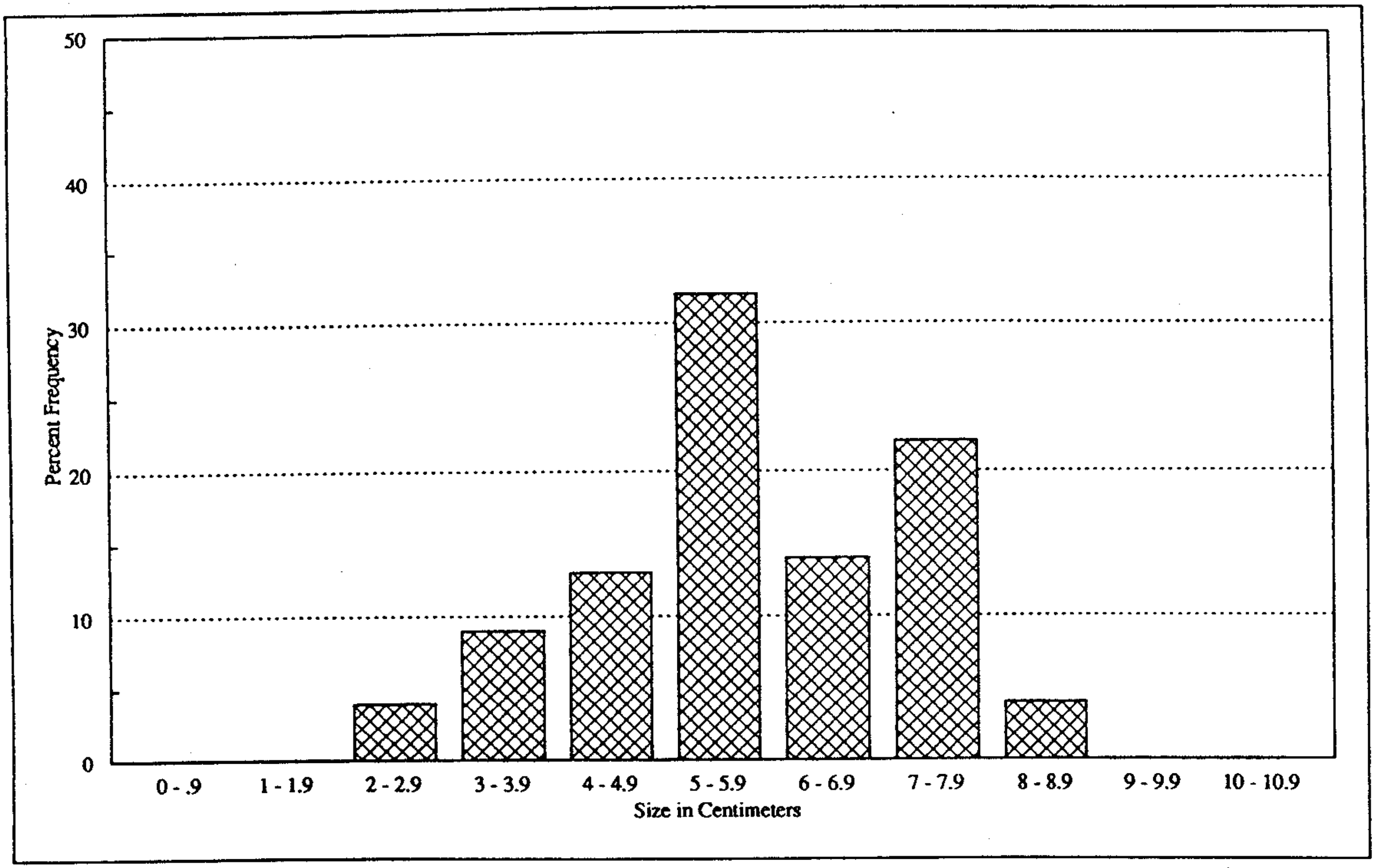


Figure 4.6-14
Length Frequency Distribution of Pooled Hard Clams
Collected from Rehoboth Bay 1988 - 1989
Source of Data: DNREC, 1989

4.6.4 Commercial and Recreational Catch Statistics

The hard clam (*Mercenaria mercenaria*) represents the only commercial fishery in the Delaware Inland Bays. In 1990, reported commercial clam landings amounted to about 45,700 pounds of meats valued at close to 46 thousand dollars. Indian River and Rehoboth Bays have supported a commercial hard clam fishery since the mid-1940's. Records of commercial landings began in 1943. Figure 4.6-15 presents the reported commercial hard clam landings since 1943. The commercial clam harvest peaked in 1956. In the last 35 years, the commercial hard clam harvest as measured by total landings had declined over 98 percent.

A single reason for the decline in the commercial harvest is difficult to determine, and the decline may be attributed to a variety of factors including: (1) a decreased fishing effort; (2) closure of shellfish beds due to poor water quality; (3) a decline in standing crop associated with overharvesting, (4) a decline in standing stock associated with poor recruitment; and (5) a combined effect of each of the above reasons.

In the mid-1950's with the onset of MSX, many of the oystermen turned to commercial clamming to help offset the loss of income due to the decimated oyster population. At about the same time, Delawareans supplemented their income by part-time clamming. It is not clear, however, whether this catch was incorporated in the commercial landing statistics. Therefore, in the mid-1950's during the period of peak harvest, it appears that numerous individuals were involved in commercial clamming either on a part-time or full-time basis. By contrast, in 1990, only about 40 licensed clammers were fishing Indian River and Rehoboth Bays. Of these, however, about ten clammers were responsible for 95 percent of the harvest (Tinsman, personal communication).

In addition to the possible decline in harvest from decreased effort, the closure of shellfish beds and the consequent reduction in available clamming area in Rehoboth and Indian River Bays may also be responsible for the decline. Figure 4.6-16 shows the progression of restrictions on the

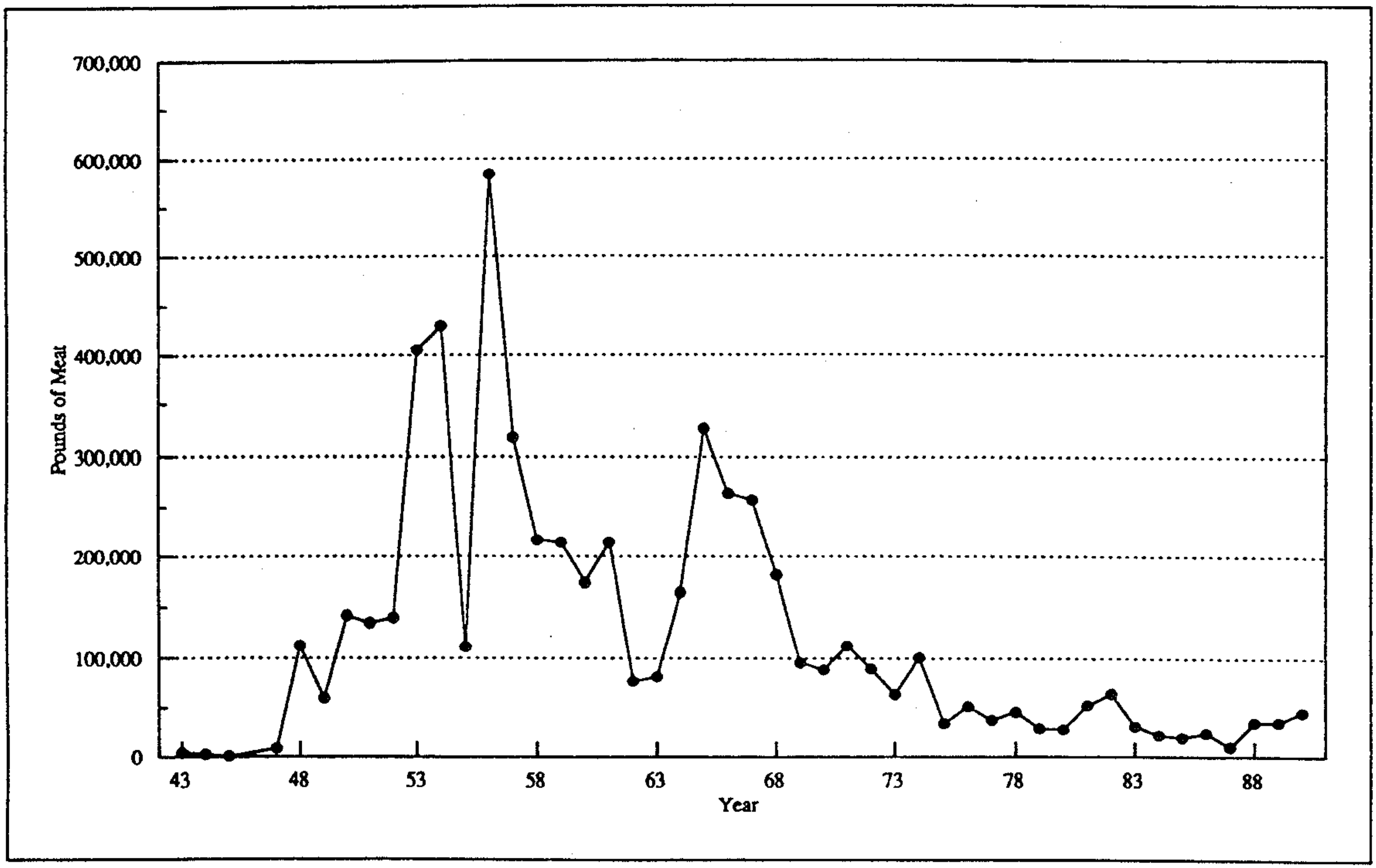


Figure 4.6-15
Reported Hard Clam Landings
Indian River and Rehoboth Bay

Fish38-D18

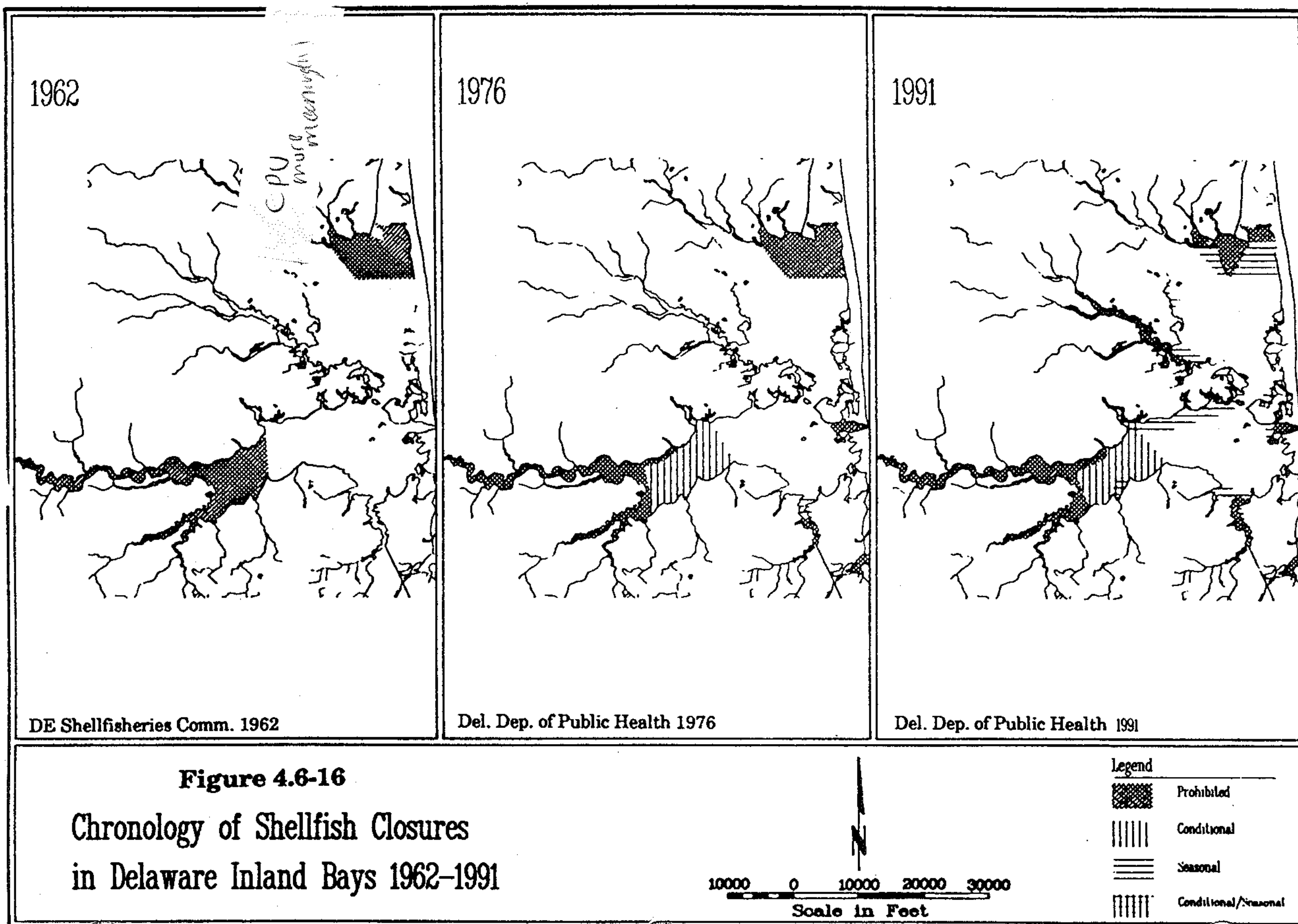


Figure 4.6-16

Chronology of Shellfish Closures in Delaware Inland Bays 1962–1991 hard clam fishery in both bays from 1948 through 1991. Due to the institution of regulations to protect consumers of shellfish from decline in water quality, namely bacteriological contamination, the total harvestable acreage has been reduced by about 20 percent.

To better define the current status of the fishery, Figures 4.6-17 through 4.6-19 describe the annual commercial hard clam catch, the annual commercial effort, and the annual catch per unit effort respectively for the hard clam fishery of the Inland Bays since 1983. Peak harvest during the last nine years occurred in 1990 when more than 1.4 million quahogs were taken from the bay by commercial fishermen.

A more meaningful measure of the annual success of the fishery is provided by the catch per unit effort statistic (Figure 4.6-19). Catch per unit effort (CPUE) represents the ratio of the number of clams caught in any given year and the effort in terms of commercial clamming days during the same year. By normalizing the catch by the effort expended, the CPUE provides an unbiased comparison of the success of the commercial fishery between years. Based on these data, the mean CPUE since 1983 has been about 960 clams per clammer day, with a maximum CPUE occurring in 1986 when 1069 clams were harvested per clammer day. With the exception of 1987, CPUE effort has declined by about 10% over the 5-year period from 1985 through 1990. A 20% decline in CPUE from 1986 to 1987 is unexplained but coincides with a period of greatly reduced effort.

In addition to the commercial fishery, the hard clam is also harvested recreationally in the Inland Bays. Recreational catch statistics are available from surveys of recreational clammers conducted by the Division of Fish and Wildlife in 1979, 1985 and again in 1987. Figure 4.6-20 presents a comparison of the recreational catch surveyed for these years in both Indian River and Rehoboth Bays. Based on these data the recreational landings declined over 46 percent between 1979 and 1987. As with the commercial fishery statistics, catch per unit effort (CPUE) for the recreational fishery was derived and represents a ratio of the number of clams harvested recreationally and the hourly effort in catching these clams. Figure 4.6-21 presents a comparison of the recreational CPUE for the period of the surveys in 1979, 1985 and 1987 for both bays.

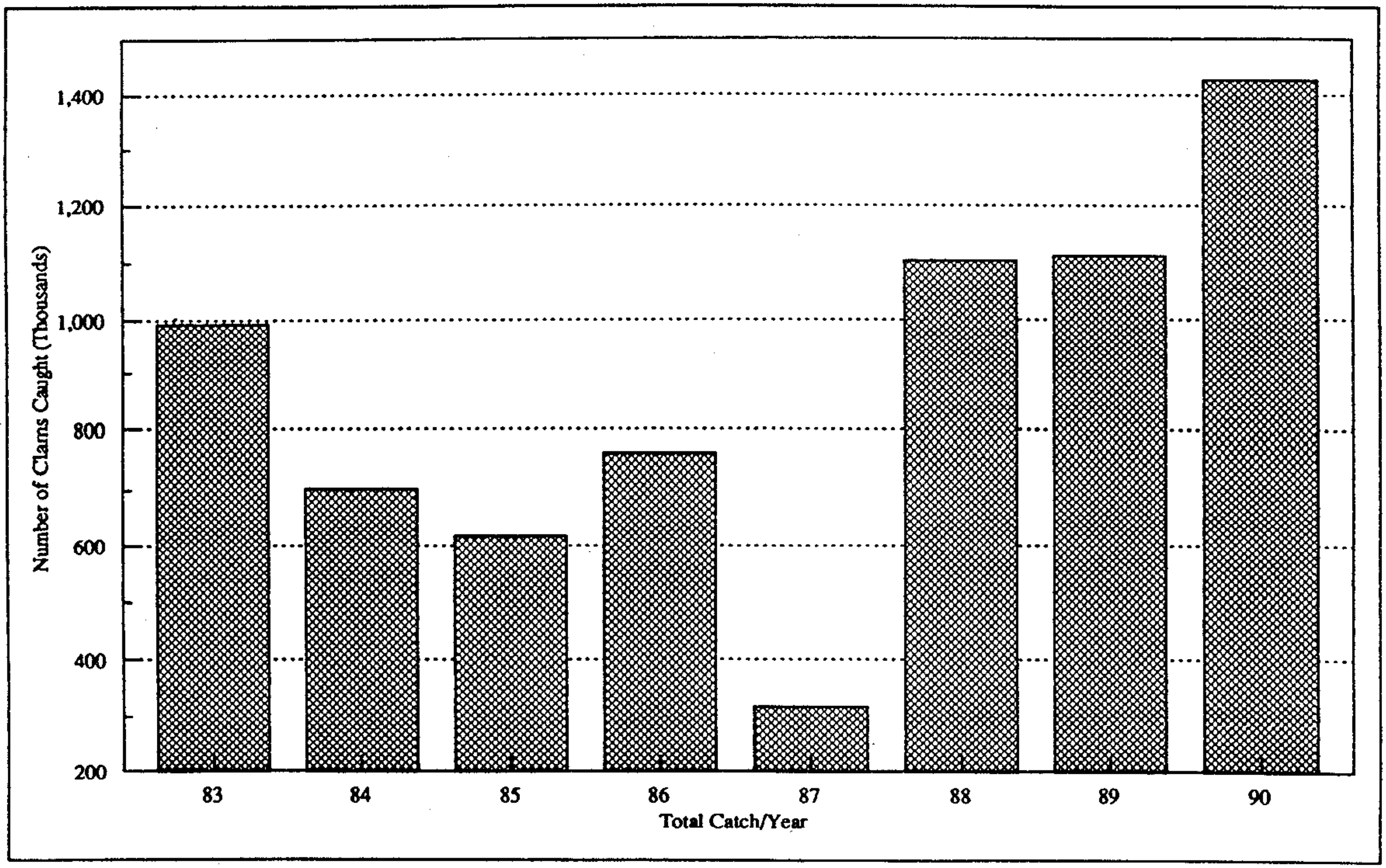


Figure 4.6-17
Delaware Inland Bays
Hard Clam Catch Statistics - Catch
Source of Data: DNREC, 1990

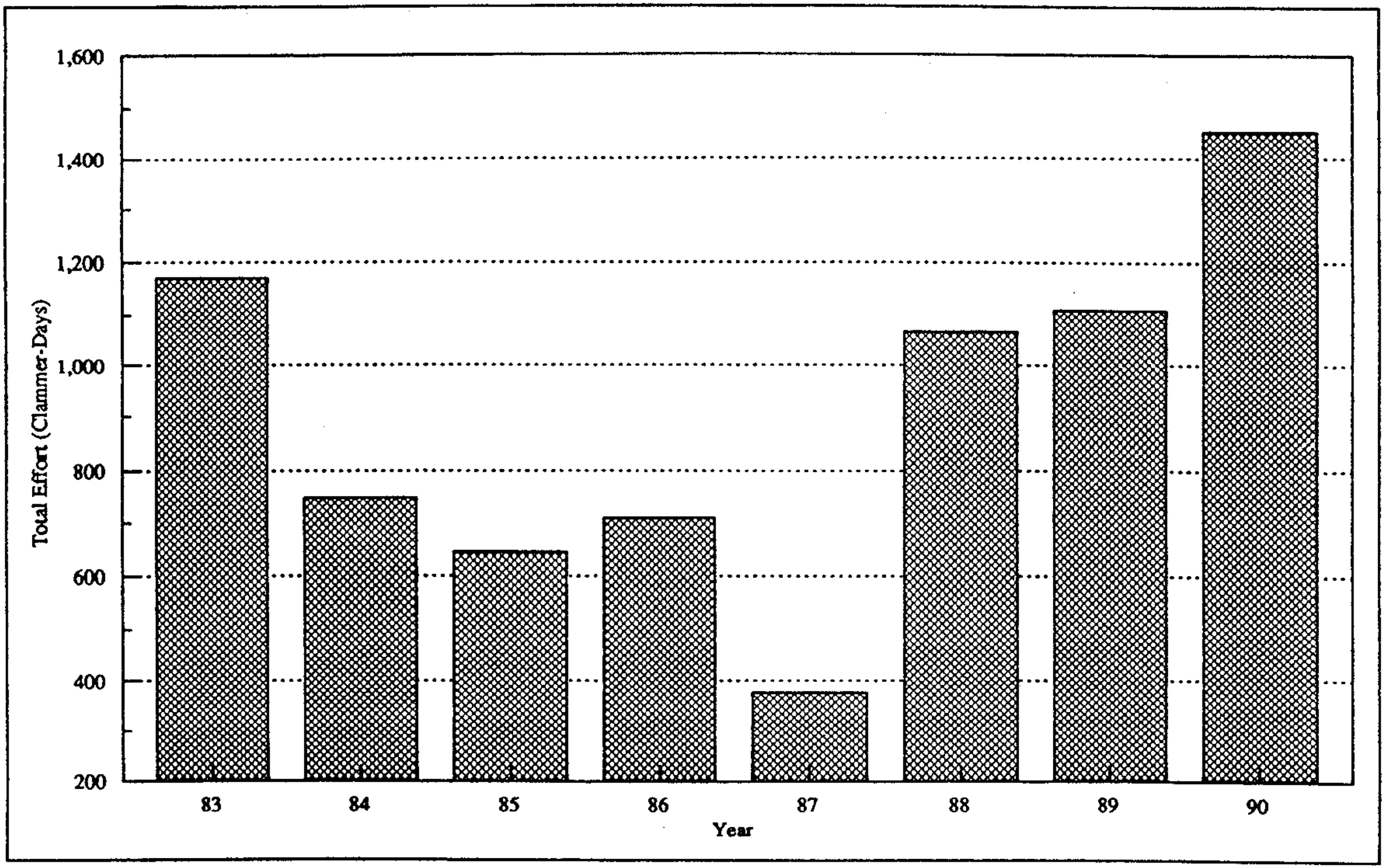


Figure 4.6-18
Delaware Inland Bays
Hard Clam Catch Statistics - Effort
Source of Data: DNREC, 1990

Fish34 D18

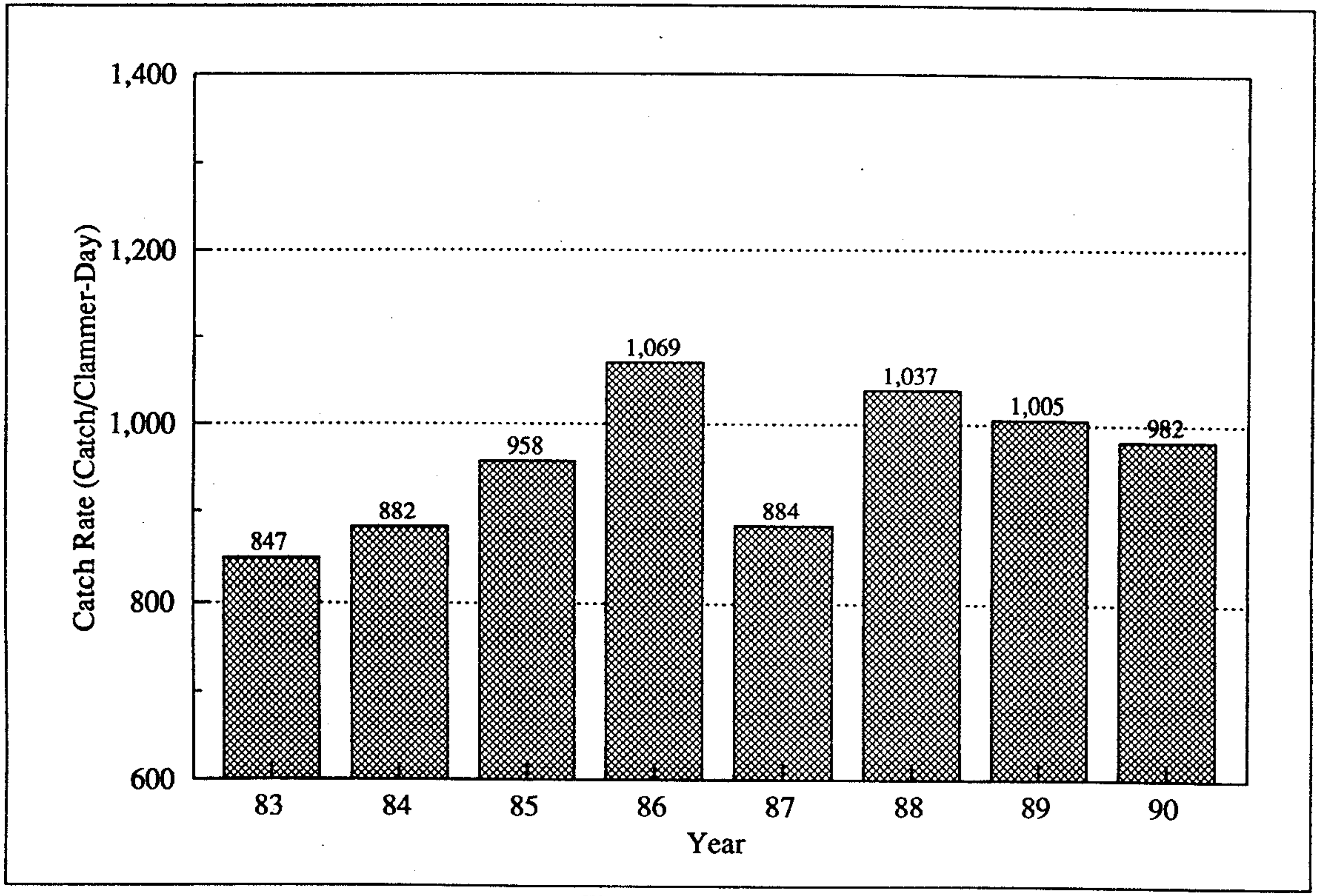


Figure 4.6-19
Delaware Inland Bays
Hard Clam Catch Statistics - Catch/Effort
Source of Data: DNREC, 1990

Fish32-D18

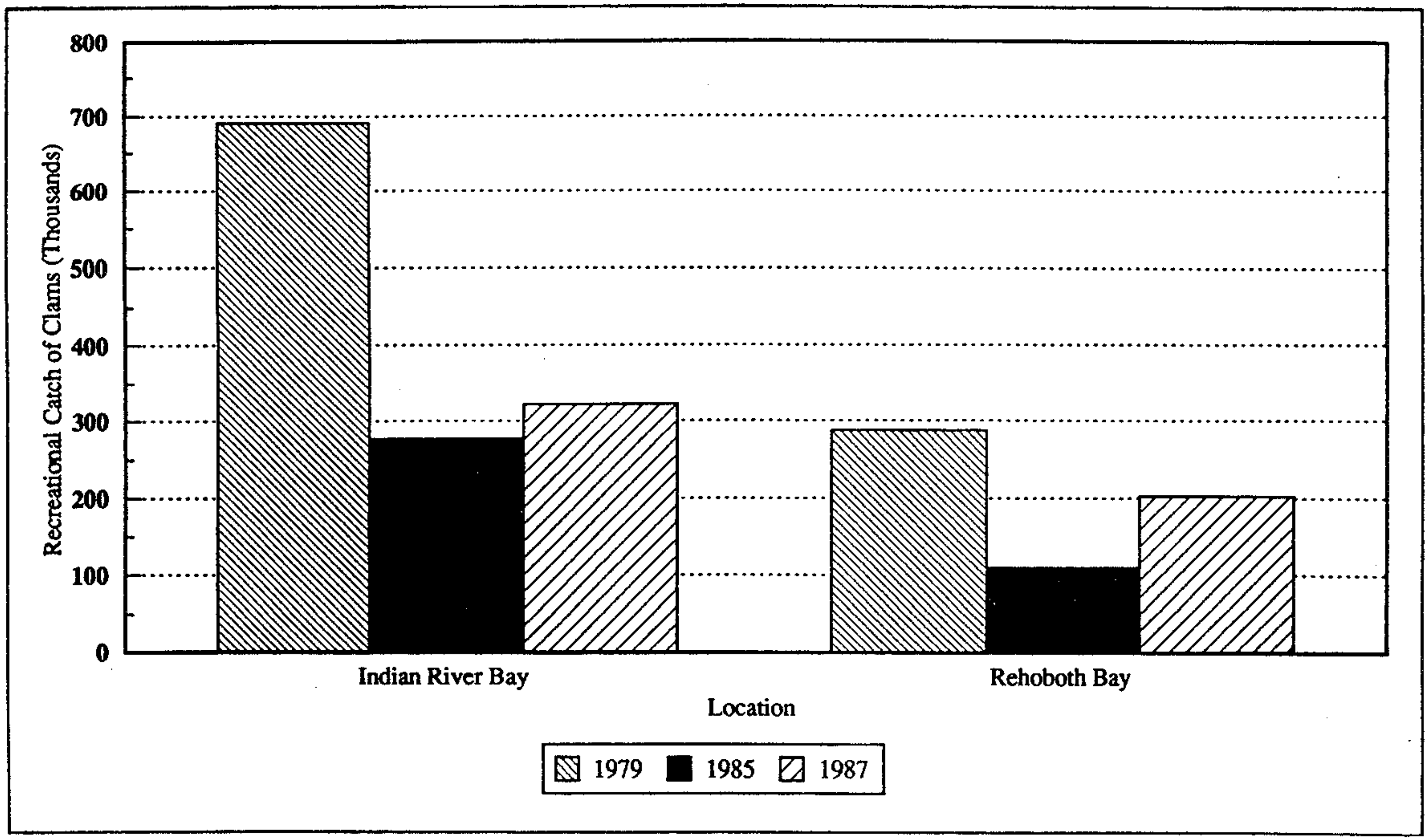


Figure 4.6-20
Comparison of Recreational Catch for Several Years in Indian River Bay and Rehoboth Bays
Source of Data: DNREC, 1990

Fish35-D18

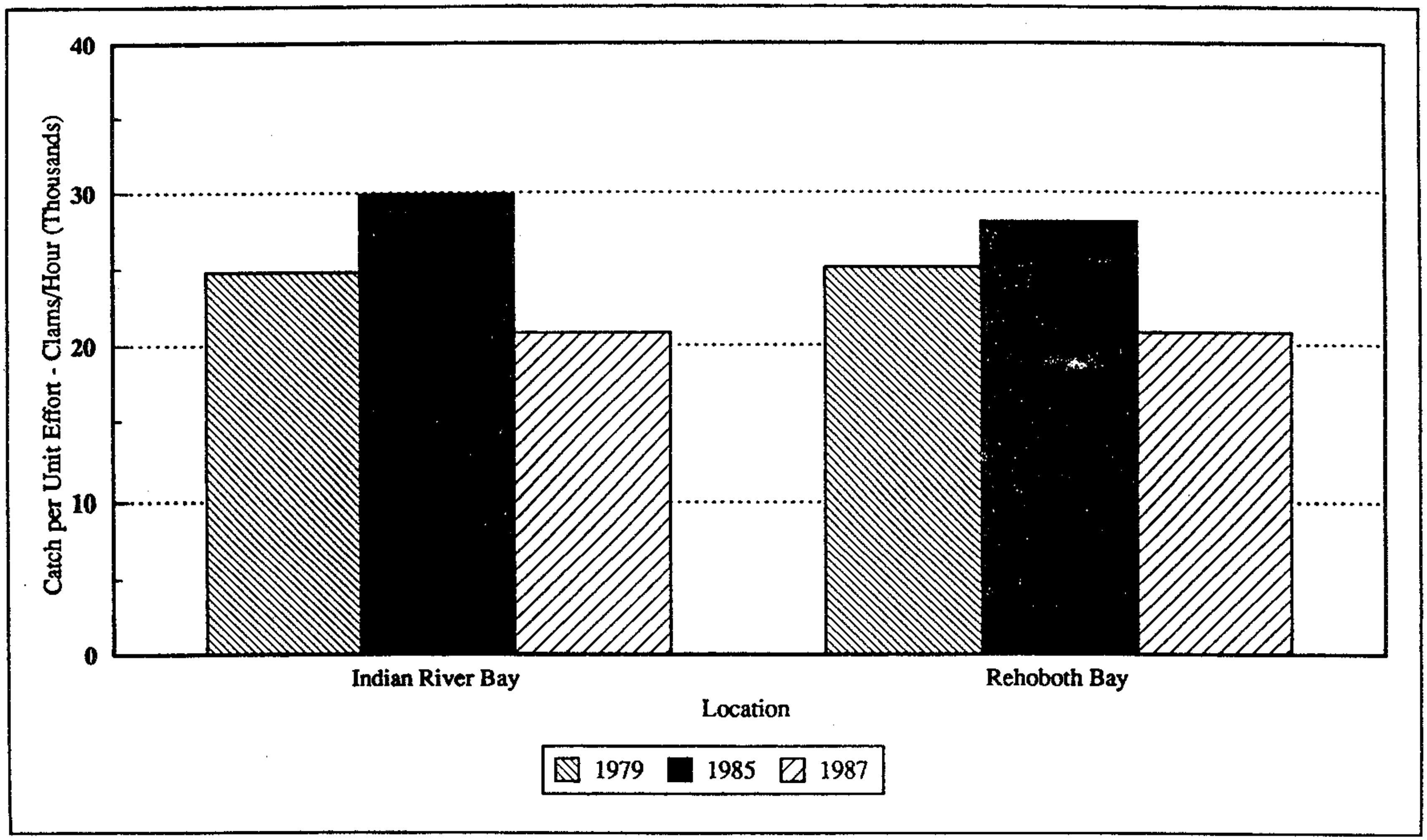


Figure 4.6-21
Comparison of Recreational Catch for Per Unit Effort for the Years 1979, 1985, and 1987 in Indian River and Rehoboth Bays
Source of Data: DNREC, 1990

Fish36-D18

Combined commercial and recreational catch statistics represent a harvest of 1,003,359 clams in 1985 and 842,053 clams in 1987. In 1985, the recreational catch accounted for about 40% of the total clam harvest for both bays in that year. However, due to the steep decline in commercial landings in 1987, the recreational catch dominated the combined harvest and represented more than 60% of the total yield of clams.

In summary, the hard clam population of Rehoboth and Indian River Bays has supported and continues to support an extensive commercial and recreational fishery. To enhance the well-being of this shellfishery and maintain optimum levels of sustainable harvest, an adequate knowledge of the hard clam stock, its variability, and the effects of commercial and recreational harvest, as well as, effects of pollution on population dynamics particularly growth, mortality and recruitment are necessary. Because of the economic and recreational importance of hard clams to the Inland Bays, we suggest that a comprehensive hard clam monitoring program be designed and implemented. This program should establish a periodic survey of clams in Rehoboth and Indian River Bay to determine recruitment, abundance, distribution and growth.

APPENDIX 4.6-A

SHELLFISH

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SECTION 4.7
FINFISH

4.7.1 Introduction

Before Indian River inlet was stabilized in 1939, the Delaware inland bays were periodically isolated from the ocean. Section 3 of this report, *Habitat Characterization*, provides a historical account of the opening and closing of the inlet prior to 1939. During prolonged closings of the inlet, like that of the 1920's, freshwater runoff from the bays' tributaries produced lower salinities in these waters. Although no specific data are available regarding the changing salinity, anecdotal information suggests that fresh and brackish water fish species made more extensive use of the bays during this period (Horn, 1957). During restricted openings, the Indian River estuary supported a variety of marine migrants as well as freshwater species. In particular, the estuary supported large spawning runs of anadromous fishes, such as alewife, herring, and striped bass (Fowler, 1911; Horn, 1957). With the dredging and stabilization of the inlet and the resultant increase in salinity of the bays, freshwater species became less common and marine and estuarine migrants became more important components of the Inland Bays fishery. Today, these waters serve as an important habitat for the spawning, nursery and maintenance of a variety of resident and non-resident species of finfish.

The principal objectives of the *Finfishery Resource* section of the *"Living Resource"* characterization are several and include:

- The identification of studies that have been conducted of the finfish community of the bays and selection of those studies most appropriate to characterization;

- The definition of the status of the finfish community, as defined by such measures as species composition and relative abundance; and

- A description of the historical record and the identification of changes in finfish community over time, where data allow.

4.7.2 Supporting Information

The earliest report of the finfish of the Inland Bays was made by Fowler (1911) in *The Fishes of Delaware*. His account provided general information on species distribution in Rehoboth and Indian River Bays in the early 1900's. Fowler reported that although these bays maintained a limited tidal exchange with the ocean, marine fishes entered the bay through the inlet sometimes in large numbers. Around the turn of the century, "great" spring runs of alewife, as well as, abundant weakfish were observed in the bays. Commonly found species included white perch, butterfish, striped bass, white catfish, croaker, spotted seatrout and winter flounder. In addition to these species, Fowler also noted that the "fresh" reaches of Indian River estuary contained gar pike, carp, and sunfish.

The first reported field investigation of the fish community of the Inland Bays was conducted in 1957 by Pacheco and Grant (1965) who investigated the early life history of the Atlantic menhaden (*Brevoortia tyrannus*) in White Creek, a tributary to Indian River Bay. Since that time, numerous studies have been conducted to describe the fish community of Indian River and Rehoboth Bays. Table 4.7-1 presents a summary of key studies for the inland bays that were used to describe the finfishery in this subsection of the *"Living Resources"* characterization. In addition, Figure 4.7-1 presents a chronology of those studies.

As is the case with any individual study, sampling methods, gear selection, and frequency of monitoring are largely defined by the objectives of the study. Because no long-term monitoring program has been established for the bays until recently, most of available information on the finfishery comes from a number of discrete case studies, each with its individual objectives. Because of the frequent incomparability of sampling methods, comparison of studies to identify historic trends is difficult. Although it is difficult to compare a number of these studies, two types of habitats have been typically sampled as defined by the sampling gear used. For the most

Table 4.7-1 A Summary of Key Studies of the Finfishery of the Delaware Inland Bays
DNREC, DIVISION OF FISH AND WILDLIFE, 1985 to 1991 Monitoring Reports - Federal Aid in Fisheries Restoration Act
MILLER, ROY W., 1985-1990; COLE R. and R. MILLER, 1991 Commercial Fishing in Delaware 1984-1991
DELMARVA POWER AND LIGHT (Ecological Analysts, Inc.), 1976. Ecological Studies in the Vicinity of Indian River Power Plant: A 316 Demonstration (1974 to 1976)
CAMPBELL, T.G., 1975 The Fishes and Hydrographic Parameters of White Creek, Delaware: A Description and Comparison of 1973-1974 to 1957-1958.
EDMUNDS, J.R. and L.D. JENSEN, 1974 Fish Populations: Environmental Responses to Thermal Discharges
DERICKSON, W.K. & K.S. PRICE, 1973 Fishes of the Shore Zone of Rehoboth and Indian River Bays.
RADLE, E.W., 1971 Partial Life History of the Winter Flounder
SCOTTON, L.W., 1970 Occurrence and Distribuiton of Larval Fishes in the Rehoboth and Indian River Bays of Delaware
PACHECO, A.L. & G.G. GRANT, 1965 Studies of the Early Life History of Atlantic Menhaden in Estuarine Nurseries

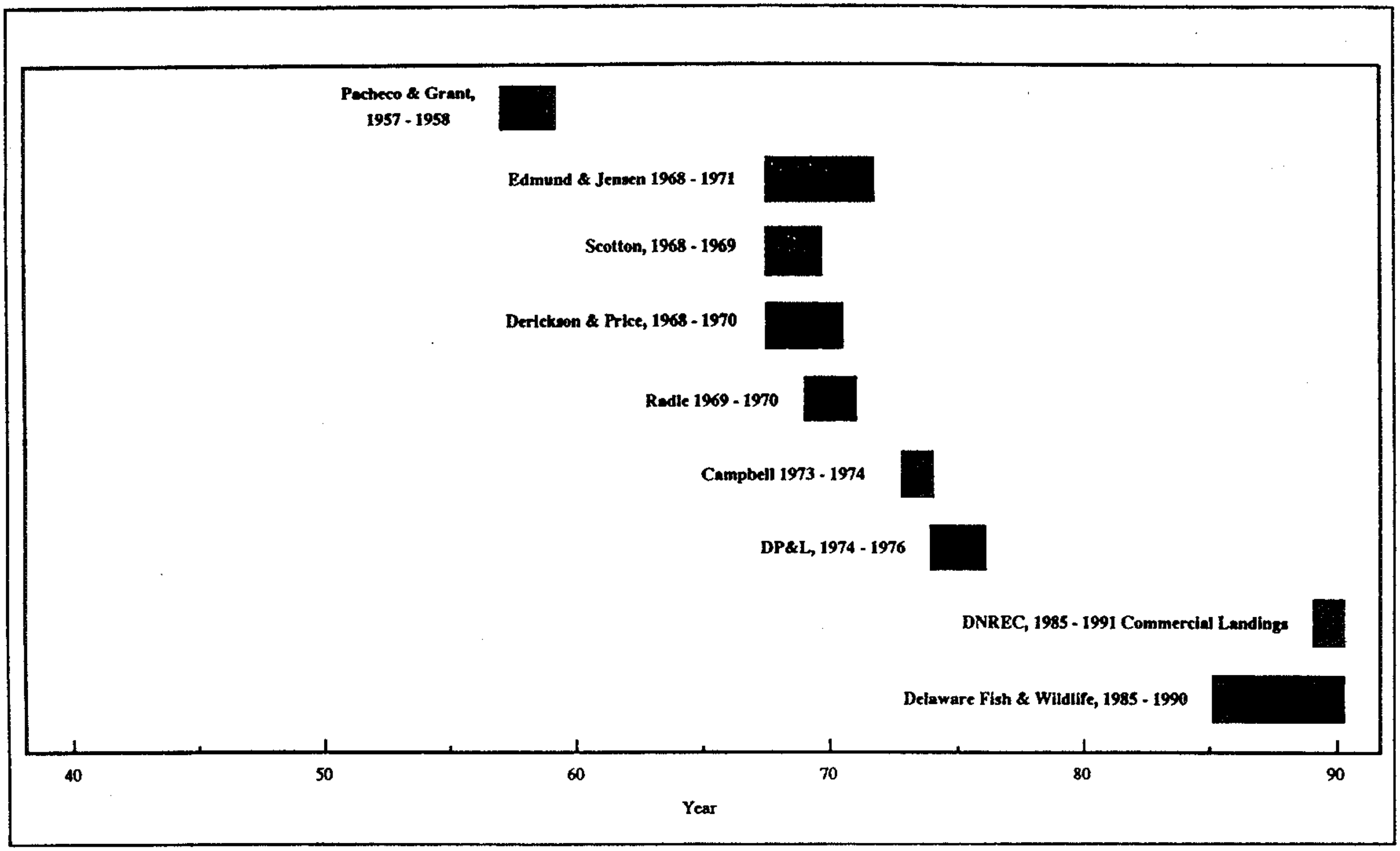


Figure 4.7-1
Timeline of Key Finfish Projects in Inland Bays (1950 - 1990)

Fish40-D18

part, juvenile finfish inhabiting the open waters of the bays have been sampled with a 16-foot semi-balloon or otter trawl.

Studies of finfish in the Inland Bays have produced two principal sets of trawl data. They include:

- Monthly trawl samples collected from Indian River estuary between 1974 and 1976 (DP&L, 1976),

- Trawl collections made by Delaware Fish and Wildlife since 1985 in Indian River and Rehoboth Bays (DNREC 1986-1991).

Because the otter trawl is most efficient in capturing demersal or epibenthic species, long term trawl data represent the principal source of information for juvenile fish inhabiting the open water demersal fishery. However, due to the shallow nature of the bays, it is expected that mid-water populations, e.g., the bay anchovy, are also represented by trawl data to some degree. Table 4.7-2 provides a comparison of sampling gear, frequency and duration of monitoring employed in each of these studies.

Trawl data typically provides little information about the pelagic component of the open water finfish community. Sources of information for the pelagic species are generally limited to anecdotal accounts and landings data of key commercial and sport fish caught in the bays. Recently, Tracy Bryant of the University of Delaware's Marine Communications Office conducted interviews with a number of long-time residents of the Inland Bays area. As part of the interview process, individuals were asked, among other things, to recall what they remembered about the kinds of fish and the numbers of fish using the bays in earlier times. To the extent possible, this narrative incorporates some of this information although compilation of the interview notes is not yet complete.

Table 4.7-2
Sampling Methodology of Studies of the Open-Water Finfish Community of the Inland Bays

Study	Study Period	Study[a] Location	Sampling Gear	Duration of Trawl	Sampling Frequency
DNREC 1986-1991	1986-1991	Rehoboth - 6 Stations Indian River - 8 Stations	16 ft semi- balloon (otter) trawl	10 minutes	Monthly May-November
DP&L 1976	1974-1976	Indian River 6 Stations	16 ft semi balloon (otter) trawl	10 minutes	Semi-monthly July 1974-May 1975 Monthly June 1975-Aug 1976

Consistent with Fowler's observations in the early 1900's, anecdotal accounts by long-time residents of the area recall large spawning migrations of anadromous fish. As late as the 1960's, alewife, blueback herring, striped bass, and shad would make the run to the upper Indian River where they were caught in great numbers in the pool just below Millsboro Dam. These same accounts suggest, however, that in the last twenty years, the great runs have all but disappeared and once commonly caught fish like the white perch are now seldom taken. Wong and Kernehan (1979) reported that the white perch population in Indian River estuary in the early and mid-1970's was considerably less than that found in other Delaware tidal waters. They attributed low level populations to limited freshwater input at Millsboro.

Estimates of commercial finfish landings have been collected by Delaware's Division of Fish and Wildlife since 1984 (Miller, 1985-1990; Cole and Miller, 1991). A discussion of commercial catch statistics for the Delaware Inland Bays is discussed separately in this section.

As the open-water juvenile fishery is best represented by the trawl data, the fishery of the shore zone is best defined by seining data. Three principal sets of seine data are available and include:

- Near-monthly seine collections of Indian River and Rehoboth Bays between 1968 and 1970 (Derickson and Price, 1973).
- Monthly seine collections of Indian River Estuary between 1974 and 1976 (DP&L 1976).
- Near-monthly samples collected from April through October in Rehoboth and Indian River Bays between 1986 and 1988 (DNREC, 1989).

A comparison of sampling methodology for each of these studies of the shore zone fishery is provided in Table 4.7-3.

The fish communities inhabiting the Inland Bays can be broadly classified as two principal types, viz., the shore zone community dominated primarily by permanent year-round residents such as

Table 4.7-3
Sampling Methodology of Several Studies of the Shore-Zone Finfish Community of the Inland Bays

Study	Study Period	Study[a] Location	Sampling Gear	Length of Haul	Sampling Frequency
DNREC	1986-1988	Rehoboth - 8 Stations Indian River - 7 Stations	50' x 6' Beach Seine 0.25" sq. mesh	150 feet	Monthly May-November
DP&L	1974-1976		50' x 6' Beach Seine 0.25" sq. mesh	150 feet	Semi-Monthly 1974-1975 Monthly 1975-1976
Edmunds & Jensen	1970-1971	Upper Indian River - 10 Stations	50' x 6' Beach Seine 0.25" sq. mesh	~ 220 feet	Monthly
Derickson & Price	1968-1970	Rehoboth - 8 Stations Indian River - 7 Stations	60' x 6' Haul Seine 0.50" sq. mesh	~ 150 feet	Monthly
Price & Schneider	1991	Little Assawoman Bay - 5 Stations	33' x 4' Seine 0.25" str. mesh	~ 100 feet	Single Event June

the mummichog (*Fundulus heteroclitus*), and the open-water community comprised principally of seasonal migrants entering the bays to spawn or feed, for example, the bay anchovy (*Anchoa mitchilli*).

The location of the Inland Bays in relation to fisheries distribution along the Atlantic Coast contributes to the variability in species and species abundance found in these bays. June and Reintjes (1957) noted that because of its central location in the distribution of migratory stocks from Cape Cod to Cape Hatteras, Delaware waters were at the southern limit of more northern boreal fish stocks, like the winter flounder, and at the northern limit of warm temperature species like the Atlantic croaker. Consequently, this central location between cold temperate species and warm temperate species contributes to the annual fluctuations in species abundance (Versar, 1991).

In addition, many of the species inhabiting the shore zone and open-water habitat of the Inland Bays are juveniles of seasonally migratory adult stocks, many of which spawn on the shelf off the coast and include bluefish, croaker, menhaden, among others. Their abundance in the bays is influenced by a number of factors including the migratory pattern of the adult stock, the size of the adult spawning stock offshore, as well as the fecundity and reproductive success of the adult spawning population. These, in turn, are influenced by a number of natural and anthropogenic factors whose relative importance are unknown.

To provide a comparison of species inhabiting the shore zone community with that of the open-water community, fish observed in the bays were categorized as either permanent residents, warm water migrants, cool-water migrants or others based on a classification scheme developed by Tatham et al. (1984) for Barnegat Bay, New Jersey (Table 4.7-4). According to this scheme resident fish represent endemic species that spend their entire life in the estuary, and are restricted in their migratory patterns. Note that in this classification scheme, juvenile winter flounder, which are present in the bays throughout their entire first year, are considered year-round residents. Warm-water migrants represent temperate species that migrate north along the Atlantic coast in spring and summer and enter the estuary to spawn, nurse, or forage as water temperatures rise, e.g., the weakfish, *Cynoscion regalis*. As juveniles, these fish are generally present year-round except during winter. Conversely, cool-water migrants are boreal species that enter the estuary as water temperatures fall, e.g., the adult winter flounder and the spotted hake. Figures 4.7-2 and 4.7-3 provide a comparison of percent composition by finfish community type, i.e., resident, warm-water migrant, cold-water migrant, for several sets of trawl data and seine data, respectively. Although there is obviously some overlap due to the shallow nature of the embayments, especially Rehoboth and Little Assawoman Bays, and especially during the seasonal migration of resident species to deeper waters, the spatial distribution and abundance of species based on available data suggest distinct communities. Accordingly, the two communities are discussed separately.

Many of the studies that have been conducted on the Inland Bays have focused on the finfishery of Indian River and Rehoboth Bays. Few data were found for the fish community of Little Assawoman Bay; this represents a potential data gap in this analysis.

4.7.3 Shore Zone Finfish Community

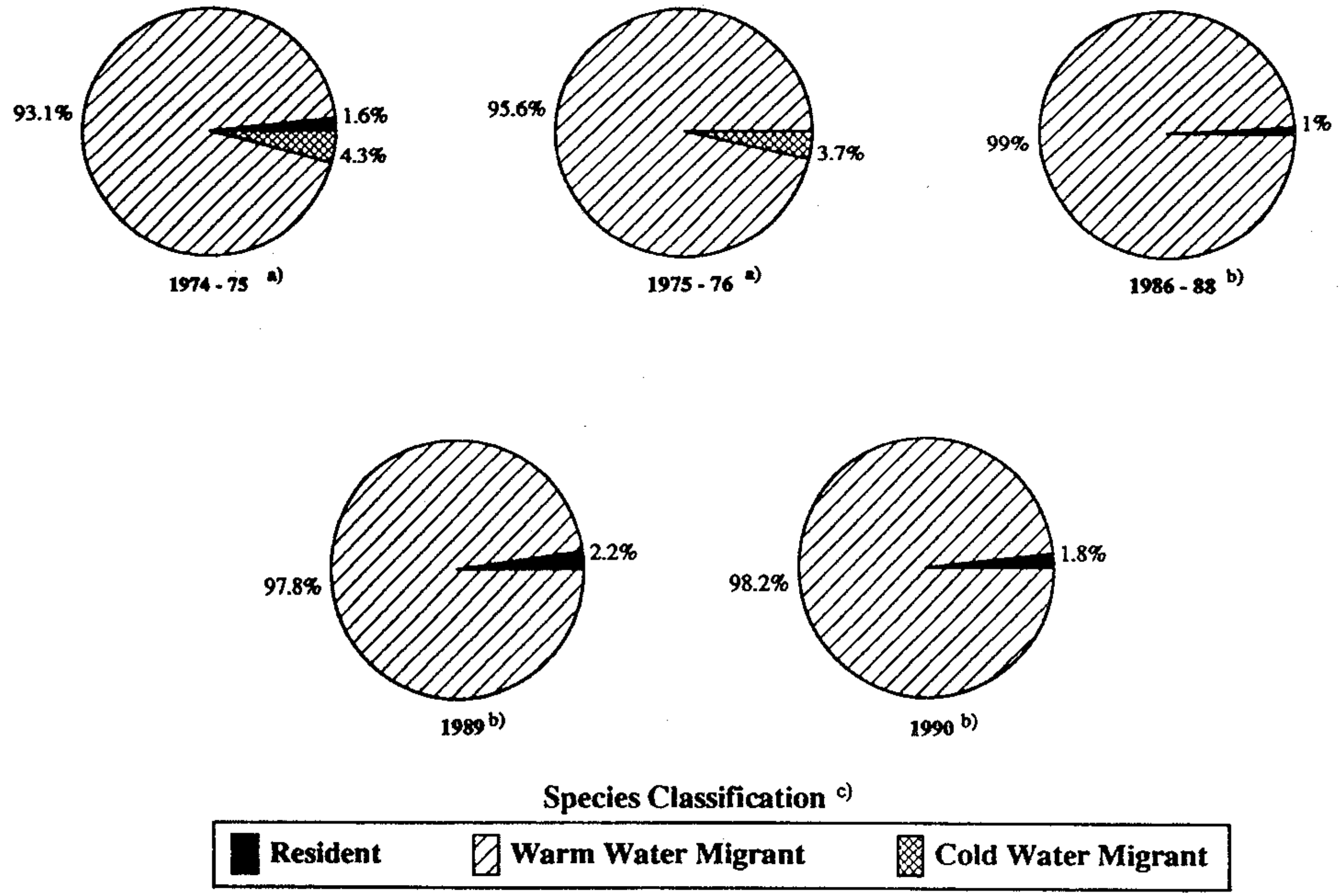
4.7.3.1 Status

The most recent study of the shore zone fish community of Rehoboth Bay and Indian River estuary was conducted by DNREC from 1986 through 1988. No studies of the shore zone community of Rehoboth and Indian River Bays have been conducted in the last four years. The status of the shore zone finfish community of these bays is unknown.

Table 4.7-4
Classification of Common Fishes Observed in Delaware Inland Bays[a]

Residents Striped killifish Mummichog Rainwater killifish Atlantic silversides Inland silversides Hogchoker Sheepshead minnow Winter flounder	*Warm-Water Migrants* Atlantic croaker Atlantic menhaden Atlantic herring Bay anchovy Striped anchovy Bluefish White mullet Silver mullet Silver perch Northern puffer Spot Weakfish
Cool-water migrants Red hake Spotted hake Winter flounder[b]	*Other* Banded killifish Golden shiner Gizzard shad

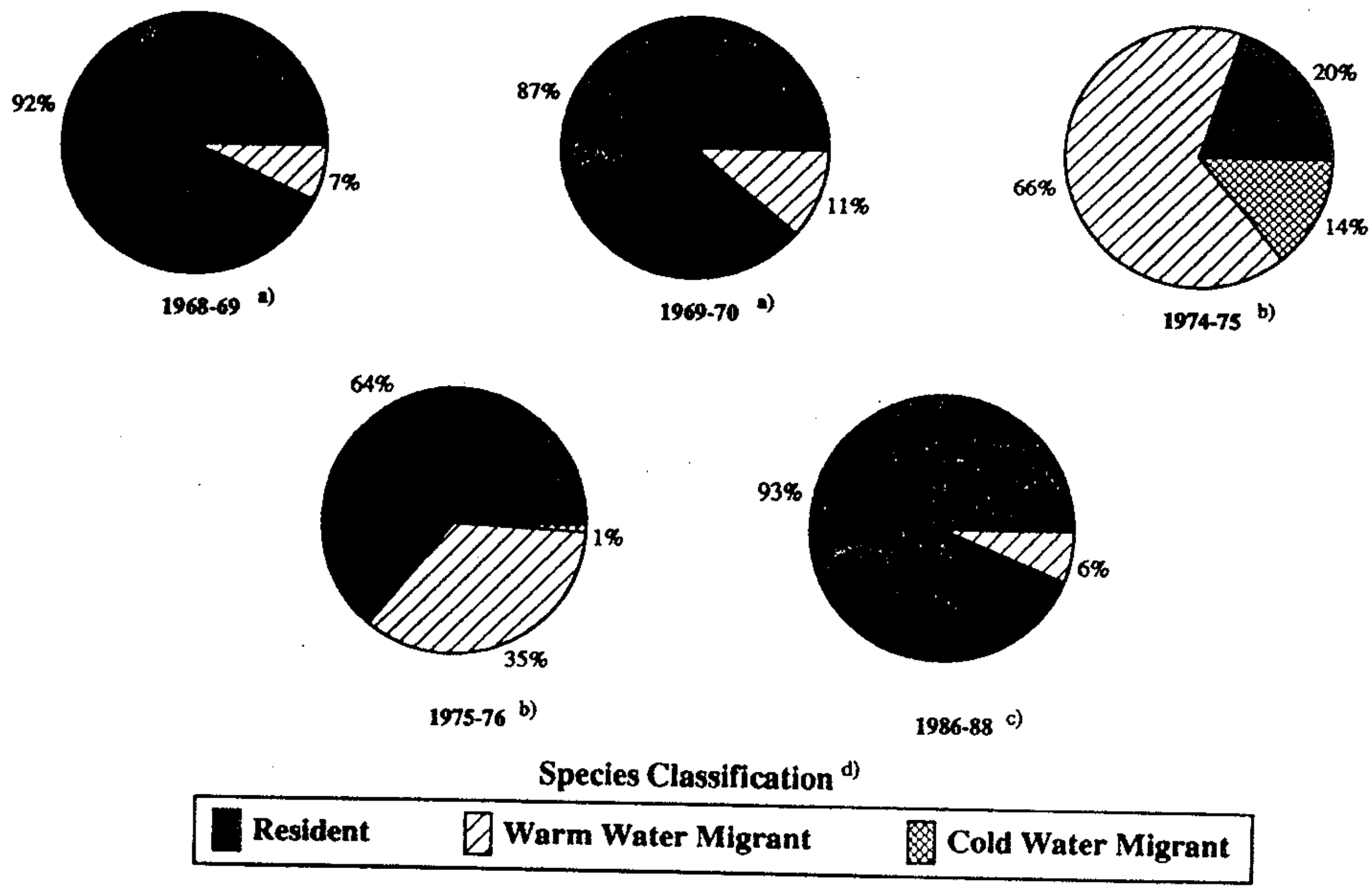
[a]Based on classification scheme of Tatham et al (1984) for Barnegat Bay.
[b]Immature individuals are residents year round, adults are cool-water migrants.



a) DP&L, 1976 - Data for Indian River only (includes year-round sampling)
b) DNREC, 1986 - 1990 - Data for Indian River and Rehoboth Bays combined (May - November only)
c) (Based on Tatham et.al., 1984 See Table E.6-5)

Figure 4.7-2
Comparison of Percent of Open Water Juvenile Finfish Community by Type Collected by Trawl in Indian River and Rehoboth Bays

Fish22-D18



a) Derickson & Price, 1973 - Rehoboth and Indian River (year round)
b) EA, 1976 - Data for Indian River only (includes year round sampling)
c) DNREC, 1986-1988 Indian River and Rehoboth Bays seine data (May - November combined)
d) Based on Tatham et. al., 1984 See Table E.6-5

Figure 4.7-3
Comparison of Percent of Shore Zone Finfish Community by Type Collected by Beach Seine in Indian River and Rehoboth Bays

Fish23-D18

In June 1991, a qualitative survey of the shore zone fish of Little Assawoman Bay was conducted (Price and Schneider, 1991). In this survey, a 10 meter by 1.2 meter seine with a 1/4-inch stretch mesh was hauled approximately 30-35 meters at each of five sampling locations.

Table 4.7-5 presents a summary of the fish collected and provides the rank, mean catch per seine haul, and the percent composition of individual species. During this survey, Price and Schneider collected a total of 1,967 fish representing twelve species. Mean catch per seine haul was 393 fish/haul. The catch was dominated by the Atlantic silverside, *Menidia menidia*, which represented 70 percent of the total number of fish caught. The mummichog, *Fundulus heteroclitus*, and the spot, *Leiostomus xanthurus*, accounted for 16 percent and 6 percent of the catch, respectively. Results of this study led Price and Schneider to report that Little Assawoman Bay appeared to be "a thriving nursery" for the recreationally important blue crab, *Callinectes sapidus*, spot, and summer flounder, *Paralichthys dentatus*. Comparison with the results of a previous study of Derickson and Price (1973) in Indian River Bay and Rehoboth Bay, suggested that the composition of fish found in Little Assawoman Bay was similar to that of the earlier study, with the exception of fewer species being collected, i.e., 12 species in this study in contrast to 40 species in the earlier study. Limited sampling frequency and the cursory nature of the current study were cited as the probable causes for the difference.

4.7.3.2 Historical Record of the Shore Zone Community

The shore zone of Indian River, Rehoboth and Little Assawoman Bays provides habitat that supports a diverse community of fishes. In studies of the shore zone community of Indian River estuary and Rehoboth Bay between 1968 and 1988, 63 species representing 30 families were collected.

Although many fish of the shore zone community have little or no commercial or recreational importance, they are, nevertheless trophically important to the commercial and recreational

Table 4.7-5
Rank, Catch per Haul, and Relative Abundance of Fish Collected in Shore-Zone of Little Assawoman Bay, June 1991

Species	Rank	Catch per Haul	Relative* Abundance (Percent)
Atlantic Silverside *Menidia menidia*	1	277	70
Mummichog *Fundulus heteroclitus*	2	64	16
Spot *Leiostomus xanthurus*	3	24	6
Striped Mullet *Mugil cephalus*	4	16	4
Striped Killifish *Fundulus majalis*	5	6	2
Summer Flounder *Paralychthys dentatus*	6	3	1
Atlantic Needlefish *Strongylura marina*	7	1	<1
Naked Goby *Gobiosoma bosci*	8	<1	<1
Inshore Lizardfish *Synodus foetens*	9	<1	<1
Sheepshead Minnow *Cyprinodon variegatus*	10	<1	<1
Blunthead Puffer *Sphoeroides pachygaster*	11	<1	<1
Hogchoker *Trinectes maculatus*	12	<1	<1

* Relative abundance - The proportional representation of a species in the sample collection, expressed as a percentage.

fishery. Moreover, these fish provide important forage for the numerous wading birds that frequent the intertidal shore zone. Impact to these species either from loss of habitat (e.g., bulk heading) or degradation of water quality may affect the survival and maintenance of species that depend upon the shore zone for food.

Due to differences between studies in sampling methods and the inherent variability in the seining technique, quantitative comparisons of the results of these studies are difficult. Nevertheless, a qualitative comparison of some of the key community metrics, such as species dominance and relative abundance provides some insight into the general composition of the shore zone fish community. Table 4.7-6 presents a summary of the numerical dominance ranking and the relative abundance of the top ten shore zone fish collected in several studies of Rehoboth Bay and Indian River estuary between 1968 and 1988. The relative abundance, presented as a percentage, describes the proportional representation of a species in a sample collection. Results of the seining studies demonstrate that the shore-zone community is dominated numerically by species that are permanent residents of the Inland Bays and juvenile finfish that use the shallow intertidal areas as nursery grounds or feeding sites. Resident species inhabiting the shore zone include:

- Mummichog (*Fundulus heteroclitus*).
- Striped killifish (*Fundulus majalis*).
- Atlantic silverside (*Menidia menidia*).
- Sheepshead minnow (*Cyprinodon variegatus*).
- Juvenile winter flounder (*Pseudopleuronectes americanus*).

These species accounted for 69 percent (by number) of all fish sampled in the shore zone of Indian River and Rehoboth Bays between 1968 and 1988. In addition to the resident species, a number of non-resident species also inhabit the shore zone. Principal non-resident finfish that use the shore zone based on the results of these studies include:

Table 4.7-6
Rank and Relative Abundance of Top-Ten Shore Zone Fish Collected by Seine from Indian River and Rehoboth Bays
Between 1968 and 1988

	Derickson & Price[a]				DP&L[b]				DNREC[c]	
	1968-1969		1969-1970		1974-1975		1975-1976		1986-1988	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Striped killifish	1	30.2	1	34.1	7	1.3	4	4.	4	3.4
Atlantic silverside	2	20.0	2	25.1	3	2.9	2	26.	1	85
Mummichog	3	19.2	3	20.6	2	12.2	1	28.	3	4.3
Winter flounder	4	7.7	5	4.3	35	<0.1	38	<0.1	14	<0.1
Bay anchovy	5	4.3	11	0.3	4	2.9	7	2.	6	0.3
Sheepshead minnow	6	2.5	7	1.2	10	0.6	14	0.4	10	0.1
Northern puffer	7	1.5	8	1.1		NF	56	<0.1		NF
Rainwater killifish	8	1.2	21	0.1		NF		NF		NF
Silver perch	9	0.8	4	7.8	20	<0.1	41	<0.1	8	0.1
White mullet	10	0.6	10	0.5	12	0.3	13	0.6	NF	NF
Spot			6	1.6	6	2.6	3	26	2	4.
Silver mullet			9	0.8	18	0.1	27	<0.1	5	1.1
Atlantic menhaden					1	59.	5	3.3	7	0.2
Inland silverside					5	2.9	6	3.2	20	<0.1
Atlantic croaker		NF		NF	8	1.0	11	0.9	31	<0.01
Bluefish					9	0.7	15	0.4	15	0.01
Golden shiner							8	1.3		NF
Banded killifish							9	1.2		NF
Weakfish							10	1.1	9	0.1
Total #spp	38		46		51		56 spp		32 spp	
Total #fish	28,300		13,440		70,000		30,000		60,400	

[a] Rehoboth and Indian River (year round sampling)
[b] Indian River only (year round)
[c] Rehoboth and Indian River (May-November only)
NF Not found

I-I 7 6.028

- Bay anchovy (*Anchoa mitchilli*).
- Spot (*Leiostomus xanthurus*).
- Atlantic menhaden (*Brevoortia tyrannus*)

A summary of the seasonal distribution of various life stages of some of the more important permanent resident and non-resident species found in both the shore-zone and open water communities of the Inland Bays is provided in Figure 4.7-4.

A comparison of the rank and relative abundance of key finfish species based on the three data sets used in this analysis suggests that with few exceptions, there was little temporal variation in species dominance or composition of the shore-zone community between 1968 and 1988. With the exception of 1974 to 1975, the shore zone community was numerically dominated by the killifish, the Atlantic silverside and the bay anchovy. In 1974 to 1975, a large run of Atlantic menhaden into the bays resulted in that species comprising 59 percent of the shore zone community.

The killifishes, principally the striped killifish, *F. majalis*, and the common killifish, *F. heteroclitus*, were typically the most common and abundant fishes of the shore zone community. Collectively, they ranked first in numerical abundance for three of the five sampling periods, the exceptions being 1974 to 1975 when they ranked second behind the menhaden, and the 1986 to 1988 period when they ranked second behind the Atlantic silversides. The killifish are common inhabitants of fringe marsh and tidal creek in the Inland Bays and its tributaries. They inhabit areas that are often oxygen deficient in summer and that exhibit large seasonal temperature extremes. During winter, the killifish burrow in the mud in deeper waters of the bays. 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 heron, the crested night heron, and green herons.

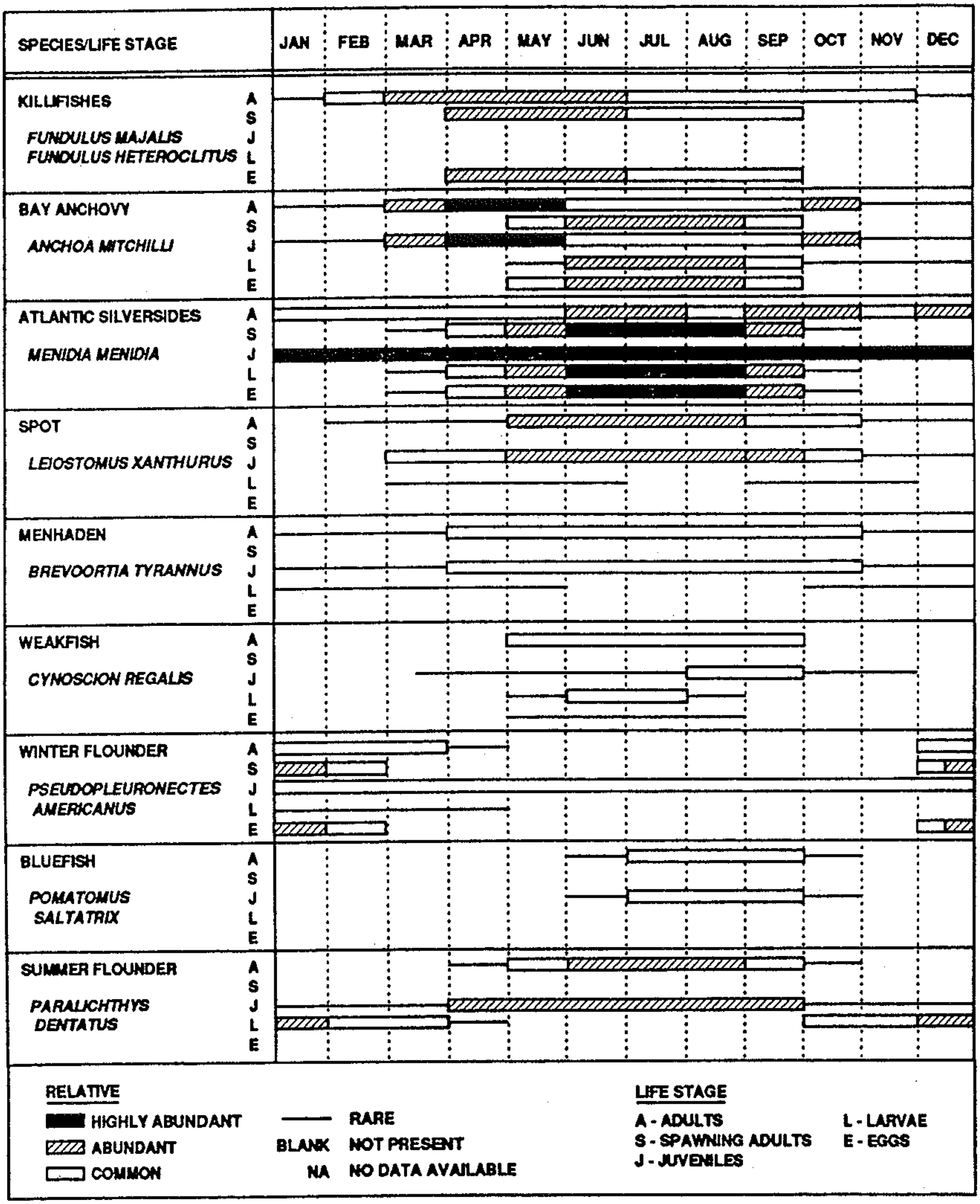


Figure 4.7-4
A Summary of the Seasonal Distribution
of Life Stages of Key Fish of Delaware Inland Bays
Source of Information; DP&L, 1976; Wang & Kernehan, 1979; NOAA, 1992

Fish29-018

In the most recent sampling of the shore zone community, i.e., 1986-1988, the Atlantic silverside, *Menidia menidia*, ranked first in numerical abundance accounting for 85 percent of the individuals collected in that period. The Atlantic silverside is a common shoreline species along the entire mid-Atlantic coast. It supports no commercial fishery but is one of the more important ecological species in the bays. The silverside feeds chiefly on mysids, small copepods and some amphipods, polychaetes, fish eggs and molluscan larvae (Bigelow and Schroeder, 1953). In the Inland Bays, this species is important forage for bluefish, striped bass and weakfish. The silverside spawns in the spring, laying demersal eggs that are attached to shoreline grasses. Larvae and juveniles prefer the quieter, more protected shore zones for their nursery areas (DP&L, 1976). It grows rapidly reaching 60 to 80 mm (2.5-3 inches) by the end of the first summer, and after spawning the following spring (April-May), reaches 100 mm (4 inches) before it dies at 14 to 16 months.

The bay anchovy, *Anchoa mitchilli*, is a widely distributed engraulid, found in coastal, estuarine and freshwater habitats along the Atlantic seaboard. The bay anchovy is one of the most abundant fish species in its range, and not only is a common inhabitant of the shore zone where it ranked among the top four species in these studies, it is also one of the most abundant species in the open water community as determined by trawl data. In terms of numbers, the bay anchovy is the single most abundant fish in the Delaware inland bays. It is a small species with a maximum size not exceeding 110 mm (4.33 inches), and individuals larger than 90 mm (3.54 inches) are uncommon.

The bay anchovy is an important forage species for predator fishes throughout its range. Predators include striped bass, bluefish, weakfish and summer flounder. Bay anchovy are mid-water carnivores, that primarily feed on zooplankton and are an important link between primary producers and harvested predator species in the Inland Bays. Male and female bay anchovy mature at age 0+ when 35 to 40 mm (1.4 to 1.6 inches) in length. Spawning season varies with latitude, being more protracted in the southern part of its range. Most spawning in the mid-Atlantic region occurs from mid-May through mid-September. Spawning occurs over a wide range of salinities and temperatures (15 to 30 C). Eggs and larvae are abundant in both shelf and estuarine waters (Houde and Zastroco, 1991).

Causes for interannual variability in abundance and recruitment are little known, primarily because bay anchovy are not exploited. The population dynamics are relatively little understood. Bay anchovy are short-lived; length-frequency and otolith (ear bone) analyses indicate that maximum age probably does not exceed 3+ years. Few individuals attain two years of age (Chesapeake Bay Program, 1988). In the Delaware Bay during 1983, annual mortality was estimated to average 80.2 percent. Results of long-term trawling surveys in the Virginia portion of the Chesapeake Bay, and egg and larvae abundance indices in Maryland have suggested major fluctuations in yearly abundance. Unlike the Chesapeake Bay populations that overwinter in the bay, the bay anchovy using the Inland Bays migrates offshore in winter. Abundance of mature individuals in the Inland Bays apparently is highest in late summer (August-September) when new recruits predominate (DP&L, 1976).

Perhaps of special interest, the juvenile winter flounder (*Pseudopleuronectes americanus*) was found to be a significant component of the shore zone community in 1968/1969 and 1969/1970 when it ranked fifth and fourth in numerical dominance, respectively. The winter flounder contributes to both the sport and commercial fisheries of the northeast and mid-Atlantic region of the east coast. This juvenile flounder is a year-round resident of the shallow waters of the inland bays until it is about 12 months when it leaves the bay. In a study of the population dynamics of the winter flounder in the Inland Bays, Radle (1971) observed that the 0-year class juveniles leave the nursery in late fall to early winter, and for the most part, do not return to the Bays until they are two or three years old. In the same study, Radle observed that juvenile flounder occurred predominantly in the shore zone and that few individuals were taken in deeper waters.

A significant decline in the juvenile winter flounder population of the shore zone community was noted between 1970 and 1974. Having ranked fourth and fifth in relative abundance, the winter flounder represented from 5 to 8 percent of the shore zone community (by number) from 1968 through 1970. Four years later, DP&L (1976) observed that the flounder was virtually absent from the shore zone community. The reason for its disappearance from this habitat is unknown. However, it has been speculated that the decline may have been a reflection of a regional decline in the winter flounder population. The decline in the winter flounder fishing in the Inland Bays at that time coincides with similar declines regionally. Figure 4.7-5 presents the commercial landings of winter flounder in New Jersey and Barnegat Bay from 1950 through 1980. A similar comparison of yearly average abundance based on catch/trawl data of the Chesapeake Bay is provided in Figure 4.7-6. As with the Inland Bays, regional data show that a sharp decline in the winter flounder fishery occurred around 1969-1970. Several reasons have been suggested for the regional decline including environmental changes such as climate, as well as overfishing of the resource (Jeffries and Johnson, 1974; Tatham, 1980). The potential impact due to overfishing is presented in a subsequent discussion related to commercial finfishing.

In addition to seasonal fluctuations, spatial variation in the shore-zone community may result from changes in habitat and salinity regime along the length of the estuary. Table 4.7.7 presents the spatial distribution, abundance, and percent composition of shore zone fish of Indian River Estuary observed during DP&L's 1976 study. As might be suspected, the shore zone of the upper segment of the estuary contained a number of typically oligohaline species such as the banded killifish, the golden shiner, and the bluegill. Of the killifish, the striped killifish (*Fundulus majalis*) was found to be more prevalent in the lower estuary and reflects its preference for sandier sediment.

4.7.4 Open Water Finfish Community

The open-water community of the Delaware Inland Bays, as defined by trawl collections, consists primarily of seasonal migrants that use the bays as spawning sites and nursery and feeding grounds. Because the trawls are most efficient in catching juvenile dermersal or epibenthic fish,

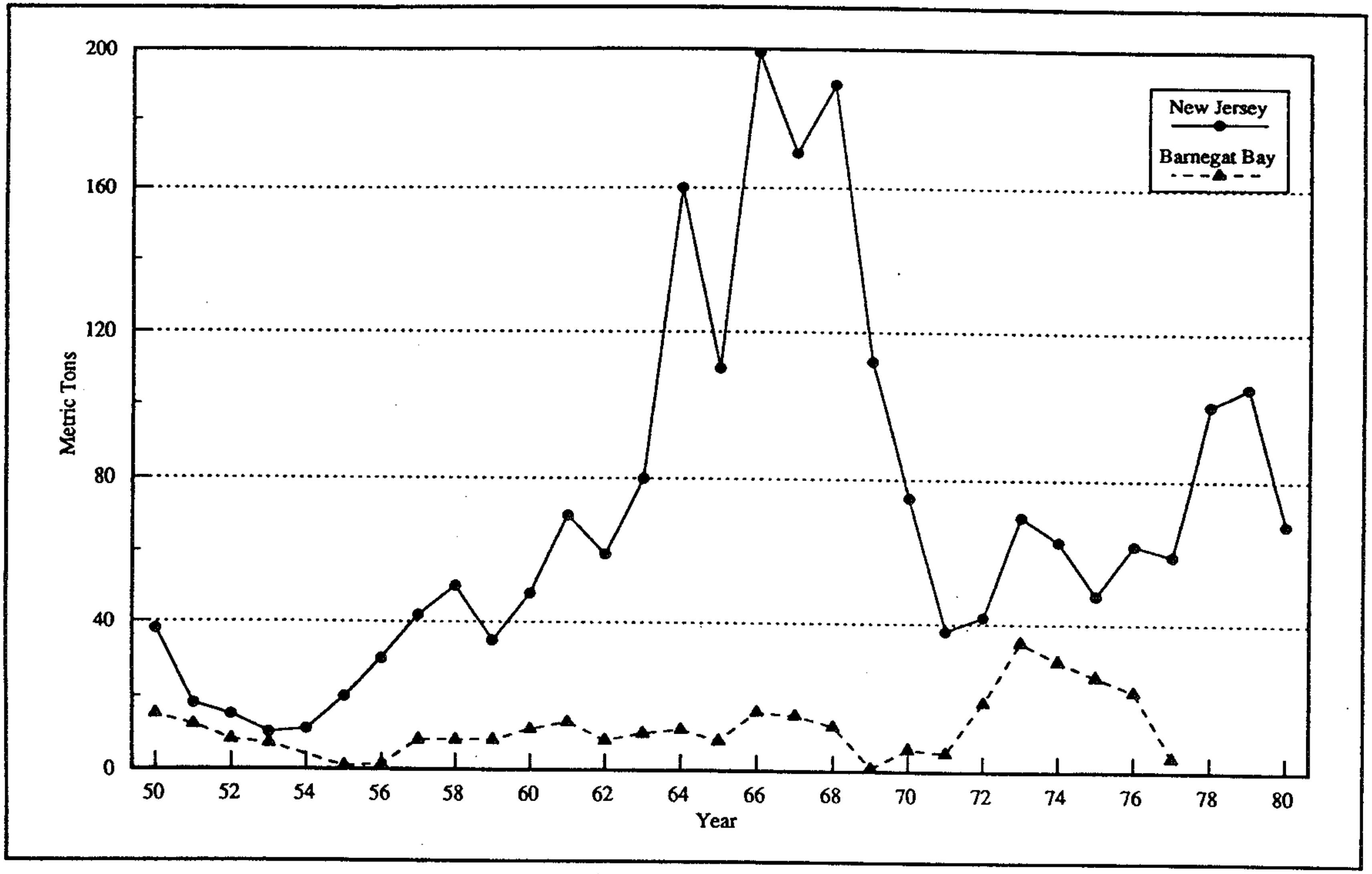


Figure 4.7-5
Commercial Landings (MT) of the Winter Flounder in New Jersey and Barnegat Bay from 1950 to 1980
(Hillman and Kennish, 1984)

Fish26-D18

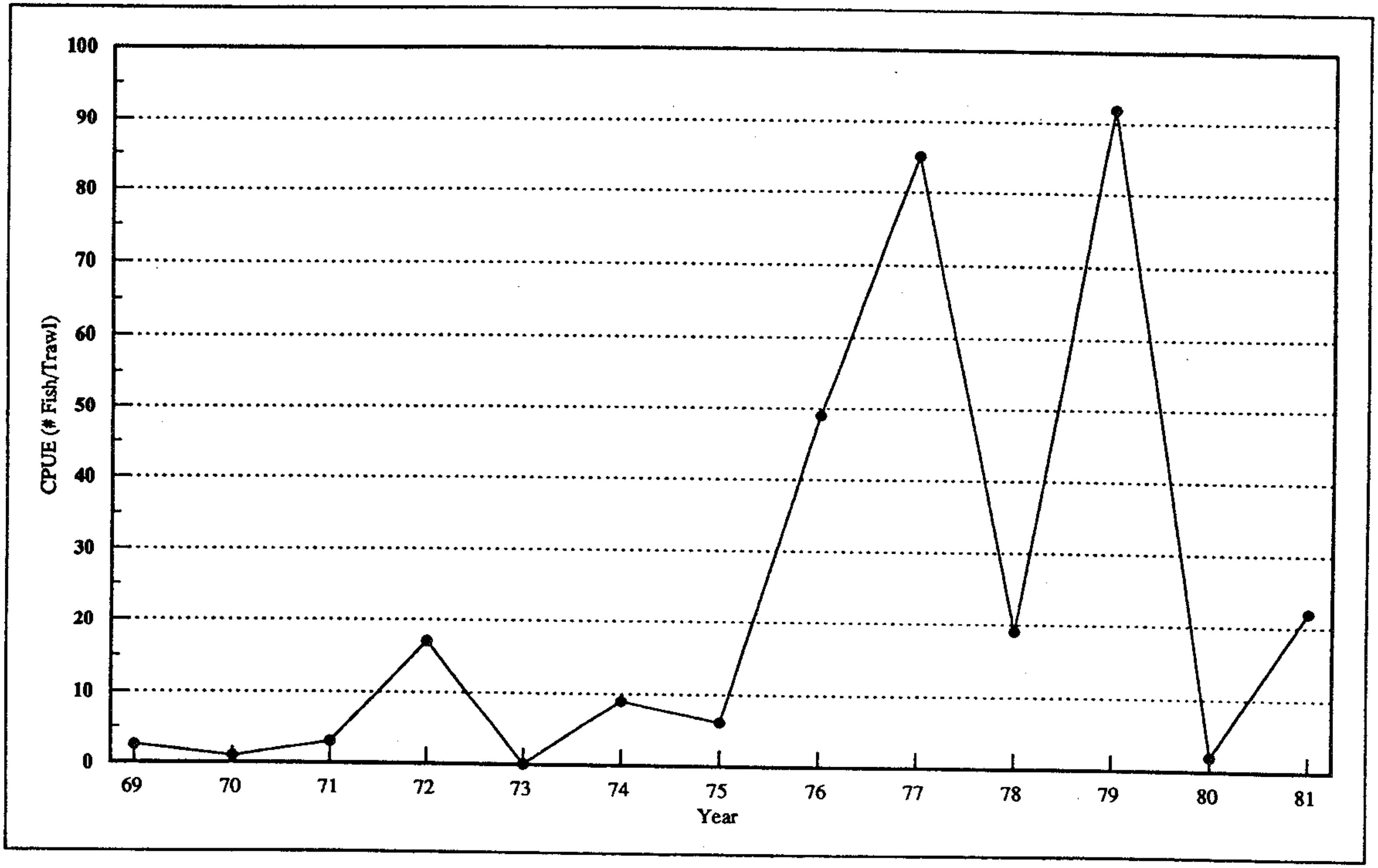


Figure 4.7-6
Average Yearly Abundance of Winter Flounder
in Chesapeake Bay in the Vicinity of Calvert Cliffs
(Data from Horwitz, 1987)

Fish23-D18

Table 4.7-7
Distribution Abundance and Percent Composition by Segment of Indian River Estuary Shore Zone Fish June 1975 to May 1976 (DP&L 1976)

Upper Segment	Middle Segment	Lower Segment
1. Spot (34%)	1. Mummichog (42%)	1. Atlantic silversides (75%)
2. Mummichog (30%)	2. Spot (33%)	2. Striped killifish (10%)
3. Atlantic silversides (6%)	3. Atlantic silversides (10%)	3. Bay anchovy (7%)
4. Golden shiner (5%)	4. Atlantic menhaden (4%)	4. Spot (3%)
5. Inland silversides (5%)	5. Inland silversides (4%)	5. Atlantic menhaden (1%)
6. Gizzard shad (4%)	6. Striped killifish (3%)	6. Inland silversides (1%)
7. Banded killifish (4%)	7. White mullet (1%)	7. Mummichog (.5%)
8. Atlantic menhaden (4%)	8. Croaker (1%)	8. White mullet (.3%)
9. Bluegill (2%)	9. Bay anchovy (1%)	9. Windowpane flounder (11%)
10. Croaker (2%)	10. Sheepshead minnow (.5%)	10. Other

Millsboro Dam IRPP Rock Point Inlet

NF = Not found

.028

5 Novemb

the trawl data primarily reflects the contribution of those species to the open water community. Nevertheless, these trawls comprise some portion of the mid-water fish community. The average vertical opening of a 4.6 meter semi-balloon trawl in operation is about 1 meter (Kjelson and Johnson, 1978). With a mean depth of 2 to 3 meters in the channelized areas of the bays, the trawls probably sample between one-half and one-third of the water column. Consequently, trawl data probably reflects some combination of the demersal and midwater finfish community.

4.7.4.1 Status

The open water community of the Inland Bays has been sampled continuously since 1986. Trawl collections in Rehoboth and Indian River Bay are conducted monthly between May and November.

Data for the previous two years trawl sampling (1990-1991) are discussed below. Table 4.7-8 presents the rank, relative abundance (percent composition) and catch per unit effort of the top ten finfish collected by trawl from Rehoboth and Indian River Bays in 1990 and 1991.

Based on these results the dominant juvenile finfish of the open water community in 1990-1991 include:

- Bay anchovy
- Spot
- Weakfish
- Atlantic Croaker

In aggregate these four species accounted for about 95% (by number) of the open water community as measured by the trawl data for the last two years. A large influx of juvenile croaker in May of 1991 resulted in that species being ranked second in numerical dominance with a mean CPUE of almost 47 fish/haul. In 1991, the croaker accounted for 12.5 percent of the total fish collected by trawl for that year. This represented the first time since the mid-1970's that croaker comprised a significant portion of the open water finfishery.

Table 4.7-8
Rank, Relative Abundance and Catch per Unit Effort[1] of Top-Ten Juvenile Finfish Collected by Trawl from Rehoboth and Indian River Bays in 1990 and 1991

	1990			1991		
	Rank	%	CPUE	Rank	%	CPUE
Bay anchovy	1	70.8	157	1	69.5	260
Spot	2	14.0	31	4	7.2	27.1
Weakfish	3	9.7	21.5	3	7.6	28.3
Atlantic menhaden	4	1.9	4.2	6	0.4	1.6
Winter flounder	5	0.8	1.8	20	<0.1	0.2
Summer flounder	6	0.4	0.9	10	0.2	0.7
Hogchoker	7	0.4	0.9	8	0.2	0.8
Striped anchovy	8	0.4	0.9	13	0.2	0.6
Black seabass	9	0.3	0.7	25	<0.1	0.1
Butterfish	10	0.2	0.4	12	0.2	0.6
Atlantic Croaker				2	12.5	46.6
Inshore Lizardfish				5	0.4	1.6
Silver Perch				7	0.3	1.2
Scup				9	0.2	0.8
# Species	35			47		
Abundance	13,500			25,451		
CPUE			222			374

[1]CPUE - Represents the mean number of fish per haul.

4.7.4.2 Historical Record of the Open Water Community

From trawl data collected periodically since the early 1970's, results indicate that warm-water migrants dominated the open-water community, representing an average of about 95 percent (by number) of the total finfish collected (Figure 4.7-2). Note, however, that winter trawl data, and therefore, cool-water migrant statistics are available only for the period 1974 to 1976. Nevertheless, in those years where winter trawl collections were made, warm-water migrants still represented more than 90 percent of the total number of fish collected throughout the year.

Table 4.7-9 presents the rank and the relative abundance of juvenile finfish species collected by trawl from Rehoboth Bay and Indian River estuary between 1974 and 1991.

Based on these results, the numerically dominant juvenile finfish of the open water community for those years for which data are available have included:

Bay Anchovy (*Anchoa mitchilli*)
Spot (*Leiostomus xanthurus*)
Atlantic menhaden (*Brevoortia tyrannus*)
Weakfish (*Cynoscion regalis*)
Atlantic Croaker (*Micropogonias undulatus*)

For any given sampling period, these five species have accounted for more than 90 percent of the total numbers of juvenile finfish collected in the open water community (Figure 4.7-7).

A comparison of the relative abundance of juvenile finfish between sampling periods indicates that although sufficient similarity exists between years among the numerically dominant species, significant fluctuations in relative abundance since the mid-1970's has been observed for several species. A Friedman Rank Test was conducted to test the significance of the variability in relative abundance of the ten-most abundant juvenile finfish collected between 1974 and 1991. Results indicated that there is a significant similarity in the numerical ranking of relative

Table 4.7-9
Rank and Relative Abundance[a] of Top-Ten Juvenile Finfish Collected by Trawl from Rehoboth and Indian River Bays Between 1974 and 1991

Study

	DP&L				DNREC							
	1974-1975		1975-1976		1986-1988		1989		1990		1991	
	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%
Bay anchovy	1	62.3	1	71.9	1	71.	1	63	1	70.8	1	69.5
Spot	2	22.9	2	15.4	2	21.	2	22.4	2	14.0	4	7.2
Atlantic menhaden	3	5.4	3	7.5	3	3.0	4	1.2	4	1.9	6	0.4
Atlantic croaker	4	3.4	4	3.7	40	<0.1	9	0.2	25	<0.1	2	12.5
Weakfish	5	2.1	5	0.7	4	2.0	3	11.0	3	9.7	3	7.6
Atlantic silverside	6	1.0	6	0.2	7	0.4	8	0.3	NF	NF		NF
Spotted hake	7	0.9		<.1				NF	33	<0.1	14	<.1
Summer flounder	8	0.4	8	0.1	10	0.2		<.1	6	0.4	10	0.2
American eel	9	0.3	7	0.1	13	0.08	31	<0.1	17	<0.1	NF	NF
Hogchoker	10	0.3	14	<0.1	11	0.1	5	0.3	7	0.4	8	0.2
Gizzard shad			9	<0.1		0.02		NF	NF	NF	NF	NF
Black seabass			10	<0.1	12	0.1		NF	9	0.3	25	<0.1
Winter flounder					14	0.08	7	0.3	5	0.8	20	<0.1
Striped anchovy						0.3		NF	8	0.4		
Butterfish					17	0.07	NF	NF	10	0.2	12	0.2
Silver perch					5	0.4	10	0.2	--	--	7	0.3
Clear-nose skate					6	0.4	6					
Atlantic herring					9	0.3						
Scup											9	0.2
Inshore Lizardfish											5	1.6
# Species	39		37		45		48		35		47	
Abundance	34,800		48,300		65,200		33,000		13,500		25,451	
CUE	249		804		315		403		222		374	

[a] Relative Abundance - The proportional representation of a species in the sample collection, expressed as a percentage.
NF - Not Found

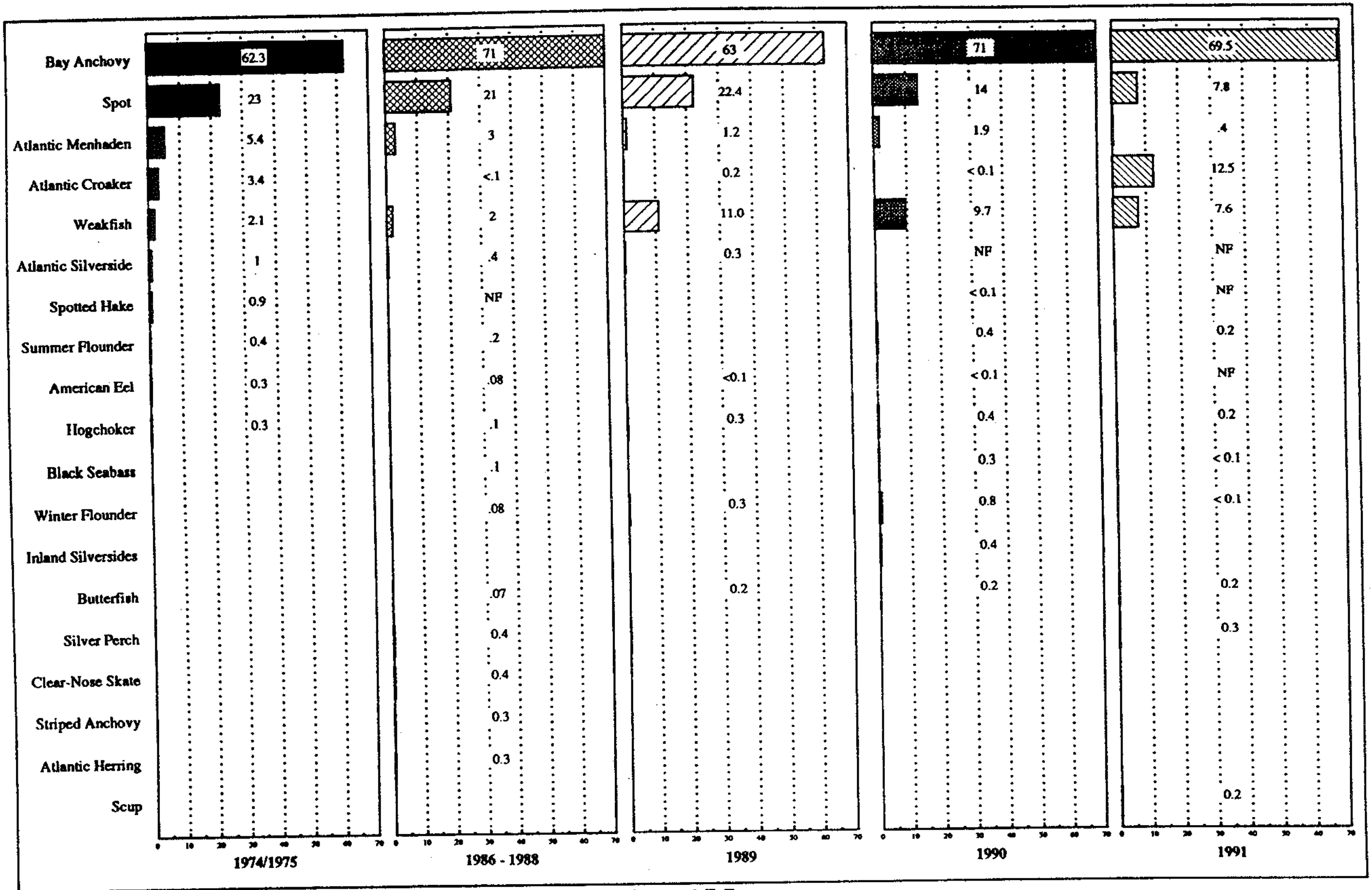


Figure 4.7-7
Comparison of Relative Contribution (as percentage) of Top Ten Finfish to Total Finfish Community in Rehoboth and Indian River Bays between 1974 - 1990

Fish27-D19

abundance for the dominant species such as bay anchovy, spot, menhaden, and weakfish. However, significant differences in the relative abundance rank of several species suggested significant fluctuations in the populations of those species since the early 1970's. Those species include the Atlantic croaker (*Micropogonias undulatus*), the spotted hake (*Urophycis regia*), and the winter flounder. An apparent decline in the hake population appears to be an artifact of the different sampling periods monitored in 1974-1976 and 1986-1990. Year-round trawl sampling in 1974 to 1976 favored the collection of cool water migrants, while sampling from 1986 to 1991 was conducted from April to October when hake would not be expected in the bay.

To account for the possibility of bias in fishing effort between studies a comparison was made of the catch per unit effort (CPUE), defined as the number of fish (by species) caught per trawl. See Table 4.7-2 for comparison of sampling methodology. The comparison of the CPUE for those years for which data are available, indicates a similar distribution and contribution of numerically dominant species to the open water fish community as that found for the unadjusted data (Table 4.7-10). Again, bay anchovy, spot, menhaden, and weakfish typically dominated the trawl catch. Moreover, a comparison of the CPUE also demonstrates several years in which the stocks of specific juvenile finfish were significantly higher than those of other years. For example, the average CPUE for weakfish in 1989 was almost ten-fold higher than the combined average CPUE for other years. Similar pulses in fish stock were noted for the bay anchovy in 1975-1976 and menhaden also in 1975-1976. By contrast, a comparison of CPUE for several species also showed results similar to that of the Rank Friedman Test. For the period of record, long-term fluctuations, i.e., longer than a single year, in CPUE were noted for the croaker, the hake, the winter flounder, and the silver perch.

The Atlantic croaker, once abundant in the Inland Bays in the mid-1970's, went through a period of significant decline in the 1980's. A member of the Sciaenidae family, the croaker is a temperate species that ranges from Massachusetts to Mexico. The species is most abundant along the southeast coast of the United States and in the northern Gulf of Mexico. Adult croaker tolerate a wide range of temperatures 2° to 30°C (25° to 86° F) and salinities (0 to 35 ppt), but the juveniles prefer the lower salinity and oligohaline environment of the estuaries which serve

Table 4.7-10
Variation in Average Catch per Unit Effort of Common Fishes Collected by Trawl in Rehoboth Bay and Indian River Estuary (1974 - 1990)

Species	1974-75 [a]	1975-76 [a]	1986-1988	1989 [b]	1990 [b]	1991 [b]
Bay Anchovy	155	578	224	252	157	260
Spot	57.1	124	67.0	90.1	40	27.1
Atlantic Menhaden	13.5	60.6	8.2	4.7	4.1	1.6
Atlantic Croaker	8.6	29.4	0.004	0.8	0.003	46.6
Weakfish	5.2	5.6	6.0	44.6	21.5	28.3
Atlantic Silverside	2.5	1.2	1.2	1.1	NF	-
Spotted Hake	2.2	0.3	0.2	NF	0.02	-
Summer Flounder	1.0	0.8	0.7	0.2	1.0	0.7
American Eel	—	—	0.3	0.03	0.1	-
Hogchoker	0.8	0.3	0.6	1.3	0.9	0.8
Winter Flounder	0.4	NF	0.2	1.1	1.7	0.2
Striped Anchovy	NF	NF	1.2	0.2	0.8	-
Black Sea Bass	0.1	NF	0.4	0.2	0.8	0.1
Bluefish	0.2	0.1	0.1	0.7	0.3	-
Silver Perch	NF	NF	1.2	0.8	0.5	1.2

[a] Indian River Bay only (DP&L, 1976)

[b] Rehoboth Bay and Indian River combined (DNREC, 1986 - 1991)

Fish28-D18

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. Although estimates vary, reported size and age at maturity suggests that Atlantic coast croaker are sexually mature at 3 to 4 years. 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 epibenthic, omnivores that feed on polychaetes, mollusks, mysids, decapods, and other invertebrates found on the bottom as well as, an occasional small fish (Chesapeake Bay Program, 1988).

Although the reason for the decline in croaker population in the Inland Bays is not fully understood the decline appears to reflect a coastal trend in populations of these fish. Maryland and Virginia have generally accounted for the majority of the Atlantic croaker harvest on the eastern seaboard. The Virginia catch has varied from a high of 2,500 metric tons (mt) in 1945 to a low of 3 mt in 1968, peaking again in 1977 with a catch of 3,900 mt before dropping once again. In 1986 the harvest totalled only 1,034 mt. Maryland's landings show a similar trend, but the relative catch was much smaller, the largest catch being 2,260 mt in 1944. The 1984 harvest totalled 12 mt. Maryland currently imposes a 10-inch minimum size for species. The mid-Atlantic recreational catch, recorded since 1979, revealed a decline in catch between 1979 to 1980, but has since steadily increased to 23,426 mt in 1984 (Chesapeake Bay Program, 1988).

The abundance of Atlantic croaker seems to be closely related to climatological trends and fishing pressure. Warmer temperatures appear to favor the species as evidence by increases in landings during the first part of the 20th century. The abundance of croaker has been linked to water temperature, with low abundance in the mid-Atlantic estuaries following cold winters and high abundance following warm winters. Recently spawned croaker migrate to the oligohaline reaches of the upper estuary in fall and early winter. Cold winters have been shown to cause significant mortality in young of year fish (Joseph, 1972; Chad and Muszik, 1977; and Grosslein and Asaravita, 1982). Between 1958 and 1971, increased fishing pressure and cold winters reduced the Atlantic catch to <3,000 mt from 1961 to 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 (Figure 4.7-8).

It is of interest to note that in 1991, the largest CPUE for the croaker population in the Inland Bays was observed. This was due primarily to a large influx of juvenile croaker to the system in May of that year.

In addition, the winter flounder showed a decline in the open water fish community similar to that found in the shore zone community of the Inland Bays in the mid-1970's. The significance of the variation of relative abundance in the winter flounder also represents some recovery of the species in the Inland Bays in 1989 and 1990. Again, the variation in juvenile winter-flounder population may be influenced by climatic and anthropogenic factors. The relative importance of these factors is unknown.

4.7.5 Commercial Finfishing in the Inland Bays

Commercial catch statistics for Delaware represent the results of mandatory catch reports required by the Delaware General Assembly since 1984 (Miller, 1985). The data represent a compilation of monthly catch reports submitted by holders of commercial food fishing licenses in Delaware. Cole and Miller (1991) note however, that although these data represent the best available estimates of Delaware's commercial landings, "the numbers are as accurate as the records kept and submitted by each fisherman...(and)...the submission of late and incomplete reports remains a problem." In addition to these concerns, other problems with commercial landing statistics noted by Versar (1991), include: "1) a lack of effort to standardize data; 2) crediting pounds caught to port where landed when fish were harvested offshore, and 3) lack of adjustments for gear change, changes in target species, and seasonal closures."

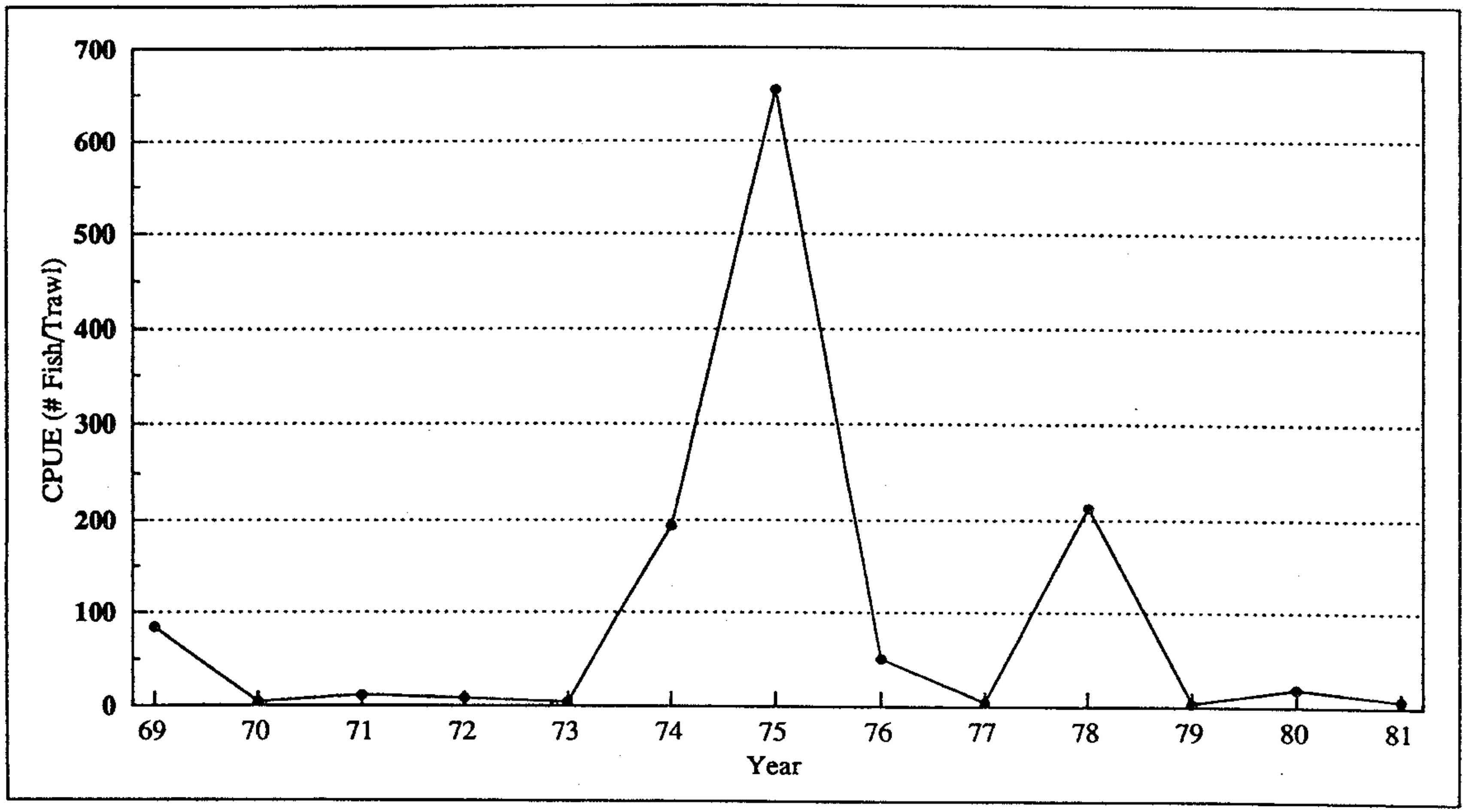


Figure 4.7-8
Average Yearly Abundance of Croaker
in Chesapeake Bay in the Vicinity of Calvert Cliffs
Source of Data: Horwitz, 1987

In addition to landings in Rehoboth and Indian River Bay, landings in Delaware are also reported for the Delaware River, the Delaware Bay, the Atlantic Ocean (in Delaware waters) and the Nanticoke River. Commercial gear used statewide and the percentage of total state landings (in pounds) in 1991 for each gear type is as follows (Cole and Miller, 1991):

- Anchored gill net (49.7%).
- Drift gill net (37.5%).
- Fish pot (9.8%).
- Hook/line (3.0%).
- Fyke net (0.02%)
- Hoop net.
- Haul seine.

Principal gear used in the Inland Bays are the gill nets.

4.7.5.1 Status of Commercial Finfishery of the Inland Bays

In 1991, commercial landings reported from Indian River and Rehoboth Bays totaled 69,682 pounds and 876 pounds, respectively (Cole and Miller, 1991). Combined, reported Inland Bay landings represented 3.7 percent (70,558 pounds) of the total landings for Delaware waters (1,968,155 pounds) in 1991. Table 4.7-11 presents the reported combined landings of commercial species caught in Indian River and Rehoboth Bays. It should be noted that in 1991, commercial landings for Rehoboth Bay were reported for the months of April and June only. In addition, data for June 1991 appears incomplete. Consequently, the total landings in Rehoboth Bay for 1991 are underestimated.

Based on these data, the most abundant commercial finfish landed in the Inland Bays in 1991 was the American shad which accounted for about 43.0 percent of the commercial catch, by weight, in Indian River. Weakfish (27.4 percent), bluefish (10.5 percent) and alewife (7 percent) also contributed significantly to the commercial catch in Indian River Bay. In addition to annual

Table 4.7-11
Comparison of Combined Annual Landings (Pounds) of Species That Generally Comprise More Than 95 Percent of Indian River Estuary and Rehoboth Bay Landings

Species	1985	1986	1987	1988	1989	1990	1991
American Shad	42	7,375	69	91	6	80	30,391
Weakfish	13,854	15,116	3,525	5,286	5,475	2,813	19,422
Bluefish	11,297	29,641	17,702	9,168	9,366	9,521	7,606
Menhaden	27	267	6,369	4,599	3,811	1,823	2,689
White Perch	67	11	160	35	54	11	1,034
Summer Flounder	155	473	46	18	1	0	372
Shark spp.	562	580	270	853	243	955	3486
Spot	701	6,059	12,186	408	3,158	149	372
Alewife	5	502	369	185	1,195	28	4,848
Other	175	365	166	65	423	755	338
Total Landings (Inland Bays)	26,885	60,389	40,862	20,708	23,732	16,135	70,558
Total (Delaware)	1,729,157	1,737,927	1,651,637	1,508,780	1,204,947	1,671,500	1,968,155
Inland Bays/Delaware (%)	1.6	3.5	2.5	1.4	2.0	1.0	3.6

Data Source: Miller, 1985; 1986; 1987; 1988; 1989; 1990
Cole and Miller, 1991.

14-7-11

total landings, Figure 4.7-9 shows the monthly catch for these principal species in Indian River Bay in 1991.

The commercial catch in Indian River for March and April dominated the total landings for 1991 comprising 77.5 percent of the annual catch in Indian River by weight. This was due principally to a landing of 30,325 pounds of shad in these months as well as a commercial catch of almost 12,000 pounds of weakfish in April.

4.7.5.2 Historical Record of Commercial Catch

Records of the commercial landings in Rehoboth and Indian River Bay have been maintained since 1984. Tables 4.7-12 and 4.7-13 present a comparison of annual finfish landings of species in Indian River and Rehoboth Bays since 1985. Note that although records of monthly collections were initiated in 1984, only a partial year's data is available for 1984.
Since 1984, when records of commercial landings of finfish was initiated, weakfish and bluefish have dominated the commercial catch of the Inland Bays. In 1991, the American shad comprised the largest component of the catch accounting for 43 percent of the total landings by weight. The dominance of shad in the commercial catch in 1991 represented the first time since landings data were collected for the bays that neither bluefish nor weakfish dominated the Inland Bays landings.

Although the total landings of shad increased significantly in 1991 over previous years in Delaware waters, shad, as well as bluefish and weakfish catch per unit effort (pounds per yard of gill net) declined. Cole and Miller (1991) point out that although the total landings for shad increased substantially, considerable additional effort was required. Moreover, weakfish and bluefish landings in Delaware waters still declined from 1990 levels even though effort increased.

As stated earlier, the abundance of fish in any year class or location may be controlled by a number of factors including, among others, climate, larval success, predation and fishing pressure.

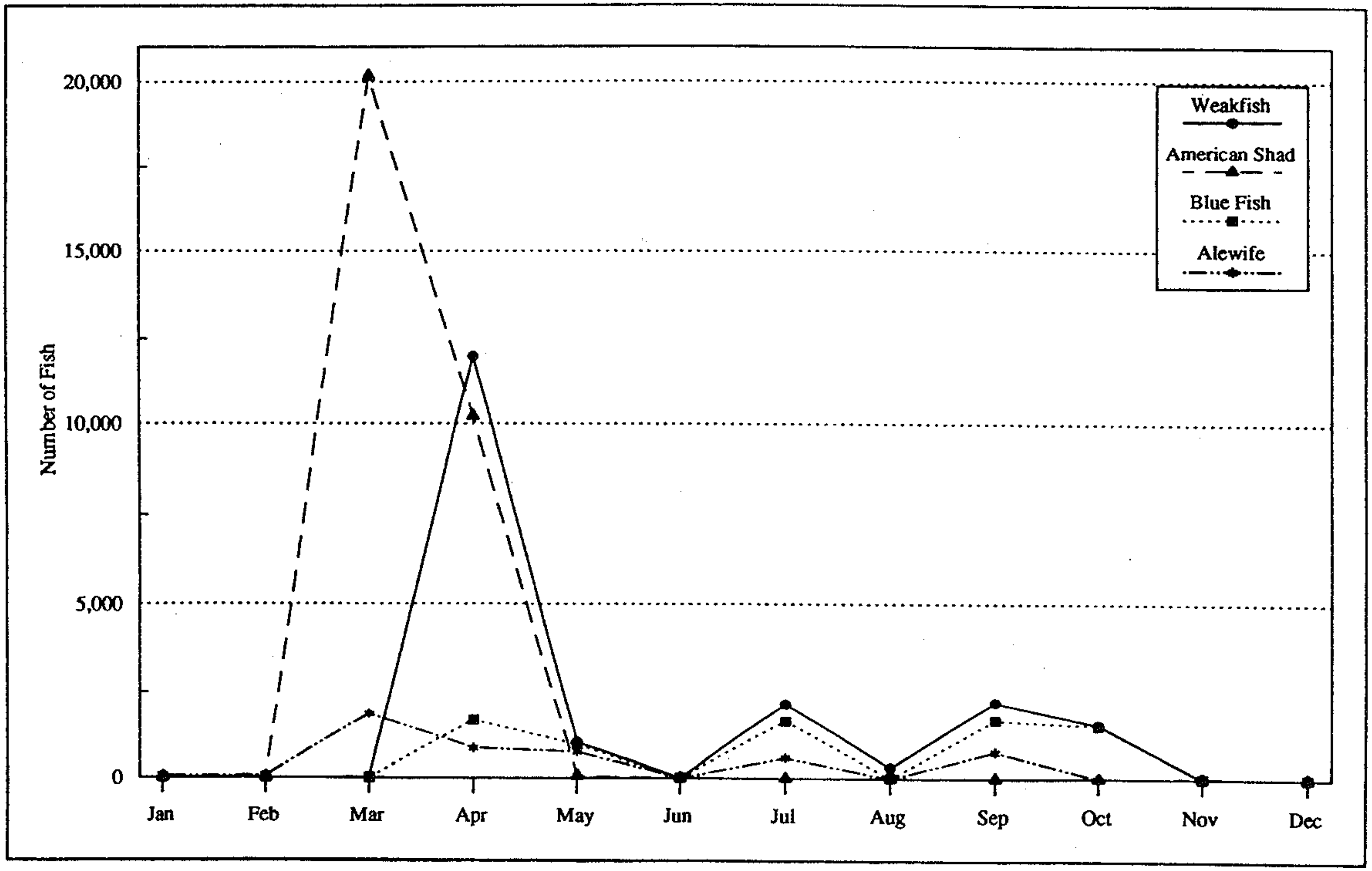


Figure 4.7-9
Monthly Commercial Landings for Principal Top Finfish Harvested from Indian River Estuary in 1991
Source of Data: DP&L, 1976

Fish43-D

Table 4.7-12
Comparison of Annual Landings (Pounds) of Finfish Species That Comprise 95 Percent of Rehoboth Bay Landings

Species	1985	1986	1987	1988	1989	1990	1991
American Shad	0	0	0	25	0	0	0
Weakfish	6,428	8,045	2,048	770	2,808	494	317
Bluefish	4,777	20,773	15,788	998	3,667	5,900	263
Menhaden	27	0	5,687	2,410	455	0	285
White Perch	12	0	140	0	25	0	0
Summer Flounder	0	0	0	17	0	0	11
Shark spp.	512	540	270	150	16	363	0
Spot	566	4,616	9,245	272	2,974	145	0
Alewife	0	0	0	0	0	0	0
Other	67	352[1]	140	0	423[1]	606[1]	0
Total Landing (lbs)	12,389	34,326	33,318	4,642	10,368	7,508	876

[1]Principally butterfish.

Data Source: Miller, (1985 through 1990)
Cole and Miller, 1991.

M-7-12

Table 4.7-13
Comparison of Annual Landings (Pounds) of Specific Species That Generally Comprise More Than 95 Percent of Indian River Estuary Landings

Species	1985	1986	1987	1988	1989	1990	1991
American Shad	42	7,375	69	66	6	80	30,391
Weakfish	7,426	7,071	1,477	4,516	2,667	2,319	19,105
Bluefish	6,520	8,868	1,914	8,170	5,699	3,621	7,343
Menhaden	NR	267	682	2,189	3,356	1,823	2,404
White Perch	55	11	20	35	29	11	1,034
Summer Flounder	155	473	46	1	1	0	361
Shark spp.	50	40	0	703	227	592	3,486
Spot	135	1,443	2,941	136	184	4	372
Alewife	5	502	369	185	1,195	28	4,848
Other	108	13	26	65	0	149	338
Total Landing (lbs)	14,496	26,063	7,544	16,066	13,364	8,627	69,682

NR - Not Reported.

Data Source: Miller, (1985 through 1990)
Cole and Miller, 1991

Water temperature appears to be a major determinant of the distribution and abundance of marine stocks in any given location. In addition, fishing pressure has also been shown to be a significant factor in determining population success. To supplement the discussion of trends in finfish, a brief discussion of the regional status of some of the key commercial and recreational species is presented. The sources of information for this discussion is the NOAA technical memoranda *Status of Fishery Resources Off the Northeastern United States for 1991* (NOAA, 1991a) and *Status of Fishery Resources Off the Southeastern United States for 1991* (NOAA, 1991b). The following is a brief account of the regional status of select finfish.

Winter Flounder

As previously noted, the winter flounder fishery of the Inland Bays was once an important recreational fishery especially in Indian River. Since the mid-1970's, the recreational catch appears to have declined substantially. Figure 4.7-10 shows the record of commercial landings, recreational catch, and spring survey index for winter flounder off southern New England and the middle Atlantic region. The Northeast Fisheries Center (NEFC) spring survey index indicates that the stock biomass has shown a general decline since about 1981. A mean catch of about 3 kg/tow was similar to the low levels recorded in the period of 1974-1976 in this region. According to NOAA (1991a), the continued decline in commercial landings since 1981 and the low spring survey indices in recent years suggest that landings will not increase in the future. However, it also points out that the local fluctuation in catches might be expected since fishing pressure is not uniform throughout the region. Nevertheless, NOAA concluded that on average, the winter flounder fishery of the mid-Atlantic region is overexploited. The winter flounder fishery is managed by the New England Fisheries Management Council's "Multispecies" Fisheries Management Plan.

Bluefish

As previously noted, bluefish and weakfish have typically dominated the commercial landings of the Inland Bays. Nevertheless, recent CPUE records indicate that bluefish landings are

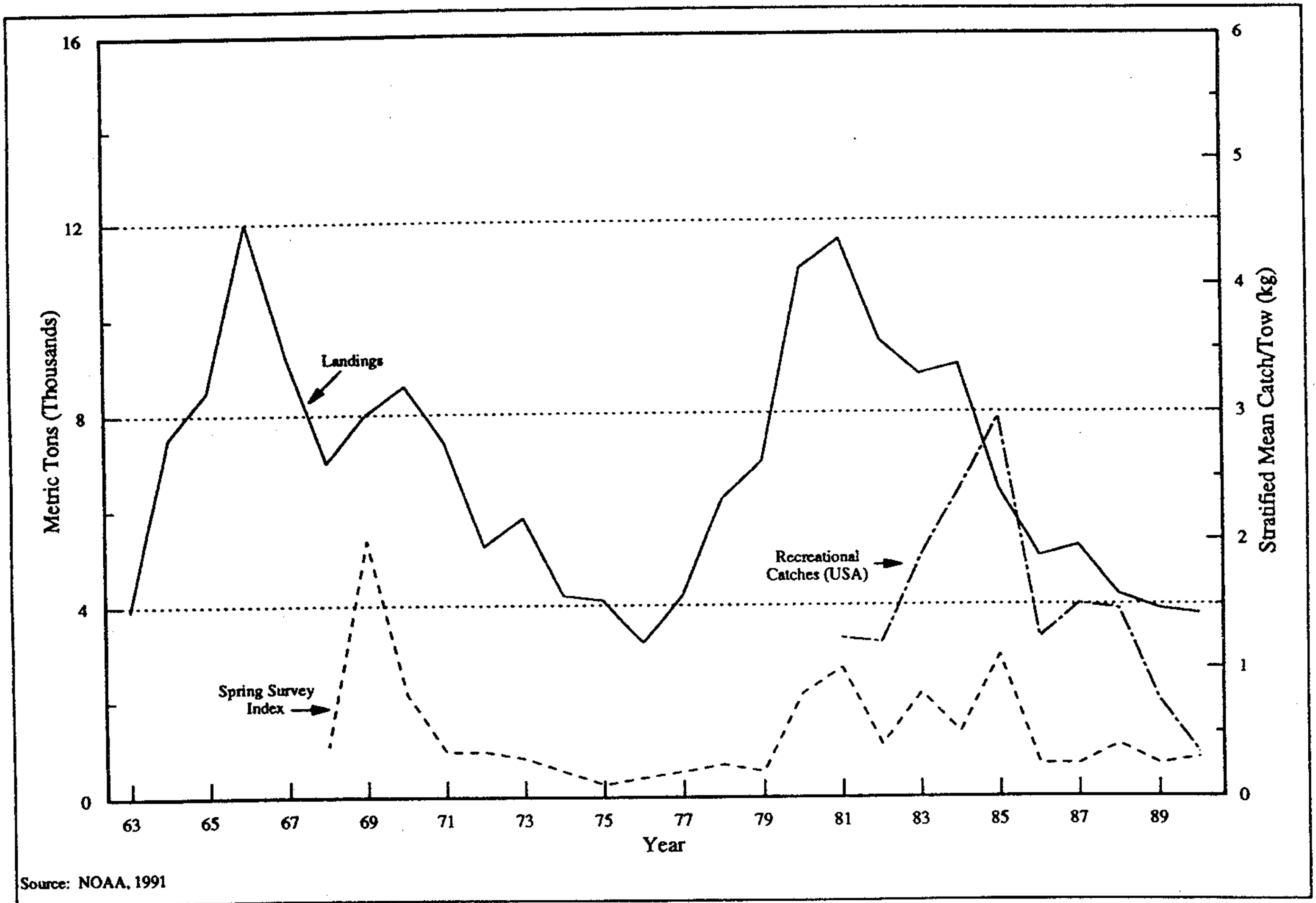


Figure 4.7-10
Winter Flounder
Southern New England-Middle Atlantic

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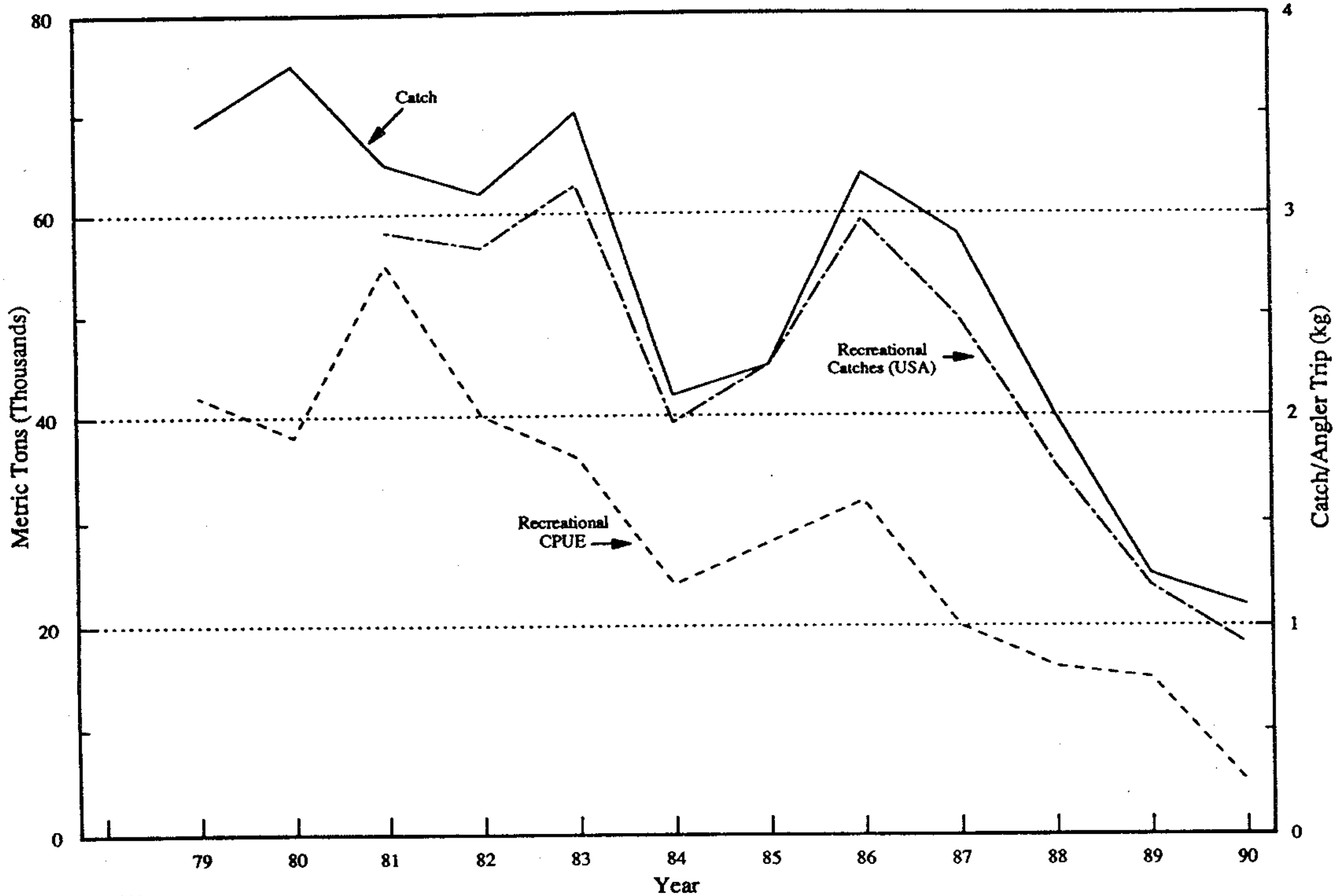
declining even though effort has increased (Cole and Miller, 1991). Bluefish are an important recreational and commercial fishery of the Delaware Inland Bays. Figure 4.7-11 shows the recreational catch per unit effect (catch per angler trip) and commercial landings of bluefish along the Atlantic Coast since 1979. As noted, both the commercial landings and recreational CPUE have declined substantially since the late 1970's. Based on total catch statistics, the recreational catch accounted for 74 percent of the total catch in 1990, down from historical percentages of 80 to 90 percent of total catch. Since 1981, recreational CPUE has declined from 1.49 fish/trip to 0.52 fish/trip. These data suggest that bluefish abundance has decreased substantially and that the regional stock is fully exploited (NOAA, 1991a). The bluefish fishery of the mid-Atlantic managed by the Mid-Atlantic Fishery Management Council and the Atlantic States Marine Fisheries Commission under the Bluefish Fishery Management Plan.

Weakfish

As noted, the weakfish is an important commercial and recreational fishery of the Inland Bays. In 1991, reported commercial landings for the Inland Bays was the highest on record, however, total CPUE suggests a decline in available weakfish stock not only in the Inland Bays but in other Delaware waters (Cole and Miller, 1991). Commercial and recreational landings of weakfish along the east coast are presented in Figure 4.7-12. Data from 1980 to 1990 show an overall decline in both the commercial and recreational catch along the east coast in the last 10 years (NOAA, 1991b).

Summer Flounder

Once an abundant species in the recreational fishery of the Inland Bays, a significant decline in abundance was noted around the mid-1970's based on previous studies. Figure 4.7-13 shows the commercial landings and the spring survey index in the mid-Atlantic region from 1963 to 1990. In addition, the recreational harvest since 1980 is also provided.



Source: NOAA, 1991

Figure 4.7-11
Bluefish
Atlantic Coast

Fish02-D18

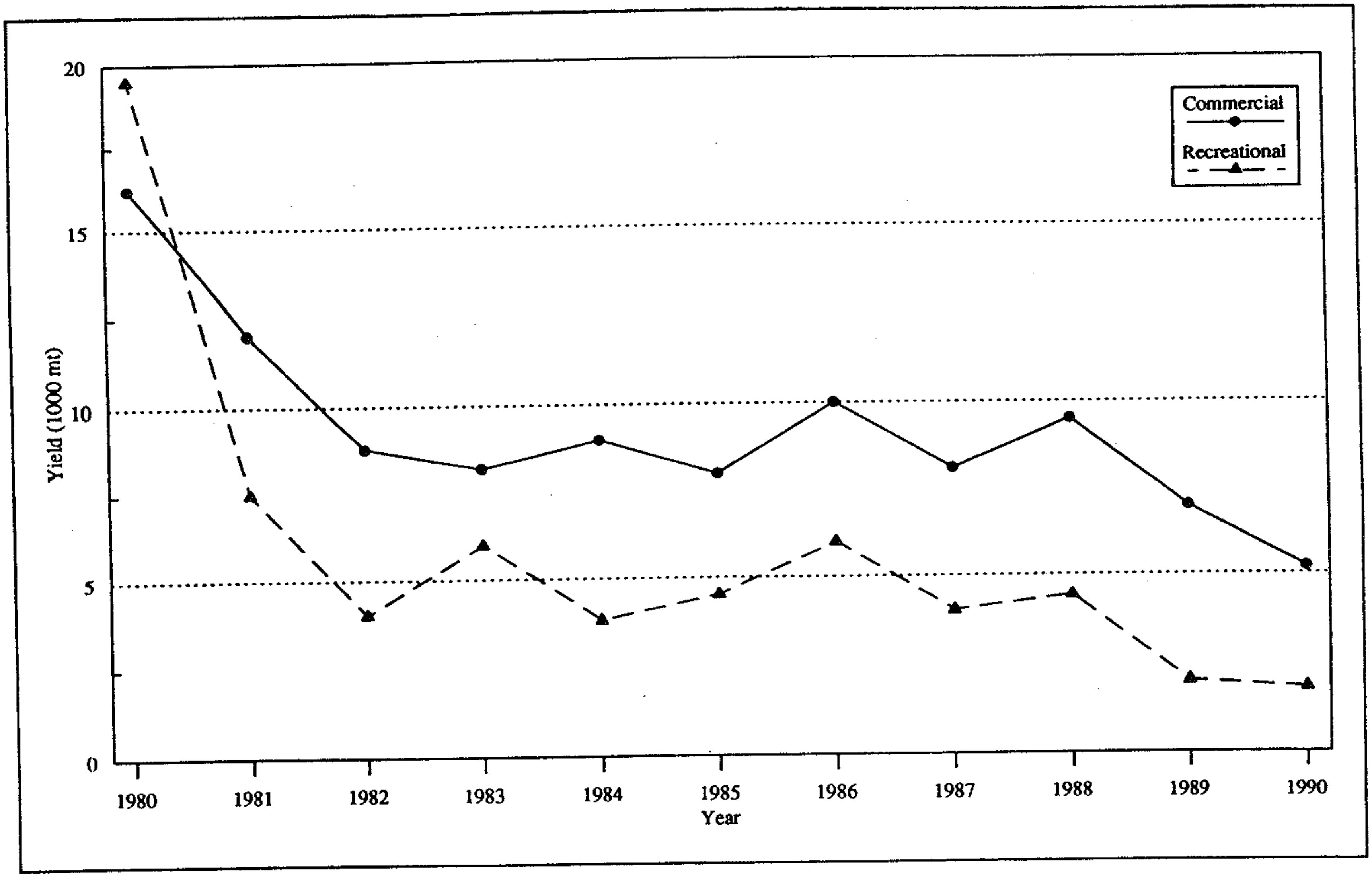


Figure 4.7-12
Commercial and Recreational Yields of Atlantic Weakfish
Source of Data: NOAA, 1990

Fish53-D19

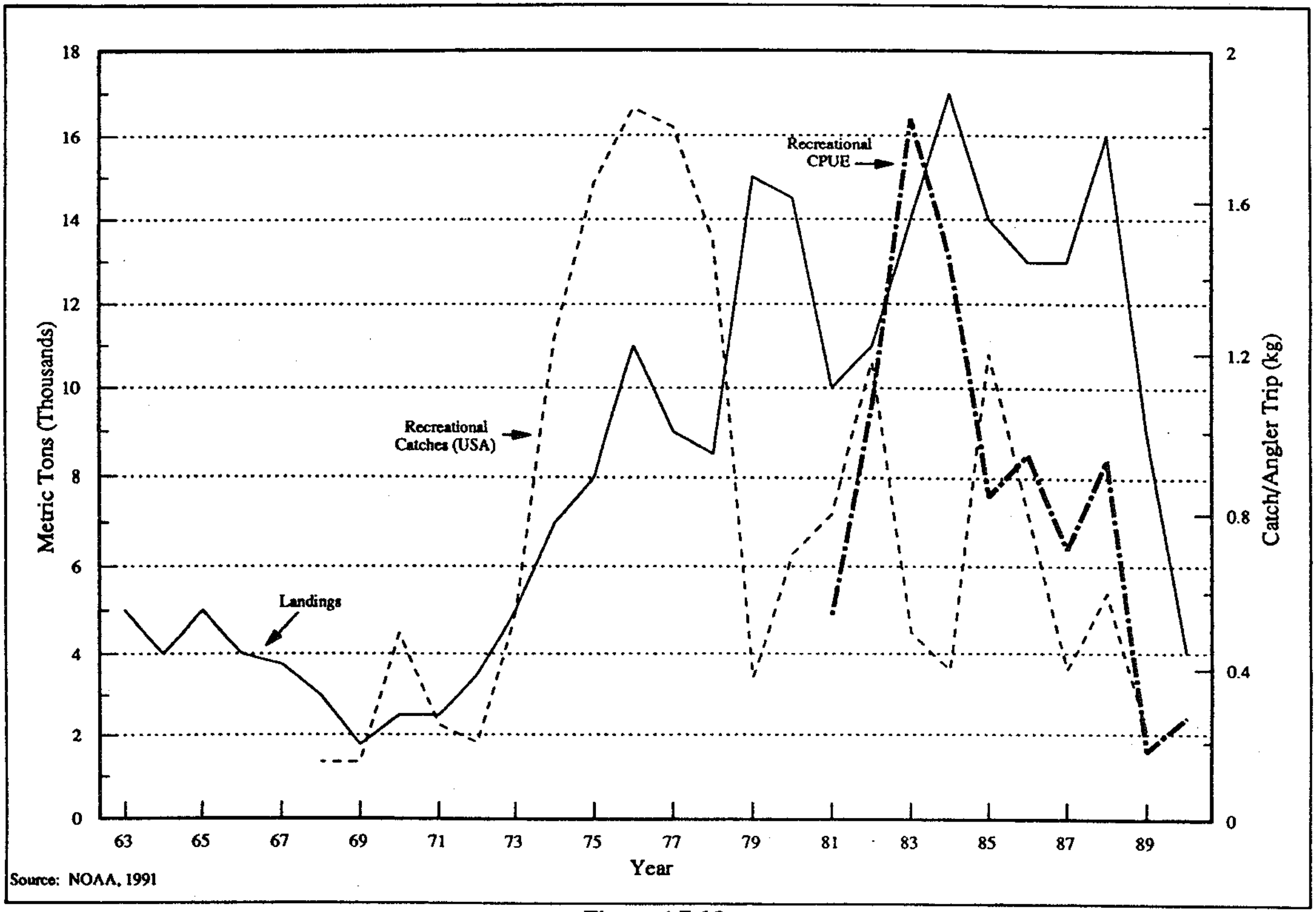


Figure 4.7-13
Summer Flounder
Georges Bank-Middle Atlantic

Fish03-D18

Based on the spring survey index, the stock biomass of summer flounder in the northeast region of the Atlantic Coast is currently at the lowest average level since the late 1960's and early 1970's. The spring survey index is a measure of abundance of individual species, a mean weight (kg) per tow, and represents the results of an annual trawling program conducted at several locations off the northeast Atlantic Coast. The index is used to assess the distribution and abundance of commercially important finfish stocks (NOAA, 1991a).

The principal gear used in the commercial fishing of summer flounder is the otter trawl. Recreational catches historically account for about 40 percent of the total catch. Current data and analyses indicate that the summer flounder stock is significantly overexploited. The summer flounder resource is managed by the Mid-Atlantic Fisheries Management Council under the Summer Flounder Fisheries Management Plan.