IV. FISHERIES

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CHAPTER IV: FISHERIES

CHAPTER IV: FIGURES and TABLES

A. INTRODUCTION

The fishery resources of the Albemarle-Pamlico (A/P) estuarine system are extremely important to the state and region. The estuary is not only a major fishing area, but also provides essential habitats for the production of fishery resources caught along the entire Atlantic Coast. Evidence of water quality degradation, alteration of the estuary's habitats, modification of riverine flow, and intense harvest effort raise serious concerns about the future of the area's important fishery stocks and fisheries.

The A/P system's habitats include one of the largest bodies of coastal freshwater in the country (Albemarle Sound), one of the most productive lagoonal estuaries in the country (Pamlico Sound), major anadromous fish spawning and nursery grounds, large seagrass meadows, vast expanses of adjacent wetlands (including peat pocosins), and nursery grounds for most of the economically important fishery species in the mid-Atlantic area. About 90% of North Carolina's commercial seafood catch (by weight) is in some way dependent on the vast, shallow sounds and the many embayments and tributaries around the sounds (Table IV-1). More than 60% of the recreational catch (by number) is also estuarine-dependent (Mumford and West 1989).

The fishery resources of the estuary can be classified according to life history strategies. The first are anadromous fishes, which spend the bulk of their lives in salt water, but return to freshwater streams to spawn. Such fish include the river herrings and shads (Alosa sp.), striped bass (Morone saxatilis), and sturgeons (Acipenser sp.). The second are resident species, which spend their entire lives in the estuary. This group includes finfish, such as white perch (M. americana) and catfish (Ictalurus sp.), as well as molluscan species such as hard clams (Mercenaria mercenaria) and oysters (Crassostrea virginica). The third are estuarine migratory species, the most economically important fishery resource, which generally spawn in the open ocean, around inlets, or near shore, but which recruit into the estuaries. Included in this group are spot (Leiostomus xanthurus), Atlantic menhaden (Brevoortia tyrannus), Atlantic croaker (Micropogonias undulatus), weakfish (Cynoscion regalis), flounders (Paralichthys lethostigma and P. dentatus), shrimp (Penaeus spp.), and blue crabs (Callinectes sapidus) (Figure IV-1). These species not only overwhelmingly dominate the fisheries in the estuary (approximately 80% of the commercial catch), but also emigrate to join important nearshore stocks which migrate seasonally along the Atlantic coast. It is for this group that the Albemarle-Pamlico estuarine system serves as a major nursery area for the entire Atlantic Coast.

The Albemarle-Pamlico estuarine system is not only an important habitat for the production of fishery resources, but is also a major fishing area. Recreational and commercial fishermen in the area use as wide a variety of gears and methods as the variety of species they seek. The area contains numerous fishing ports for the state's "highly migratory" fishing fleet. Commercial and recreational fishing and their associated industries have major economic impacts on the region (Street and McClees 1981).

Historically, fishing has been extremely important. Native Americans and, subsequently, European settlers in coastal North Carolina relied on fishing as a source of food and commerce. Early colonists took advantage of the abundant shad, herring, and striped bass runs in the spring and other finfish and shellfish year-round.

The A/P region's modern commercial and sport fisheries depend on variety. No single species is consistently available for harvest throughout the year, principally because of migratory habits related to sawning, feeding, and growth. Regulatory controls also limit the harvest of some species, such as striped bass and oysters, to certain seasons. Commercial fishermen utilize both movable and fixed gears. Otter trawls, oyster dredges, and long haul seines are the most important moveable gears. Common fixed gears include pound nets, gill nets, and crab pots. Recreational fishermen generally use hook-and-line gear. In North Carolina, however, recreational fishermen also use commercial gear, though in much

Table IV-1. Commercial Landings of Estuarine-dependent Finfish, Crustaceans, and Shellfish in North Carolina, 1986-1990, in Thousands of Pounds. (DMF Data)

Species	1986	1987	1988	1989	1990
Finfish					
River herring	6,814	3,195	4,191	1,491	1,158
Atlantic croaker	9,425	7,289	8,434	6,824	5,731
Flounder (summer, southern)	8,845	7,984	10,265	7,555	5,137
Atlantic Menhaden	66,378	55,499	73,716	66,756	71,647
Mullet	1,932	2,590	3,061	2,062	2,909
Weakfish and spotted seatrout	14,501	12,198	15,388	10,568	5,998
Spot	3,354	2,806	3,080	3,254	3,380
Striped bass	189	262	116	101	114
Others	9,888	9,151	11,372	7,957	7,824
Subtotal	121,326	100,974	129,622	106,568	103,898
Crustaceans					
Blue crab	23,755	32,424	35,604	34,725	38,002
Shrimp (heads on)	6,162	4,416	8,139	8,923	7,802
Subtotal	29,917	36,870	43,743	43,648	45,804
Shellfish (meats)					
Clams	1,356	1,207	940	1,295	1,334
Oysters	745	1,426	913	530	323
Bay scallops	306	155	39	84	62
Others	99	94	106	66	80
Subtotal	2,506	2,882	1,998	1,975	1,799
Total (estuarine-dependent)	153,749	140,726	175,363	152,191	151,501
Total (state-wide)	168,882	157,324	192,693	165,197	173,909
% estuarine-dependent	91.0	89.4	91.0	92.1	87.1

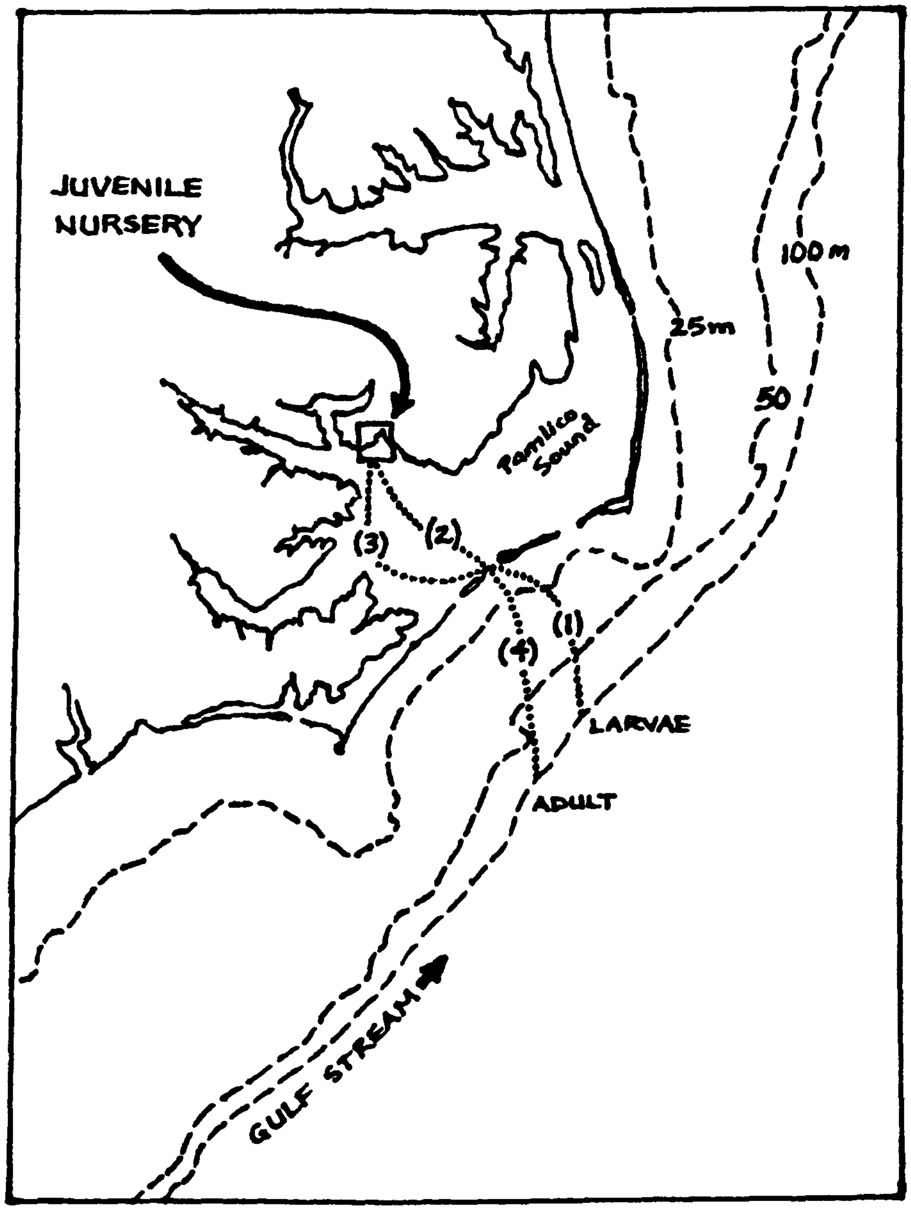


Fig. IV-1. Migration Patterns of Typical Fish Species in the Albemarle-Pamlico Estuarine System. (From Miller et al. 1984.)

1. Passive transport of larvae towards inlet (winter).
2. Wind-driven movement of juveniles towards nurseries (early spring).
3. Movement of juveniles from nurseries towards inlets (late summer).
4. Spawning migration of adults (late fall, early winter).

smaller quantities than commercial fishermen. Over half of the commercial vessel licenses sold annually by the North Carolina Division of Marine Fisheries (DMF) are issued for recreational use of commercial gear. Of the licenses which indicated that they used gill nets in 1988, most were recreational (DMF Unpublished Data). More than half of the licensed vessels using crab pots were recreational (DMF Unpublished Data). Several thousand fishermen pull small shrimp trawls for recreation.

A. 1. Available Data

A variety of data are available for evaluating trends in fisheries and the fishery resources. The DMF samples the catches of the major commercial fisheries (pound net, long haul, oceanic trawl and gill net, crab pot, and anadromous gill net fisheries) for species composition, size composition, age (for selected species), and fishing effort. Division personnel sample juvenile finfish, shrimp, and blue crabs in estuarine nursery areas to determine relative abundance and growth. Similar sampling is conducted for oysters and bay scallops (Argopecten irradians concentricus). A survey of the open waters of Pamlico Sound is conducted to gather data on relative abundance, distribution, and growth of species present. Anadromous fishes are sampled in the Albemarle Sound area.

Most DMF sampling programs, whose data are presented in this report, began in the early to mid-1970s. Sampling of planted oysters began in the mid-1970s, while sampling of wild oysters began in 1987 in the Pamlico Sound area. The sounds survey was also initiated in 1987. Sampling of the blue crab fisheries began in 1990.

Because of their long-term importance to commercial and recreational fishermen, the DMF considers certain species to be "target species". Biological sampling and analyses emphasize these species: three species of shrimp, oysters, bay scallops, Atlantic croaker, spot, weakfish, red drum, summer flounder, southern flounder, bluefish (Pomatomus saltatrix), blueback herring (Alosa aestivalis), alewife (A. pseudoharenaus), American shad (A. sapidussima), hickory shad (A. mediocsis), striped bass, Spanish mackerel (Scomberomorus maculatus), king mackerel (S. caralla), and spotted sea trout (C. nebulosis). All except king mackerel are principally riverine, estuarine, or near-shore ocean species. These relatively long-term programs have generally utilized standard methods and allow comparisons over time and area.

The longest fisheries database is that for commercial landings statistics; for North Carolina, it extends back to 1880. Commercial landings data are frequently used to indicate levels and trends in fisheries, primarily because they are the longest record available. However, landings data are influenced by many factors, such as market demand, price, fishing effort, weather, availability of alternate species, regulations, data collection procedures, as well as stock abundance. As a result, landings data should be viewed primarily as a very general indicator of the fisheries themselves, but not of the fish stocks. As such, the data can characterize the various fisheries and provide insight into the fishing trends relative to all of the various factors which influence the statistics. The present commercial fisheries statistics program in North Carolina is conducted cooperatively by DMF and the National Marine Fisheries Service (NMFS) and provides data on landings, value, fishing gear, and water body of harvest.

Unfortunately, no long term data exist on the recreational fisheries of the area. Recreational fishery statistics were collected by the NMFS from 1979 to 1986 to characterize regional and national sport fisheries, but they have very limited applicability to North Carolina alone due to low sample sizes. In 1987, DMF began a cooperative program with the NMFS to increase the amount and reliability of recreational data collected in order to characterize the North Carolina recreational fisheries. The program, which gathers catch and biological data, uses the same methodology as the national program and provides statistically reliable estimates of catch of major species for the entire state. Modifications to the survey were made to obtain species composition and average catch rates by water bodies, which are comparable to the reported commercial landings, however, the data cannot be extrapolated to total estimates for the A/P region.

In addition to the monitoring programs noted above, numerous short term projects have been conducted, directed at certain species or specific areas and habitats. Short term projects rarely provide information which can be compared with other data to detect trends over time.

The principal weaknesses in the existing data gathering programs are the general brevity of most databases, lack of consistent sampling for some important species (such as hard clams), incomplete sampling for other species (blue crabs, for example), and lack of effort data for many fisheries.

Two kinds of effort data are generally recognized: effective effort and nominal effort. Data on effective effort, a measure of the actual mortality effects of a given unit of fishing effort on a stock of fish, are very rare. To determine effective effort, detailed biological and fisheries data are needed over an extended period of time. Information on vessels, and gear are usually required (vessel length, horsepower, net specifications, and other parameters). Nominal effort is simply a measure of some selected unit, such as number of trips or days, regardless of vessel or gear characteristics. For example, in the Atlantic menhaden fishery, if a purse seine vessel lands at least one catch in a given week, one unit of effort is recorded. Thus, a small vessel landing a small catch is accorded the same unit of effort as a large vessel which lands several large catches during the same week (Atlantic Menhaden Management Board 1981). The DMF collects nominal effort for several important fisheries: the Chowan River pound nets, the winter trawl fishery, the shrimp trawl fishery, the Pamlico Sound summer pound net fishery, and the long haul seine fishery.

A. 2. General Trends

Commercial landings data provide the best available information to reflect possible trends in fisheries. An examination of total commercial landings data for North Carolina indicates, however, that the five-year period with the greatest recorded landings was 1978-1982, with average landings of 357 million pounds, and a peak of 432 million pounds, the all-time record (Street 1988). Landings for the Albemarle-Pamlico-Core Sound area also rose during this period, reaching their highest level in 1980 (DMF Unpublished Data). During the late 1970s and early 1980s, commercial landings of a number of species (or species groups) taken in the A/P area established all-time records or reached levels not seen for many years (Table IV-2). Such species included Atlantic menhaden, blue crabs, flounder, weakfish, Atlantic croaker, white perch, hard clams, and shrimp. Biological data, such as size and age composition, which has been anecdotal since the late 1970s, and anecdotal information from fishermen strongly indicate that the elevated harvests during this period reflected actual increased abundance relative to previous years. Why the apparent abundance of all those species increased at the same time, however, is unknown. Since that period, harvests have declined, although they generally remain above those of the years immediately preceding the peak (Table IV-2).

A. 3. Water Quality Concerns

As in most estuaries, the high productivity of the Albemarle-Pamlico system is a result of dynamic interactions of chemical, physical, and biological characteristics. In recent years much attention has been focused on whether water quality changes in the Albemarle-Pamlico estuarine system are threatening or have already negatively affected fisheries' productivity. Some of the estuary's problems which are water quality-associated and concern fisheries' productivity include: 1) fish and shellfish diseases, 2) algal blooms, 3) fish kills, 4) anoxia and hypoxia, 5) loss of critical habitats, 6) freshwater discharge, 7) fecal contamination resulting in shellfishing closures, and 8) toxic substances.

Fish and shellfish diseases are a significant problem in the Albemarle-Pamlico estuarine system. During the 1970s, large numbers of freshwater finfish species in the western portions of Albemarle

Table IV-2. Commercial Fisheries Landings in Albemarle, Pamlico, and Core Sound Areas, NC, 1972-1990 (in thousands of pounds). (Data do not include menhaden landed by purse seine). (DMF Data)

Year	Albemarle Sound area	Pamlico Sound area	Core Sound area	Total	Percent state total
1972	16,205	13,746	6,881	36,832	44.3
1973	12,734	14,350	8,845	35,929	56.6
1974	12,270	17,835	12,480	42,585	56.9
1975	11,326	20,611	10,700	42,637	54.7
1976	11,635	22,383	6,555	40,573	47.4
1977	13,385	25,678	6,612	45,675	49.0
1978	13,107	36,383	8,559	58,049	54.1
1979	12,906	45,651	10,869	69,426	51.0
1980	13,755	62,161	13,633	89,549	56.2
1981	12,506	50,227	8,579	71,312	58.2
1982	20,657	49,478	9,159	79,294	65.6
1983	16,633	41,542	9,507	67,682	61.7
1984	13,916	41,796	10,166	65,878	55.1
1985	22,005	42,319	11,392	75,716	64.6
1986	19,050	29,568	8,198	56,816	55.4
1987	18,439	33,645	7,336	59,420	58.4
1988	14,142	42,743	8,698	65,583	55.6
1989	15,489	37,911	7,442	60,842	61.8
1990	11,495	45,659	8,022	65,176	66.0
Mean	14,824	35,457	9,139	59,418	55.2
% state total	15.3	35.5	9.3		

Sound were affected by red sore disease (NC Division of Environmental Management et al. 1975, 1976). Approximately 50% of all commercially harvested finfish were observed with red sore disease during peak occurrences. While red sore disease subsided in Albemarle Sound in the 1980s, a multitude of ulcer-diseases has occurred, principally in the Pamlico River, but also in other areas (Noga and Dykstra 1986; Noga et al.1991; Levine et al. 1990(a)). Most of the commercially important estuarine fish species utilizing the Pamlico River, including Atlantic croaker, spot, weakfish, southern flounder, red drum, spotted seatrout, and Atlantic menhaden have been observed with lesions. The most prevalent disease is ulcerative mycosis, a fungal infection primarily affecting Atlantic menhaden (Noga and Dykstra 1986; Dykstra et al. 1986). As many as 80-100% of the Atlantic menhaden in random cast net samples have had ulcerative mycosis (Levine et al. 1990(b)). Recently, an aggressive shell disease has been noted on blue crabs in the Pamlico River (McKenna et al. 1990; Engel and Noga 1989).

Diseases can affect fisheries productivity by several means. The stocks of affected species can be depleted by acute mortalities caused by disease; however, acute mortalities usually have to be of enormous magnitude to be detected in the fish population (Vaughan et al. 1986). Of greater concern is the effect on fish stocks of the chronic recurrence of disease which induces continual mortalities (Merriner and Vaughan 1987). Diseases also affect commercial fisheries' production indirectly by making infected individuals unmarketable; examples include the various ulcer-associated diseases on estuarine species recently documented in the Pamlico River. Diseases, especially those involving gross lesions, can also indirectly negatively affect recreational production by decreasing the attractiveness of fishery areas where fish disease is prevalent.

Perhaps most important is the implication that the fish and shellfish diseases are indicators of stressed environmental conditions in the Albemarle-Pamlico estuarine system. Sindermann (1983) considered skin ulcers on fish as one of the best pathological indicators of water quality stress. Environmental stress could sub-lethally affect vital life history characteristics of fish in the estuary, such as reproduction and growth. If the multitude of recently discovered fish and shellfish diseases do indicate the deterioration of water quality, the effects on fish stocks and production will be difficult to assess due to the chronic and usually cumulative nature of such effects and the natural variability of fish stocks.

Algal blooms can also affect utilization of the estuary by fish and shellfish in several ways. Extremely dense concentrations of algae can deplete dissolved oxygen from estuarine waters during periods when photosynthesis is reduced, such as at night. Also, some species of algae release toxins can bioaccumulate in, and may kill, fish and shellfish (Paerl 1987). Algal blooms are becoming more of an environmental concern; the number of events which have been documented in North Carolina has increased from 16 in 1984 to 87 in 1989 (NC Division of Environmental Management 1990). The number of documented algal blooms in the Albemarle-Pamlico estuarine system has increased since 1984, especially in the estuarine waters of the Tar-Pamlico River, where 90 blooms were recorded from 1986 to 1989. No blooms were reported in the Tar-Pamlico during 1984, approximately five were noted in 1985, and in 1989 approximately 35 algal blooms were noted in the lower Tar-Pamlico River. Stanley (1988) found that levels of chlorophyll a, an indicator of algal abundance, increased in the middle and upper Pamlico River from 1967 to 1986. Nutrient enrichment of North Carolina's waters is thought to be responsible for the increasing number of algae blooms (Rader In Press).

Algal blooms in the Tar-Pamlico River are frequently associated with fish kills (NC Division of Environmental Management 1989). The effects of such kills on the fishery resources are usually acute and very difficult to discern because of the natural variability of fish and shellfish populations. Toxins produced from algal blooms have the potential to kill fish, and so may have contributed to fish kills in the Tar-Pamlico River, but no studies have been able to conclusively isolate algal toxins as the causative agents in fish kills in the A/P region (Jay Sauber, NC DEM, per. comm.). Besides initiating acute events such as fish kills, algal blooms can affect fisheries production in subtle, chronic ways. Modification of the algae community in the Roanoke River is suspected as a reason for the decline of striped bass in

Albemarle Sound (Rulifson et al. 1986). Changes in phytoplankton species compositions may have affected zooplankton compositions and impacted the feeding ecology of larval striped bass. Changes in algae population dynamics are also suspected of negatively affecting the larval feeding ecology of fish in the Neuse River (Paerl 1987).

One of the most dramatic examples of how an algal bloom can impact fishery resources is the red tide bloom observed in the near-shore waters of North Carolina during 1987 (Tester et al. 1988; Rader In Press). Large numbers of bay scallops were killed in Core and Bogue sounds (Summerson and Peterson 1990) and hundreds of square miles of estuarine waters were closed to shellfishing due to the large bloom of a dinoflagellate (Ptychodiscus brevis). The red tide had severe economic and social impacts on the fishing industry in Bogue and Core sounds (Rader In Press).

Another major environmental concern of the fishing industry and fishery managers is the increasing occurrence of fish and crab kills in the Albemarle-Pamlico estuarine system, especially in the Tar-Pamlico River. A total of 87 fish and crab kills were reported in the Tar-Pamlico River between 1966 and 1984 (Rader et al. 1987). From 1985 to 1987 a total of 31 fish and crab kills were documented by the NC Division of Environmental Management (DEM) in the Tar-Pamlico. In 1988, DEM and DMF received 40 reports of fish/crab kills in the Tar-Pamlico, while in 1989, 69 reports of fish kills were received. Most of the documented kills have been attributed to hypoxia caused by algal blooms or salinity stratification and occur during warmer months in localized areas. In 1988 and 1989, however, the DEM and DMF documented extensive continuous Atlantic menhaden kills occurring over 10 to 15 miles of the Tar-Pamlico River during June of each year. These kills were characterized by high proportions (>90%) of Atlantic menhaden with ulcerative mycosis during periods with adequate oxygen in the water.

Fish kills can potentially affect fish stocks by inducing acute mortalities; however, as with diseases, the mortalities have to be of enormous magnitude to detect an effect on fish stocks. More important is the potential chronic effect of recurring fish kills and the apparent increase in the number of kills in the Albemarle-Pamlico estuarine system.

Another water quality problem that is related to fisheries production in the Albemarle-Pamlico estuarine system is hypoxia (low oxygen) and anoxia (no oxygen). Hypoxia and anoxia are caused by a combination of factors including freshwater runoff (with its accompanying organic matter), water column stratification, biological processes which remove oxygen, and physical processes such as wind and temperature (Davis et al. 1978; Rader et al. 1987). Stanley (1985) reviewed data from 42 areas in North Carolina, South Carolina, and Georgia, of which 23 regions had sufficient data to assess levels of oxygen depletion and eutrophication. Six of the 23 areas were found to experience substantial hypoxia and anoxia; 3 of those 6 were in the Albemarle-Pamlico estuarine system (Chowan, Neuse, and Pamlico rivers).

Hypoxia and anoxia are of concern to fishery managers and to commercial and sport fishermen because such conditions are frequently responsible for fish and crab kills in the estuaries. Low oxygen conditions often kill substantial numbers of blue crabs captured in crab pots, thereby affecting commercial fishermen who harvest with such gear. In estuaries where hypoxia is common, fishermen have to modify fishing techniques in response to the low oxygen conditions. One response is to move crab pots to shallower waters where oxygen concentration is usually higher, another is to fish the pots more frequently. Hypoxia may also cause substantial mortalities of commercially valuable benthic communities such as oysters. Hypoxia can contribute to changes in fisheries ecology, such as in the Neuse River, where low oxygen conditions appear to encourage early emigration of juvenile fish (Hester and Copeland 1975). Low oxygen is one of the primary factors affecting the distribution of benthic organisms in the Pamlico River (Tenore 1970). Hypoxia is suspected of contributing to the decline of striped bass in Chesapeake Bay (Price et al. 1985), the decline of American shad in the Hudson River (Talbot 1954), and possibly the variation of shrimp landings in the Gulf of Mexico (Renaud 1985).

Major concerns exist as to whether hypoxic events in the Albemarle-Pamlico estuarine system are becoming more severe as a result of changing temporal and spatial trends, such as were noted in Chesapeake Bay by Officer et al. (1984). A major hypoxic event occurred in August 1985, when low oxygen levels were recorded for a 100-square-mile area from New Bern, down the Neuse River, out into Pamlico Sound, and up the Pamlico River almost to Washington (DMF Unpublished Data).

The loss of critical fish and shellfish habitats as a result of water quality changes has also affected fishery resources in the Albemarle-Pamlico estuarine system. Rader et al. (1987) hypothesized that one of the major contributors to apparent declines in fisheries production in the lower Pamlico River and tributaries of Pamlico Sound is the significant increase in freshwater flow into primary nursery areas. The increased freshwater discharges are a result of large-scale land clearing and draining for agricultural purposes around the Albemarle-Pamlico estuarine system (Skaggs et al. 1980). Unstable salinity patterns in nursery areas resulting from freshwater discharges have negatively affected utilization of these areas by economically important juvenile pinaeid shrimp and, likely, juvenile finfish (Pate and Jones 1981). Several coastal tributaries in the Albemarle-Pamlico estuarine system have shown a net decrease in salinity over time which may be due to alteration of flow regimes (Sholar 1980; Phillips 1982). Concomitant with the decreased salinities has been a downstream displacement of oyster beds in the Pungo and Pamlico rivers (Sholar 1980). Changes in flow regimes also have affected striped bass spawning success and critical nursery areas in the Roanoke River (Manooch and Rulifson 1989).

Loss of estuarine submerged aquatic vegetation beds in tributaries of the Albemarle-Pamlico estuarine system greatly concerns fishery managers. These beds provide critical nursery habitat for many estuarine species. Historically, submerged vegetation beds were very common in tributaries of the Albemarle-Pamlico estuarine system, especially the Tar-Pamlico River (Davis and Brinson 1976). The loss of valuable grass beds in parts of Albemarle Sound and the western tributaries of Pamlico Sound is thought to be related to changes in water quality (Rader In Press), as has been noted in Chesapeake Bay (Orth and Moore 1984).

Closures of productive shellfishing waters due to probable contamination with fecal organisms, as indicated by the presence of fecal coliform bacteria, also merit the concern of resource managers in the Albemarle-Pamlico estuarine system. The pollution and closures do not affect the organisms, just their use by man. When open for harvest, shellfish waters provide oysters and clams for consumption as very valuable raw products. The total amount of estuarine acreage permanently closed to shellfishing in North Carolina generally remained constant from 1980 to 1989 (approximately 320,000 acres), however, closures increased to approximately 370,000 acres in 1990 and 1991. Decreases in permanent closures between 1982 and 1989 (due primarily to improvements in waste water treatment plants) seem to have been balanced by increases in temporary stormwater-related closures. Most closed areas are outside the A/P study area, but Core and Bogue Sounds and several small embayments are affected. In the A/P Study area, approximately 36,000 acres are closed to the harvest of shellfish. Roughly another 15,000 acres in the Study area are subject to temporary closures due to contaminated stormwater runoff, an indication of continued localized water quality degradation. (These areas have been closed temporarily at least 10 times in the past 5 years.)

Temporary closures since 1980 have increased (G. Gilbert, Shellfish Sanitation, pers. comm.). The closures related to runoff from agriculture and urban/residential development have increased since 1980 (Rader In Press). Closures to shellfish harvest due to marina developments have also increased (G. Gilbert, Shellfish Sanitation, pers. comm.). Under present management guidelines, as development expands and the coastal plain becomes more populous, the amount of shellfishing areas closed to fecal contamination will likely increase. As of July 1989, in the counties surrounding the Albemarle-Pamlico estuarine system, the acreage of closed shellfishing waters that have historically supported shellfish harvesting are: Dare County = 15,200 acres (3% of the total estuarine acreage); Hyde County = 2,600 (<1%); Beaufort County = 42,900 (60%); Pamlico County = 16,500 (12%); Craven County = 19,800 (70%), and Carteret County = 7,400 (2%) (Shellfish Sanitation Branch Unpublished Data).

A final major water quality concern associated with fisheries production in the Albemarle-Pamlico estuarine system is the discharge of toxic substances. Toxicants are discharged into the Albemarle-Pamlico from a variety of sources, both point and nonpoint. Point sources include industrial complexes and municipal wastewater treatment facilities, while examples of nonpoint sources are agricultural and silvicultural lands.

Relatively high metal concentrations have been found in the sediments of tributaries of the Albemarle-Pamlico estuarine system which receive both point discharges and heavy agricultural runoff (S. Riggs et al. 1989). The highest use of pesticides per unit of cropland for any estuarine drainage area in the United States occurs in the Albemarle Sound area (Pait et al. 1989). Pamlico Sound has the fifth highest pesticide use per unit of cropland of all estuarine drainage areas in the United States. Pesticides have been found in both the Tar-Pamlico and Neuse rivers (North Carolina Division of Environmental Management 1986). DDT, chlordane, lindane, and PCPs were found in fish tissue at several locations in the Neuse and Tar Rivers; however, the levels found were determined to present no problems in theses systems. Significant quantities of dioxin have been found in fish near industrial discharges located along one tributary of Albemarle Sound and an advisory concerning fish consumption was issued by the DEM in 1990 and 1991.

Toxins may affect fisheries production both directly by impacting fish stocks and indirectly through impacts on the aquatic environment. Toxins can kill fish acutely or chronically through deleterious effects on basic life history functions, such as reproduction and feeding. Lipophilic toxins, for example, would be expected to concentrate in egg tissue and so could be toxic to early developmental stages, yet not be hazardous at such concentrations to larger individuals. High levels of toxins in fish can make them unmarketable. Toxins are thought to cause environmental stress which may result in tumors and ulcerative diseases in fish (Malins et al. 1984). Toxins also can have sub-lethal effects on fish such as impeded growth (Sindermann 1979).

The potential effects of human-related environmental factors on the fishery resources of the Albemarle-Pamlico estuarine system merit concern. Similar concerns have been examined for several finfish resources along the Atlantic Coast (Schaaf et al. 1987; Summers et al. 1987; Polgar et al. 1985). The ability to distinguish the effects of individual anthropogenic activities will be difficult due to the large variability of fish stock abundance and the migratory nature of most economically valuable estuarine fishes (Schaaf et al. 1987). Efforts should begin with obtaining better estimates of fish abundance and directing research efforts towards some of the major water quality concerns.

B. CRITICAL FISHERIES HABITATS

The productive fisheries habitats of the Albemarle-Pamlico estuarine system provide fishery resources not only for this estuarine system but for other areas of North Carolina and the Atlantic Coast as well. Although all areas in the estuarine system are important for overall fisheries production, five general habitat types are especially critical for fisheries production. These habitats include: (1) estuarine nursery areas, (2) anadromous fish areas, (3) shellfish areas, (4) submerged aquatic vegetation beds (SAV), and (5) wetlands. Each habitat contributes uniquely to overall fish production, and each is a critical component of the estuarine complex as a whole. In addition, the sounds themselves are extremely important to the overall fishery production.

B. 1. Estuarine Nursery Areas

Nursery areas are those areas in which juvenile development occurs. The entire estuarine system is a major nursery area for many economically important species. Though virtually every portion of the estuarine system serves as a nursery area for some species, two special categories of estuarine nursery areas are officially recognized -- primary and secondary nursery areas.

Estuarine primary nursery areas are generally located in the upper portions of the tributaries and in embayments around the sounds and rivers. These areas are usually shallow, bordered by marsh, and have soft, detritus-rich mud bottoms. Larvae typically arrive in these areas from oceanic or near-inlet spawning grounds throughout the year; spawning times depend on individual species' life histories, however, most species enter nursery areas during the winter and spring. Larval transport mechanisms in the sound are generally believed to be related to wind-induced tides and currents combined with larval behavior (Miller et al. 1984). Primary nursery area utilization for most species lasts through the early summer; by mid-summer most winter/spring-spawned organisms are large enough to emigrate to the secondary nursery areas. Primary nursery areas in North Carolina were first defined and identified by the NC Marine Fisheries Commission (MFC) regulations in 1977. Approximately 19,000 acres of primary areas have been defined and officially designated in the Albemarle-Pamlico estuarine system. The ten most abundant species occurring in primary nursery areas of the A/P Study area in descending order of abundance in 1988 were: spot, bay anchovy (Anchoa mitchilli), Atlantic croaker, pinfish (Lagodon rhomboides), brown shrimp (Penaus aztecus), Atlantic menhaden, blue crab, pink shrimp (P. duorarum), pigfish (Orthopristis chrysoptera), and silver perch (Bairdiella chrysoura). Table IV-3 shows the species composition in primary nursery areas as determined by the DMF estuarine trawl survey during 1988. Figure IV-2 shows the legally adopted primary nursery areas of the A/P Study area. Numerous fisheries surveys have been conducted in the estuarine system; many were aimed specifically at documenting the organisms which utilize the nursery areas (Tagatz and Dudley 1961; Turner and Johnson 1973; Spitsbergen and Wolff 1974; Hester and Copeland 1975; Purvis 1976; Wolff 1976; Carpenter 1979; Ross and Carpenter 1980; Ross and Carpenter 1983; Currin et al. 1984; Ross and Epperly 1986; Hettler 1989; and Noble and Monroe 1991). The majority of the primary nursery areas in the A/P Study area, especially those in mesohaline zones, are characterized by tremendous numbers of individuals, but relatively low finfish/crustacean species diversity.

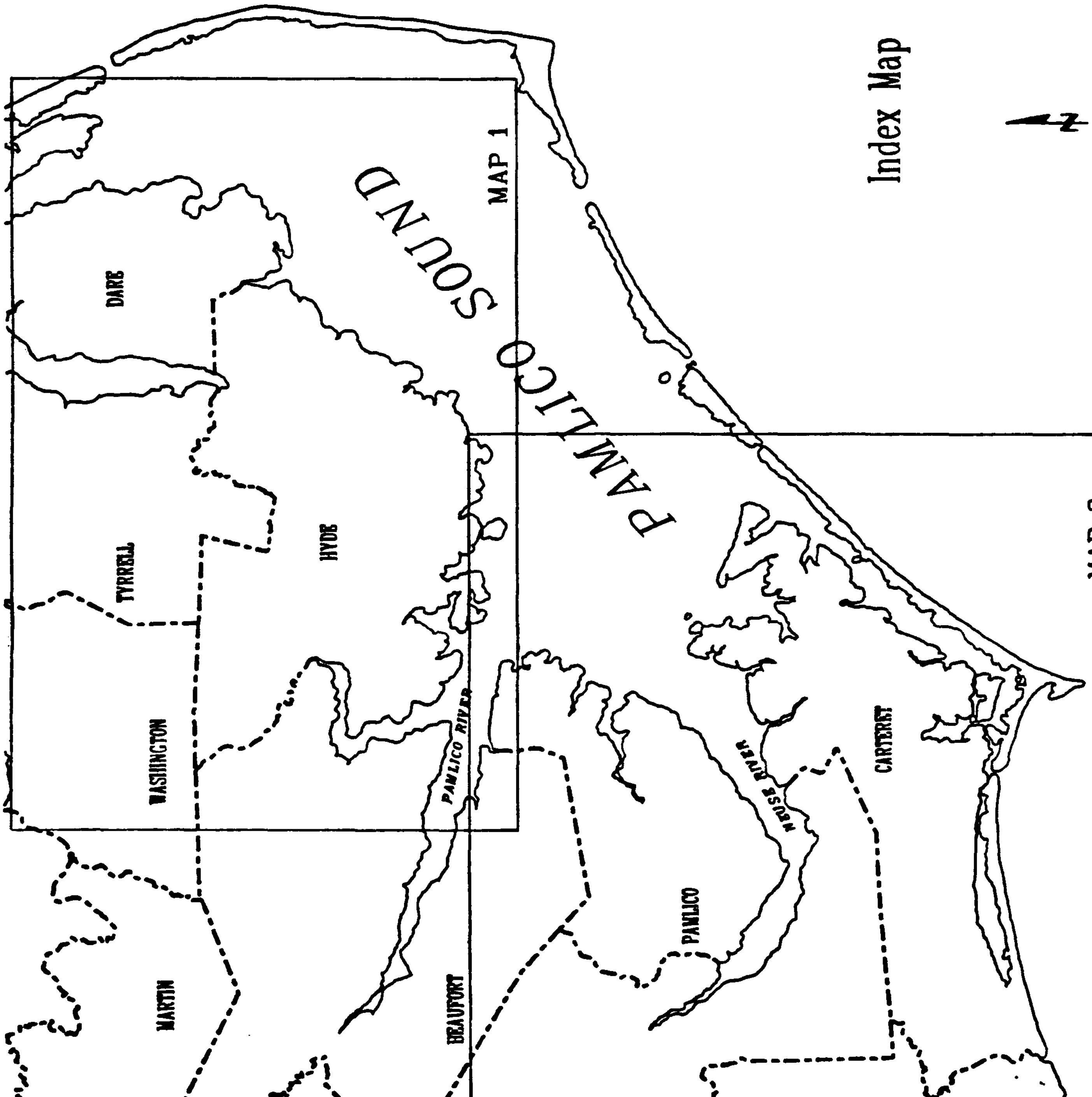
Those habitats immediately downstream from primary nursery areas are considered to be secondary nursery areas. Secondary nursery areas are legally designated in a manner similar to primary nursery areas and are also shown in Figure IV-2. They are generally larger, deeper bodies of water which contain great numbers of mixed sizes of organisms. Most juvenile organisms leave the primary nursery areas during the summer, occupying the secondary nursery areas until they migrate off-shore with declining temperatures in the fall. The species composition in the secondary nursery areas is similar to that of the primary nursery areas. The ten most abundant species noted in trawl surveys during 1988 in the A/P Study area were (in order of abundance): spot, bay anchovy, Atlantic croaker, blue crab, brown shrimp, shore shrimp (Palaemonetes spp.), Atlantic menhaden, silver perch, southern flounder, and pinfish (Table IV-4). In addition, larger adult fish are usually found in the secondary areas.

Table IV-3. Species composition of primary nursery area trawl survey, Albemarle-Pamlico estuary, 1989 (NC Division of Marine Fisheries).

Common name	Species	Number	Pct. Total
Spot	Leiostomus xanthurus	70,060	47.6
Bay anchovy	Anchoa mitchilli	39,604	29.6
Atlantic menhaden	Brevoortia tyrannus	8,212	5.6
Atlantic croaker	Micropogonias undulatus	6,137	4.5
Brown shrimp	Penaeus aztecus	6,124	4.2
Pinfish	Lagodon rhomboides	3,750	2.5
Blue crab	Callinectes sapidus	3,424	2.3
Silver perch	Bairdiella chrysoura	1,179	0.8
Southern flounder	Paralichthys lethostigma	1,050	0.7
Pigfish	Orthopristis chrysoptera	1,027	0.7
Others		6,719	4.2
Total		147,286	100.0

Table IV-4. Species composition of secondary nursery area trawl survey, Albemarle-Pamlico Estuaries, 1989 (NC Division of Marine Fisheries).

Common name	Species	Number	Pct. Total
Spot	Leiostomus xanthurus	145,995	48.5
Bay anchovy	Anchoa mitchilli	83,666	27.8
Atlantic croaker	Micropogonias undulatus	29,266	9.7
Blue crab	Callinectes sapidus	14,211	4.7
Brown shrimp	Penaeus aztecus	10,908	3.6
Atlantic menhaden	Brevoortia tyrannus	4,089	1.4
Silver perch	Bairdiella chrysoura	2,111	0.7
Weakfish	Cynoscion regalis	1,657	0.5
Southern flounder	Paralichthys lethostigma	1,540	0.5
Pinfish	Lagodon rhomboides	1,025	0.3
Others		6,617	2.2
Total		301,085	100.0


Index Map
MAP 1
MAP 2
PAMLICO SOUND
DARE
TYRRELL
HYDE
WASHINGTON
MARTIN
BEAUFORT
PAMLICO
CARTERET
PAMLICO RIVER
NEUSE RIVER

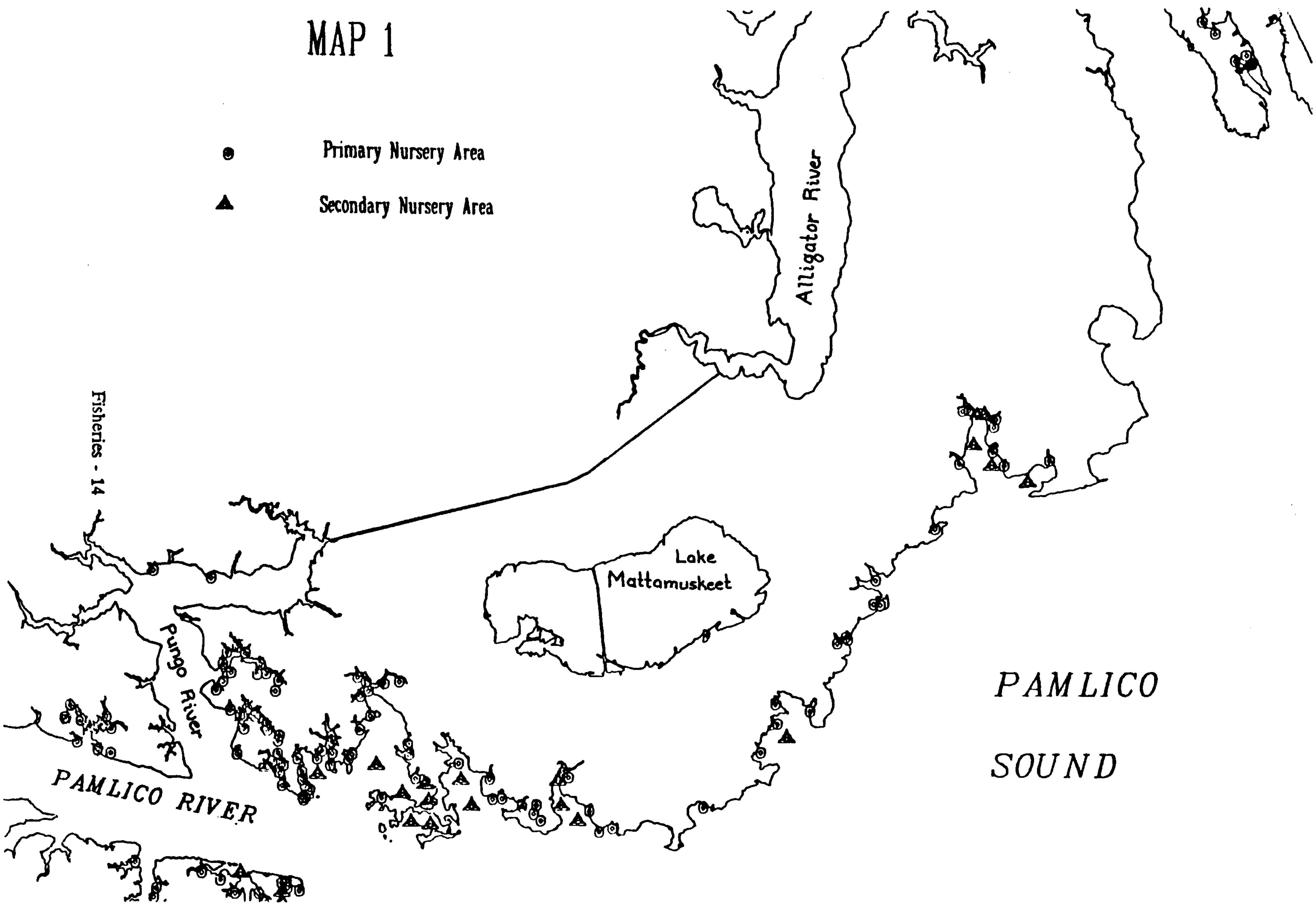


Figure IV-2 (b) Primary and Secondary Nursery Areas: Northern Pamlico Sound and the Pamlico

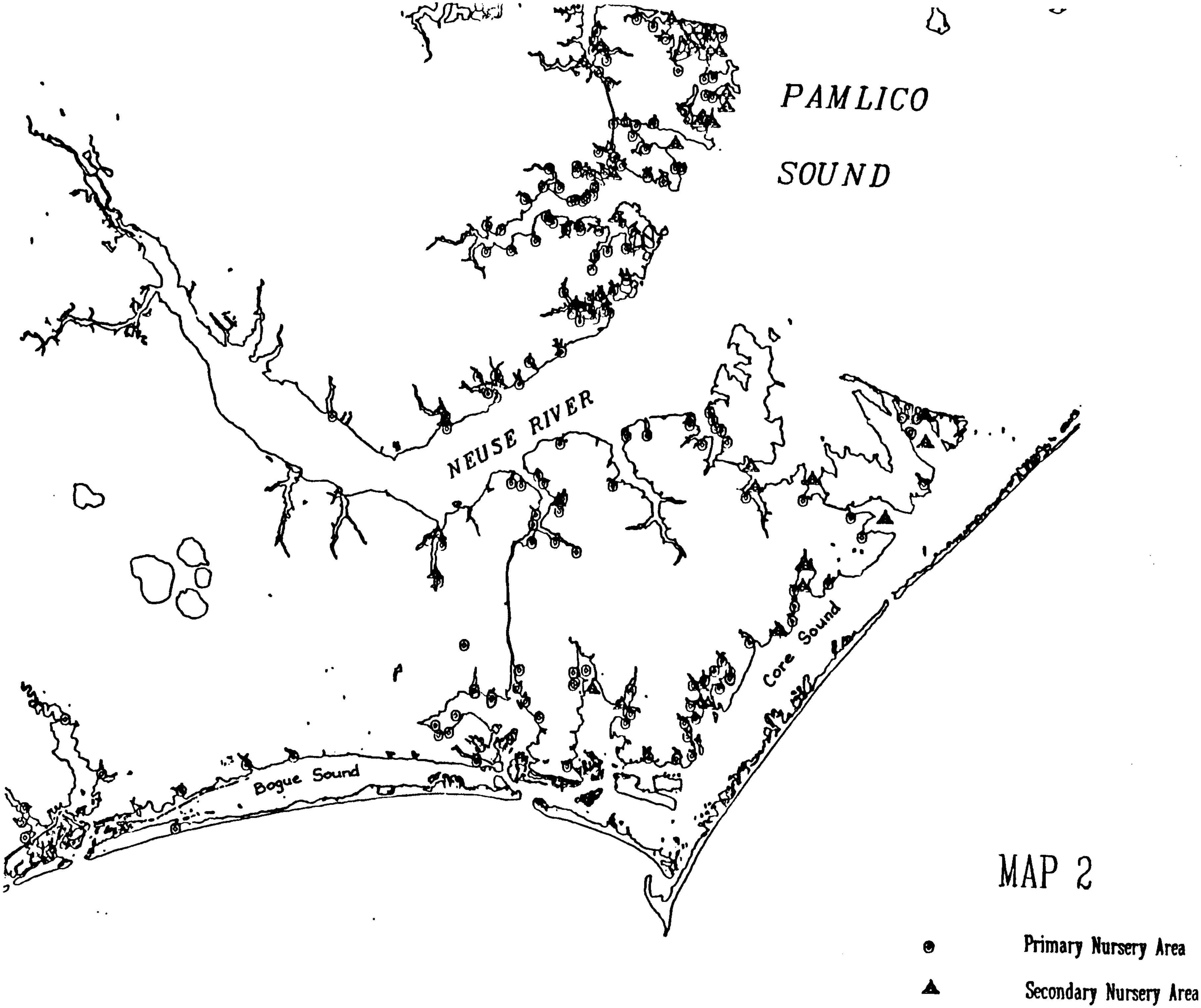


Figure IV-2 (c). Primary and Secondary Nursery Areas: Southern Pamlico Sound, Neuse River,

B. 2. Anadromous Fish Areas

Anadromous fish species have historically formed a significant component of the fishery resources of the Albemarle-Pamlico estuarine system. Spawning and early development must occur in freshwater and the upper reaches of the estuaries. The anadromous species found in the area include blueback herring, alewife, hickory shad, American shad, striped bass, and Atlantic sturgeon (Acipenser oxyrhynchus). These species utilize the major drainages around the estuarine system and especially the major rivers, including the Chowan, Roanoke, Tar-Pamlico, and Neuse. Numerous life history studies have been conducted on the anadromous species in the estuary (Walburg 1957; LaPointe 1957; Cheek 1961; Pate 1971; Tyus 1971; Manooch 1972; Street and Hall 1973; Kornegay and Humphries 1975; Pate 1975; Street and Pate 1975; Johnson et al. 1977; Loesch et al. 1977; Marshall 1977; Sholar 1977; Johnson et al. 1988; Hawkins 1980; Hassler et al. 1981; O'Rear 1983; Winslow et al. 1983; Winslow and Johnson 1984; Creed 1985; Rulifson 1985; Winslow et al. 1985).

All anadromous species in the area spawn during the spring. Critical habitats utilized by sexually mature adults for spawning are also necessary for egg development. The preferred habitat varies depending on the species. For example, striped bass spawn in the main stem of major rivers such as the Roanoke, while blueback herring prefer flooded swamps adjacent to rivers or small tributaries.

Anadromous fish nursery areas are those areas downstream from the spawning areas where juvenile development occurs. These areas often include the upper estuarine area, especially in Albemarle Sound, including the shallow waters along the shoreline as well as the deeper, open-water areas.

B. 3. Shellfish Areas

Critical shellfish habitats are those which contain high densities of oysters, bay scallops, and hard clams or those areas capable of producing oysters, scallops, and clams. Scallops occupy beds of seagrasses -- these are discussed briefly in the next section and in detail in Chapter II. E. 1. Oyster resources are found throughout the Pamlico and Core Sounds, while clams are found predominantly in eastern Pamlico Sound and throughout Core Sound (Figure IV-3). A survey of the distribution of oyster-producing areas was conducted by Winslow (1889). Coker (1907) conducted experiments in oyster farming or culture in Pamlico Sound. The state worked to rehabilitate oyster areas after hurricane Ginger in 1971 (Munden 1975). These rehabilitation efforts of planting clutch material each year continue as a major aspect of DMF's oyster program. Shellfish area criteria are currently being developed, and a shellfish mapping survey is being conducted by the DMF to locate specific resource areas. Also, planting sites and natural beds of oysters are being sampled through an oyster shoal survey in Pamlico Sound and its tributaries; these data help identify the most productive oyster areas. Shellfish habitats are discussed in more detail in Chapter II, Critical Areas.

B. 4. Submerged Aquatic Vegetation Beds (SAVs)

"Grassbeds" are highly productive areas which serve as nursery areas for a number of important organisms and are critical to the life history of some species, such as bay scallops (Thayer et al. 1984; Fonseca et al. 1984; Thayer et al. 1979; Ferguson et al. 1989; and Orth et al. 1984). Two major types of SAVs occur in the Albemarle-Pamlico estuarine system. High salinity seagrass meadows, characterized by eelgrass (Zostera marina) and shoalgrass (Halodule wrightii), are located throughout Bogue Sound, Core Sound, and eastern Pamlico Sound. Brackish water grassbeds containing species such as wild celery (Vallisneria americana), widgeongrass (Ruppia maritima), and Eurasian watermilfoil (Myriophyllum spicatum) are found in the upper estuarine zones of the Neuse and Pamlico Rivers, and in Albemarle and Currituck Sounds (Davis and Brinson 1976; Davis and Brinson 1983; Davis et al. 1985). Abundance of the brackish water species has declined greatly since the mid-1970s, especially in the Tar-Pamlico

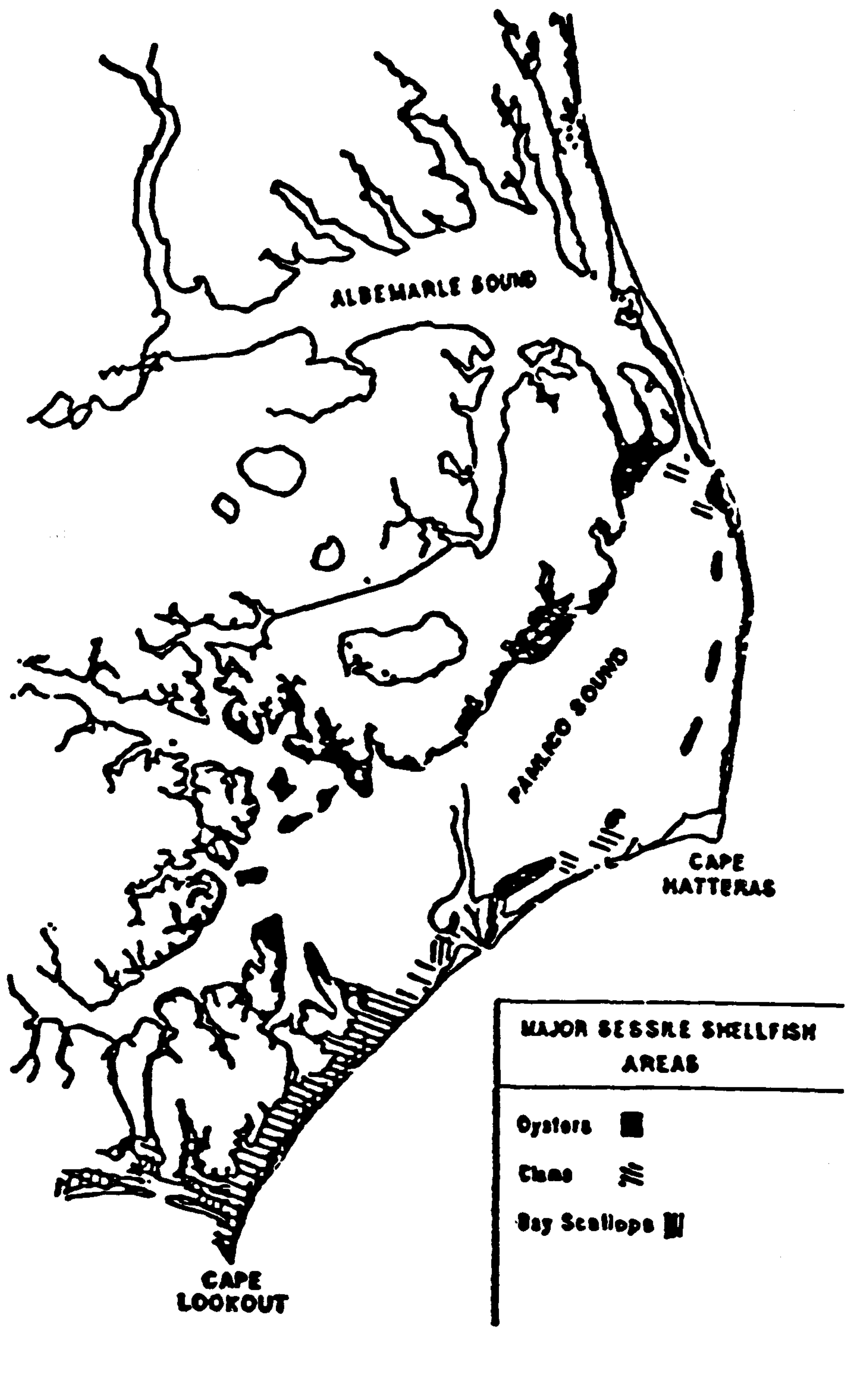


Figure IV-3. Major Shellfish Areas in the Albemarle-Pamlico Estuarine System. From Epperly and Ross (1986).

River (Davis et al. 1985). Submerged aquatic vegetation habitat is discussed in more detail in Chapter II, Critical Areas.

B. 5. Wetlands

Wetlands, located at the land/water interface, are an integral ecological part of the estuarine system and are critical for fish production. Wetlands provide direct benefits by serving as habitat for aquatic organisms and indirect benefits by helping to maintain water quality and contributing nutrients and detritus crucial for biological productivity. Wetlands also play an important role in modifying hydrologic events. The Albemarle-Pamlico estuarine system is surrounded by many wetland types, including vast marshes composed of black needlerush (Juncus roemerianus), smooth cordgrass (Spartina alterniflora) (Hettler 1989), and saltmeadow hay (S. patens). Large areas of riverine bottomland hardwoods are found along the major rivers, especially the Chowan, Roanoke, Tar-Pamlico, and Neuse rivers. Nontidal freshwater swamps are especially common in the Albemarle Sound area. Each wetland type contributes to the maintenance of the overall fisheries production of the estuarine system. Wetlands provide the basis for biological productivity in most of the A/P area and are discussed in more detail in Chapter II, Critical Areas.

C. STATUS OF MAJOR SPECIES

Well over 100 species of finfish, crustaceans, and shellfish contribute to North Carolina's commercial and recreational fisheries each year. Both commercial and sport fishermen in the Albemarle-Pamlico estuarine areas generally seek the same species, such as striped bass, white perch, Atlantic croaker, spotted seatrout, flounder, blue crabs, shrimp, and hard clams. A few species are of importance almost exclusively to commercial fishermen, including river herring, Atlantic menhaden, harvestfish, and eels. Similarly, anglers have a predominant interest in a few estuarine species, including tarpon and red drum.

The 14 species with the highest commercial landings in the Albemarle-Pamlico estuarine system are discussed below. Commercial landings data for these species is shown in Table IV-5. Data are from the DMF/NMFS cooperative statistics program. Comparable recreational data do not exist, as previously discussed.

C. 1. River Herring

Blueback herring and alewife, collectively known as river herring, ascend North Carolina's coastal rivers each spring to spawn in freshwater creeks and swamps. Millions of fish, principally in the Chowan River, are harvested for processing to yield salted herring, specialty products, and roe (Wynns 1967). River herring are also highly valued as bait for striped bass sport fishing, for blue crabs in the south Atlantic area, and for crayfish in Louisiana.

Domestic landings declined sharply during the 1970s as foreign fleets made large catches in the ocean, exceeding previous domestic landings. Ocean landings essentially ended when foreign fishing was controlled by enactment of the Federal Fisheries Conservation and Management Act of 1976. Landings, however, remained depressed into the early 1980s. Some recovery occurred in North Carolina in 1985, but landings have declined since then to the lowest on record. The fisheries in Virginia and Maryland declined along with those in North Carolina and have remained severely depressed.

Table IV-5. Landings of principal commercial species from the Albemarle Sound, Pamlico Sound, and Core Sou[illegible] areas of North Carolina combined, 1972-1990 (in thousands of pounds). (DMF Data)

SPECIES

Year	River herring	Blue-fish	Cat-fish	Croaker	Flounder	Weak-fish	Amer. shad	Spot	Striped bass	White perch	Shrimp	Blue crab	Hard clam	Oys-ters
1972	11,237	405	2,375	755	779	341	402	1,978	429	201	3,125	13,112	77	275
1973	7,926	477	1,888	2,608	898	767	289	3,723	642	145	2,827	11,659	134	380
1974	6,210	1,195	1,739	3,804	1,868	833	349	4,152	511	309	6,234	12,861	40	383
1975	5,949	936	1,654	6,775	1,696	1,639	218	6,767	716	289	2,988	10,783	13	302
1976	6,401	809	1,500	6,677	1,672	1,835	158	8,769	704	184	4,666	11,411	8	214
1977	8,523	813	2,068	8,207	672	4,781	106	2,790	480	268	4,494	11,903	533	266
1978	6,606	482	1,734	7,974	1,327	3,098	364	3,090	532	499	1,744	22,044	471	164
1979	5,031	739	1,512	11,006	1,822	3,261	201	5,570	366	361	2,596	25,154	688	433
1980	6,217	1,101	1,447	12,637	3,077	5,340	150	5,372	433	105	6,632	32,987	777	489
1981	4,611	765	1,716	8,080	2,102	3,290	192	2,729	358	395	1,646	36,202	652	315
1982	9,428	1,008	1,167	7,815	1,803	2,662	270	4,368	244	665	4,196	35,866	873	352
1983	5,868	622	1,050	5,587	2,377	2,178	377	2,373	306	498	3,754	33,042	723	497
1984	6,505	773	1,330	4,506	2,178	2,464	502	2,492	497	440	2,201	31,484	859	563
1985	11,548	977	1,279	4,166	1,841	1,922	309	2,775	280	701	9,601	28,562	886	393
1986	6,774	832	1,181	3,961	2,465	2,129	265	2,196	188	672	1,572	22,898	814	528
1987	3,176	1,044	1,228	3,181	2,519	1,771	272	1,649	262	792	2,901	31,509	617	1,210
1988	4,172	1,005	1,122	3,928	2,780	2,384	228	2,237	115	586	5,121	33,775	516	746
1989	1,491	472	812	3,983	3,123	829	272	2,140	100	295	6,230	33,630	690	293
1990	1,147	524	983	4,660	2,434	1,404	250	2,547	105	156	5,429	36,794	681	154

Area fishermen feel that weather conditions and pollution from a pulp mill in Virginia which discharges into Chowan River just upstream from the North Carolina/Virginia border together reduced fish landings from 1986 to 1990 and that adequate fish stocks were available but were not entering the nets due to those conditions (Winslow 1989). Examination of catch effort data (Winslow 1989; Winslow et al. 1985; Winslow et al. 1983; Johnson et al. 1981) indicates that pound net effort in the Chowan River during 1987, 1988, and 1989 was among the highest on record while catches and catch-per-unit-effort were the lowest on record. It has been suggested that water quality problems in spawning and nursery areas have inhibited stock recovery. Blue-green algae blooms during late spring may also affect early juveniles by releasing toxins into the water column (Winslow et al. 1985).

C. 2. American Shad

During the early 1900s, American shad was the most commercially important species in North Carolina. Landings declined from more than 8 million pounds in 1896 and 1897 to the 1-million-pound range and below in the 1930s. The lowest landings on record occurred during the mid-1970s. Some improvements occurred during the early 1980s, but landings have declined again since then (Winslow 1989). American shad, anadromous fish, enter coastal streams in the spring to spawn. Shad stocks all along the Atlantic Coast have been affected by loss of spawning areas due to construction of dams on coastal rivers, industrial and municipal pollution of rivers, and over-fishing of some stocks. Changed consumer habits have resulted in reduced market demand for shad,although seasonal demand remains high in some areas. Intensively managed shad stocks in New England are increasing with habitat improvement, stocking, fishway construction, and regulation of the fisheries. Such management has not been attempted in North Carolina. The major commercial fisheries for American shad is the gill net fishery in Albemarle Sound. Gill net fisheries are also present in Pamlico Sound, Neuse River, and Pamlico River, but have declined in the last ten years. The principal angling areas of the Albemarle-Pamlico region are the Neuse River, Tar River, and Chowan River. Recreational fishermen also use drift gill nets in the Neuse and Tar Rivers. The DMF has conducted extensive research on American shad since the early 1970s but has been unable to determine causes of apparent population declines.

C. 3. Bluefish

Bluefish are very important to both sport and commercial fishermen. Long haul seines, pound nets, and gill nets account for most of the commercial catch in the estuarine system. Most of the total catch comes from the near-shore ocean by trawls and gill nets. Recreational harvest of bluefish usually exceeds commercial harvest. Bluefish are one of North Carolina's most popular recreationally caught fish, ranking among the top three in numbers caught, and consistently ranking number one in total pounds landed. Most recreational catches are taken by trolling and surf casting. A stock assessment program sampling bluefish has been in place in North Carolina since 1981. Abundance was high all along the Atlantic coast from the mid-1970s through the mid-1980s, making bluefish one of the few species consistently available to all fishermen.

Bluefish have been found to carry varying amounts of contaminants. Recent data from NMFS indicate that the total recreational catch along the Atlantic coast has fallen dramatically (from roughly 80 million pounds to roughly 40 million pounds) from 1986 to 1989 (NMFS 1987, 1988, 1989). A coastwide fisheries management plan for bluefish has been prepared (Mid-Atlantic Fishery Management Council 1989) and was implemented early in 1990, particularly restricting recreational catches. Some large bluefish from various Atlantic coastal sites, including North Carolina, contained PCB concentrations exceeding the federal action level of 2 parts per million, however, a recent federal study of PCB's indicates that there is no general hazard to the public.

C. 4. Catfish

In the A/P Study area, channel catfish and white catfish are taken principally in western Albemarle Sound, Chowan River, and Roanoke River in pound nets, gill nets, and catfish pots. Landings have varied, generally trending downward since the mid 1970s. Certain species of catfish, including the white catfish, black bullhead, yellow bullhead, brown bullhead, and flat bullhead, are quite tolerant of degraded water quality, especially low oxygen levels. The channel catfish and other catfish of commercial value are however, not tolerant. A decline in water quality may, therefore, result in changing species assemblages towards more tolerant species. Catfish are susceptible to red sore disease, a bacterial infection prevalent in the Albemarle Sound area during the 1970s. As with most diseases, outbreaks of red sore disease in catfish are often manifestations of stress due to poor water quality. Little biological research has been conducted on catfish in the Albemarle area (Mauney 1969; Keefe and Harriss 1981) and no cause can be stated for the apparent decline in landings.

C. 5. Atlantic Croaker

Atlantic croaker is one of North Carolina's most important finfish for both commercial and recreational fishermen. Some large year classes were produced during the mid and late 1970s, which provided record landings from 1976 to 1980. During this period, relatively large numbers of three- and four-year-old fish were taken. Recreational fishing in Pamlico Sound was so good, that the term "croaker boats" was used to describe the large fleets of 16-25 ft recreational fishing boats which fished in Pamlico Sound during that period, regardless of their target species. Oceanic trawl and estuarine long haul seine catches dominated landings through 1980; since 1984, oceanic gill net catches accounted for most of the Atlantic croaker harvest (Ross 1991). Pound nets also harvest considerable numbers of Atlantic croaker. Data collected from the major commercial fisheries by DMF stock assessment surveys since 1981 indicate that Atlantic croaker are "growth over-fished", i.e., that average sizes of landed individuals have become smaller (Ross 1991). Reasons for the increase from 1976 to 1980 are unknown but are probably related to favorable changes in environmental conditions in ocean spawning areas and estuarine nursery areas. Croaker spawn principally during fall, winter, and spring; extreme winter conditions may cause mortality of eggs, larvae, or early juveniles.

C. 6. Spot

Spot is usually one of the most abundant estuarine fishes of North Carolina and is very important to recreational fishermen, it ranked first in numbers caught recreationally from 1987 to 1989. Landings and presumably population levels fluctuate wildly. The long haul seine fishery harvests most of the spot landed in North Carolina. According to DMF stock assessment data, populations show little indications of growth over-fishing in North Carolina. Fluctuations are thought to be primarily controlled by environmental conditions or other aspects of spot's life history, such as predation.

C. 7. Flounder

Two species of flounder primarily support one of North Carolina's most important commercial finfish fisheries, as well as very important recreational fisheries. Summer flounder is the most commercially important species, composing approximately 56-70% of the total flounder landings in North Carolina. The oceanic trawl fishery harvests most of the summer flounder. Landings of summer flounder along the Atlantic coast were nearly constant from 1979 to 1990, when they fell nearly 60%. North Carolina landings have gradually declined since 1984, with 1990 landing the lowest since the early 1970s. Presently summer flounder appear to be over-fished.

The harvest of southern flounder is restricted almost entirely to estuarine waters; it is reaped primarily by pound nets and gill nets. Stock assessment data show that the size of southern flounder harvested have become smaller (Ross 1991). Landings of southern flounder have increased in recent years.

Minimum size limits were increased for flounder in 1988 and tailbag (codend) sizes for oceanic trawls enlarged during 1990 in response to heavy fishing pressure. Both species spawn in the ocean off North Carolina during the winter, and the young utilize estuarine nursery areas. Summer flounder utilize the higher salinity open water for nurseries, while southern flounder utilize the lower salinity creeks and bays. The Albemarle-Pamlico estuarine system is a major flounder nursery area, possibly the most important summer flounder nursery area for the entire Atlantic Coast (see section IV-G).

C. 8. Weakfish

Generally called "grey trout" in North Carolina, weakfish utilize estuarine waters for spawning and as nursery areas. Pamlico Sound and its tributaries serve as the major nursery areas for weakfish in North Carolina; the area is also an important nursery area for the entire Atlantic coast. Weakfish is one of North Carolina's most valuable commercially landed finfish. Commercial catches reached their peak between 1978 and 1984, with most of the increased catch coming from the oceanic gill net and trawl fisheries. Most of the estuarine harvest is taken with long haul seines and pound nets in the Pamlico Sound area. Commercial landings have fluctuated widely all along the coast. Landings from northern areas have fallen recently (Unpublished information, Atlantic States Marine Fisheries Commission, December 1988), while North Carolina landings remained quite high until 1990 when they declined sharply to 5.8 million pounds, the lowest volume in 20 years. North Carolina lands approximately 70% of the total weakfish harvested along the Atlantic Coast. The historic centers of abundance appear to be Pamlico Sound and Chesapeake Bay. Reasons for the wide variations in abundance historically are unknown. Presently, DMF stock assessment data show that weakfish are being growth over-fished. The Atlantic States Marine Fisheries Commission (ASMFC) Weakfish Board has recently determined that weakfish are in an over-fished status.

C. 9. Striped Bass

Striped bass populations are found in all of North Carolina's major coastal river basins (Cape Fear River, Neuse River, Tar-Pamlico River, and Roanoke River-Albemarle Sound). In addition, the Atlantic Coast migratory stock of striped bass utilizes offshore wintering grounds which generally extend from Cape Hatteras north to the mouth of the Chesapeake Bay. The Roanoke River-Albemarle Sound complex is an excellent example of a system in which changes to the flow regime may have had a major negative effect on living resources. Historically, the Roanoke River-Albemarle Sound complex was one of the most productive striped bass spawning areas on the east-coast, ranking third only to the Chesapeake stocks and the Hudson River population (US Department of Interior and US Department of Commerce 1987). During periods of high abundance, this stock probably contributes to the Atlantic migratory population which over-winters off North Carolina and migrates north along the coast to New England during the summer. Annual landings, however, decreased from about 15 to 20 million pounds in the mid-1960s and early-1970s to less than 300,000 pounds in the late 1980s, a decline of over 80 percent in 20 years (Manooch and Rulifson 1989).

Historically, the Chesapeake Bay population has made up the preponderance of the Atlantic Coast migratory stock. However, reproductive failure of this stock after the early 1970s, combined with over-harvest, resulted in a severe population decline. This situation led to a cooperative interstate approach to management of the migratory stock. A management plan has been prepared by the Atlantic States

Marine Fisheries Commission (ASMFC), an interstate compact created by the US Congress in 1942. Implementation of this plan required severe restrictions and moratoria on fishing in some areas from 1985 to 1989. These measures have helped the Atlantic coast migratory population recover to such a point that very restricted fishing began in 1990 in ocean waters north of Cape Hatteras and in estuarine waters from Chesapeake Bay northward.

Similar to the Chesapeake Bay stock, reproductive failure has plagued the Albemarle-Roanoke stock since 1977 (Manooch and Rulifson 1989), although fishing restrictions have been less severe in North Carolina's estuarine waters than further north. Reasons for poor reproduction appear to be related to over-harvest, poor water quality, and, perhaps most importantly, instability of river flows during spawning and nursery seasons (Manooch and Rulifson 1989).

Several factors have strongly linked striped bass declines to changes in the Roanoke River-Albemarle Sound flow and circulation regime. (1) Although reliable information on landings prior to the mid-1960s is unavailable, striped bass declines occurred after the completion of a series of reservoirs on the upper Roanoke in 1963. (2) Time-series analysis has shown strong correlation between reservoir release schedules and the yearly juvenile abundance index (JAI), an indicator of spawning success (Manooch and Rulifson 1989). (3) There has been no apparent decline in the number of eggs spawned, but egg viability has decreased and juvenile mortality has increased (Manooch and Rulifson 1989). (4) There is some indication that, over the last 30 years, significant changes in bathymetry (and thus perhaps circulation) have occurred in western Albemarle Sound, the historical nursery area for striped bass larvae.

The importance of flow processes on striped bass is evident at a number of key stages in the early-life cycle of the fish. Transport and mixing processes: (1) control the rate of egg transport downstream -- eggs should remain suspended and within the channel (not the floodplain); (2) determine the location at which eggs hatch -- hatching should occur in a region with an adequate food source and moderate flows; (3) affect larval feeding success and mortality -- larvae should be transported to historical nursery grounds in the estuarine mixing zone; and (4) govern water quality. Transport and mixing processes also affect the supply of phytoplankton and zooplankton available to larval fish and appear to be modifying the bathymetry and so the circulation in the historical nursery areas (Rulifson unpublished data).

An ad hoc multi-agency committee was formed in 1987 to review the water flow situation and its possible relationship with spawning success. This group recommended river flow changes in 1988 and as a result, juveniles were somewhat more abundant. In 1988, the JAI rose from the previous year's value of 0.08 to 4.09 (Manooch and Rulifson 1989). Unfortunately, full implementation of the committee's recommendations for a flow regime could not be accomplished in 1989 due to heavy rains and resulting high flows. The high flows were, however, quite stable during the spawning and nursery seasons. The 1989 JAI was 4.27, the second consecutive year of improvement. Unfortunately, the JAI declined sharply in 1990 to 1.41.

The commercial and recreational fisheries for striped bass have been supported, to some degree, by stocking of hatchery fish in the winters of 1981 and 1983 to the present. The DMF tagging program substantiates favorable returns to both commercial and recreational harvesters, but most importantly, to the residual spawning stock utilizing the Roanoke River. The total spawning stock, natural and surviving hatchery fish combined, however, remains extremely depressed. The striped bass fishery in the Pamlico River has become virtually non-existent.

Commercial and recreational landings throughout the Atlantic coast have declined due to greatly reduced abundance of fishable year classes and severe regulatory measures imposed by all states from North Carolina to Maine, under the ASMFC. The ASMFC interstate fishery management plan has recently been amended by Amendment #4, which allowed reopening of very limited fisheries in 1990.

The US Congress, in re-authorizing the Atlantic Striped Bass Conservation Act in 1988, included an amendment directing the federal government, in cooperation with state agencies, to undertake an additional study of the Roanoke-Albemarle population and to report their recommendations within three years. In North Carolina, DMF and the North Carolina Wildlife Resources Commission, in cooperation with the US Fish and Wildlife Service, are preparing a cooperative plan to meet the requirements of Amendment #4. All of these planning efforts are directed toward managing the North Carolina stock in concert with the Atlantic Striped Bass Conservation act to restore the stock to sustained fishable levels.

C. 10. White Perch

A slow-growing fish related to striped bass, white perch has replaced striped bass as a target species for many Albemarle Sound commercial and recreational fishermen. White perch are sought by gill net fishermen in Albemarle Sound, leading to problems in taking striped bass as by-catch (Henry 1987, 1989). White perch spawn in the lower Roanoke River and throughout the Chowan River, and they utilize most of the Albemarle Sound area as a nursery. They are especially susceptible to red sore disease, which may be responsible for the extremely low landings of 1980. Commercial landings from 1985 to 1988 were among the highest on record. Landings declined sharply in 1989-1990, possibly because of gill net restrictions designed to conserve striped bass. Little research on white perch has been conducted (Conover 1958; Keefe and Harriss 1981); thus, status of the stock is unknown.

C. 11. Shrimp

Brown, white (P. setiferus), and pink shrimp all contribute to North Carolina's shrimp harvest. Brown shrimp comprise the majority of the landings (69%). North Carolina is the largest producer of brown shrimp on the Atlantic Coast. Most shrimp are harvested with trawls in the estuarine waters of North Carolina, with Pamlico and Core Sounds serving as major fishing grounds. Brown shrimp support the major summer fishery, especially in Pamlico Sound. As an annual crop, shrimp abundance depends principally on annual environmental conditions, especially the salinity and temperature of nursery areas (Hunt et al 1980; Jones and Sholar 1981; and Hettler and Chester 1982). Thus, landings fluctuate widely from year to year. Especially critical for brown shrimp are nursery area conditions during April and May of each year. Examples include the record harvest of 6.4 million pounds of brown shrimp in 1985 during warm, dry conditions versus the poor harvest of approximately one million pounds during the relatively cool, wet conditions of 1984. The strong correlation ($r^2 > 0.9$) between the number of juvenile shrimp captured in the DMF shrimp trawls and the number of adults harvested, allows good estimates of the annual crop to be made early in the season (DMF, unpublished data). Pink shrimp production is very dependent on water temperatures, since juveniles over-winter in the relatively shallow waters of Pamlico and Core Sounds. For example, pink shrimp landings dropped from approximately 3 million pounds in 1989 to approximately 1.5 million pounds after relatively cold periods during the winter of 1989-90. Recreational shrimpers probably take significant quantities of shrimp, but the amount is unknown (Pate 1977). The DMF is able to assess annual production of brown shrimp through an intensive assessment sampling program for juveniles that has been in place since 1972.

C. 12. Blue Crabs

In terms of total harvest, value, numbers of fishermen, amount of gear, processing plants, and employment, blue crabs support North Carolina's most important commercial fishery. Landings increased steadily since the mid-1970s, reaching all time peaks during the early 1980s, before declining through 1986. Landings increased again between 1987 and 1990, reaching the third highest value on record (36.9 million pounds). Pamlico Sound is the center of the fishery, although contributions from

Albemarle and Core Sounds have increased. North Carolina is the third largest producer of blue crabs on the Atlantic coast, accounting for 23% of the total landings. Currently, crab pots account for over 95% of North Carolina's crab landings, while historically, crabs were primarily harvested with trawls. Effort, in terms of the number of pots fished, has increased dramatically since the early 1970s, with hundreds of thousands of pots in use. Blue crabs are essentially an annual crop like shrimp, so annual environmental variations probably dictate population size. Controlling factors, however, are not known. An assessment program for blue crabs in North Carolina has recently been initiated by the DMF to aid in determining efforts of harvest. As with shrimp, there are large, but unquantifiable recreational landings.

C. 13. Hard Clams

Hard clams supported a minor fishery in North Carolina (<300,000 pounds of meat), principally in the southern coastal area, until the extremely severe winter of 1976-77 adversely affected the northeastern United States. Landings rose rapidly from 1976 through 1979. Since 1979, North Carolina landings have averaged approximately 1,400,000 pounds per year. Clams are harvested by hand with rakes and tongs, and mechanically with hydraulic dredges and "kick" boats (using the propeller wash to dislodge the clams and "kick" them into trawls pulled behind the vessel). Present trends in total landings suggest that, in spite of increasing effort, clams are fully exploited. Demand from northern markets has driven the price steadily upward, resulting in significant regulatory and enforcement problems. It is especially difficult to control clam harvest in areas polluted by sewage and in grass beds and oyster rocks which are productive habitats for other species such as crabs, shrimp, bay scallops, and oysters. The "red tide" algal bloom of 1987-88 resulted in the closure of most clam harvest areas and caused considerable hardship among fishermen. Although it is believed that the red tide did not kill hard clams as it did bay scallops, low availability of the smaller sizes of market clams during 1988-89 suggests that small hard clams may have been affected by the red tide. Little assessment data are available on the clam resource in North Carolina.

C. 14. Oysters

North Carolina possesses thousands of acres of potentially productive oyster bottoms, especially around the perimeter of and within Pamlico Sound. Oysters can tolerate the wide variety of conditions found in the area as long as they have the proper bottom type. In the early 1900s, North Carolina supported a very productive oyster industry, landing several million bushels annually. The major harvest area was Pamlico Sound. By 1962, however, landings had declined to 192,000 bushels, probably as a result of fishing pressure and declining water quality. While fluctuating widely, oyster landings from the Pamlico Sound generally increased from the 1960s to 1988, due largely to a DMF management program which plants roughly 300,000 bushels of shell annually in Pamlico Sound to serve as oyster substrate. In 1988, the pathogens Minchinia nelsoni (MSX) and Perkinsus marinus (Dermo or dermocystidium), both fatal to oysters but harmless to people, were documented in Pamlico Sound. Drought conditions during 1987-88 evidently resulted in high salinity levels during the summer, which combined with warm water to provide favorable growing conditions for both disease organisms. Large mortalities of oysters were noted in areas where pathogens were observed, especially Dermo. Landings have continued to decline sine 1988, and reached the lowest level on record during the 1989-90 season (52,000 bushels). The declines appear to be due to continued intense harvest pressure, loss of habitat through poor water quality, and mortality through disease. Decreasing salinity and episodes of decreasing oxygen may be the reasons that some oyster rocks in western portion of Pamlico Sound are no longer productive. Hypoxia is widespread in certain areas; in 1985, for example, several hundred square miles of Neuse River, Pamlico Sound and Pamlico River bottoms were virtually devoid of oxygen for three days, resulting in reported oyster mortalities in some areas.

The DMF has conducted spatfall surveys since 1978 to monitor recruitment and has initiated shoal surveys in Pamlico Sound for stock assessments. The DMF's oyster management activities are being adjusted to avoid spreading MSX and Dermo through transplanting. Emphasis is being placed on locating disease-free areas and planting shell in such areas to provide resources for future harvest. The DMF has established a program to monitor MSX and Dermo with the assistance of North Carolina State University School of Veterinary Medicine. Intensive management measures have been undertaken to maintain and enhance stock status.

D. STATUS AND TRENDS OF MAJOR FISHERIES

D. 1. Introduction

D. 1. a. Trends In Fish Stocks. Long-term trends in abundance of stocks of a few species can be discussed but only in very general terms because of limitations in sampling data. As discussed previously, limitations in amount and quality of data greatly restrict the ability to determine actual trends in stock abundance. Commercial landings data, when combined with biological data, can often provide insight regarding general trends in the fisheries, provided that certain assumptions are made and the limits of the data are understood.

One critical factor influencing landings data is consistency of collection methods. Prior to 1950, the federal government collected annual landings data on a sporadic basis in North Carolina. Beginning in 1950, the federal government collected North Carolina landings data every year. Parial data on landings by waterbody are available, starting in 1959. Monthly landings data have been collected since 1956. Prior to 1978, one or two federal employees collected the data through a voluntary program. Coverage of certain species, areas, and seasons was limited. Beginning in 1978, DMF and NMFS established a cooperative program with a total of six (now seven) port agents and support staff. Interviews are conducted by the port agents or by DMF biologists to collect effort data for several fisheries. It is apparent that landings data have not been collected consistently in North Carolina since the 1880s, but data collected since 1978 are consistent for virtually all species and fisheries. For some species (Atlantic menhaden, shrimp, and probably a few others), data collected prior to 1978 may also be used with confidence. For most species, use of data collected prior 1978 to for other than examining gross changes must be done cautiously.

Another factor concerns species identification. For example, historically the statistics category "flounder," as published, included five or six species, some of which never use the estuary. The DMF currently collects the data by species. Prior to 1979, all flounder were listed as "unclassified." Biological information has been utilized to improve precision of data reported for various species of porgies, snappers, groupers, and tunas. Clearly, confidence in species identifications is greater at present than in earlier periods. In order to improve the quality of landings data (commercial and recreational), Street and Phalen (1990) have recommended several changes in fisheries licensing and data collection.

The vast majority of the DMF's biological data for adults comes from sampling commercial and recreational landings. This fishery-dependent sampling provides relatively large samples at much lower unit cost than if DMF personnel conducted their own labor-intensive fishing activities. Fishery-dependent biological sampling assumes the fisheries harvest the stock in relation to its availability by area, season, size, and sex. This assumption may not be met for a variety of reasons, including regulations (size limits, seasons, area closures, gear restrictions), weather, and market conditions.

D. 1. b. Trends in Juvenile Abundance. The best data available are for juveniles. Juvenile fish abundance is monitored within the Albemarle-Pamlico estuarine system by several historical and ongoing fishery-independent surveys. These include the DMF primary and secondary nursery area surveys, red drum nursery area survey, Pamlico/Albemarle Sounds survey, juvenile anadromous fish survey, and the striped bass nursery area survey. Data from these surveys are intended for use in developing long term indices of year class strength for various species. Trend data are available only from the primary, anadromous fish, and striped bass nursery area surveys. The red drum and Pamlico/Albemarle Sounds surveys have only recently been established (<4 yr), and the secondary nursery area survey has had recent gear changes, making long term continuous indices unavailable from these data.

The primary nursery area surveys are conducted in shallow (0.1-1.2 m) upper reaches of creeks or bays where initial post-larval development occurs. These areas have been sampled, using a 3.2 meter two-seam trawl, for several months each year since the survey methods were standardized in 1979 (DeVries 1985). Data used to generate year class strengths were restricted to those collected at stations within the Albemarle-Pamlico Study area. Indices have been developed for Atlantic croaker, spot, southern flounder, weakfish, and brown shrimp.

No significant trends for any of these species are indicated during the past 12 years (1979-1990). Years of relatively high abundance were 1982 and 1986 for southern flounder, 1981 and 1986 for weakfish, 1983 for Atlantic croaker and 1985 for brown shrimp. The spot index showed one relatively poor year, 1980. Other than these few highs and lows, catch-per-unit effort values remained relatively constant with only minor fluctuations. The absence of downward trends indicates that any stress on these species (such as over-fishing) is not great enough to cause a decline in relative juvenile production. Fluctuations are most likely due to yearly variations in environmental parameters, such as temperature, salinity, weather patterns, and/or currents. These factors all affect larval transport and survival. The brown shrimp index has been shown to reflect true annual abundance by exhibiting similar trends to those found in the brown shrimp commercial landings ($r^2 > 0.9$) (DeVries 1985) and commercial catch-per-unit-effort (CPUE) data (DMF unpublished data).

The anadromous fish nursery area survey provides an index of juvenile abundance of blueback herring in Albemarle Sound extending back to 1972. This survey consists of 11 stations sampled monthly (June-October) using an 18.3 meter bag seine. Stations are located in the western Albemarle Sound area which has been identified as an anadromous fish nursery area. Catches among years are highly variable. Trends in juvenile blueback herring abundance are not readily apparent from the index. Even with relatively high and low CPUE values, differences are hard to quantify or verify due to high sampling variance (DMF unpublished data). The data indicate the 1986-1990 seasons showed relatively low juvenile abundance. Further analyses of landings and biological data and additional years of juvenile abundance data are needed to determine if a trend exists. The ASMFC, in cooperation with DMF and other states, conducted a stock assessment of river herring along the Atlantic Coast.

The striped bass nursery area survey is the longest juvenile abundance index available in the Albemarle-Pamlico estuarine system. Dr. Hassler, along with North Carolina State University personnel, conducted the survey from 1955 to 1987. The DMF adopted the same methods in 1984 and conducted a comparative survey through 1987, when the NCSU survey ended. DMF has maintained the survey to continue the historic index of juvenile abundance. Sampling is conducted twice a month, from July through October, at seven fixed stations in western Albemarle Sound using a 5.49 meter balloon trawl.

The index of juvenile striped bass abundance shows fluctuations among relatively high and low years between 1956 and 1977 (Figure IV-4). Starting in 1978 and continuing through 1987 the survey indicates that year class strength was severely depressed. This trend was also reflected in landings (Table IV-5). Some possible reasons for the low juvenile CPUE are that: (1) adult mortality became so high that recruitment was affected, and/or (2) some factor(s) caused failure in reproduction and/or larval survival. The 1988 year class index was the highest of the last 12 years. Preliminary data indicate that the 1989

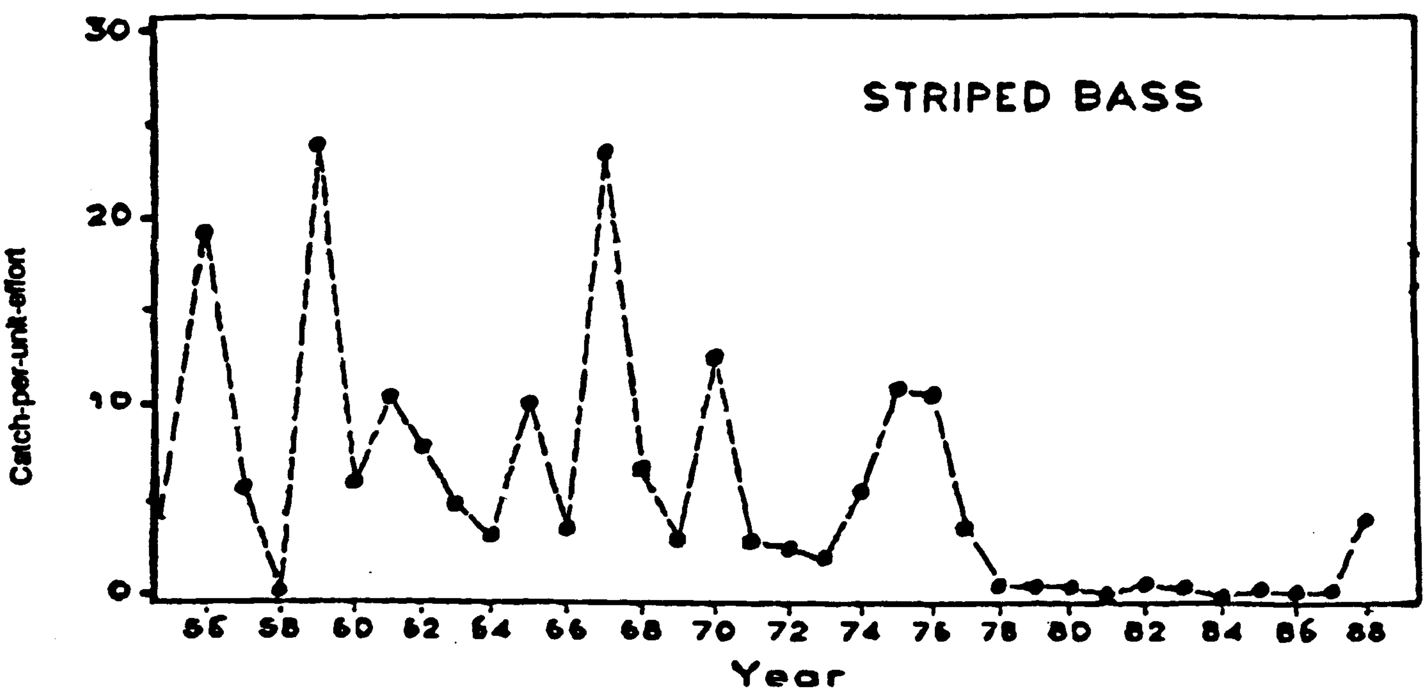


Figure IV-4. Catch-per-unit-effort for Young-of-the-year Striped Bass from Western Albemarle Sound, 1956-1990 (DMF).

index may be similar to the 1988 value. It is unclear whether future recovery is indicated by this two-year trend in juvenile abundance.

D. 1. c. Trends in Adult Abundance. Because no long term fishery-independent sampling is conducted for adult fish in the Albemarle-Pamlico estuarine system, reliable trends in abundance of adult fishes are difficult to determine with any degree of precision. Striped bass and menhaden are two examples of finfish for which data are available to estimate abundance (Data are available for other species, as discussed in the species sections).

Because the database extends back to the 1950s for juvenile abundance, spawning success, spawning stock estimates, catch and effort in Roanoke River, and some other parameters, general stock trends for striped bass in the Albemarle Sound area can be discussed. Current data are available from continuing sampling by personnel from DMF, the North Carolina Wildlife Resources Commission, and East Carolina University. Data are available from Hassler et al. (1981), Hassler and Taylor (1986), Harriss et al. (1985), Winslow and Harriss (1986), Winslow and Henry (1986, 1988, 1989), Mullis (1989), and Rulifson et al. (1986, 1988). Dominant year classes were produced in 1956, 1958, and 1967 (Figure IV-4). Landings generally increased in Albemarle Sound during the two years following production of a dominant year class. Unfortunately, age composition data are not available for the 1950s and 1960s, so year classes produced during that period cannot be followed in the fishery. Age composition data have been collected by DMF since 1971-72. Hassler and Taylor (1986) reported spawning stock estimates from 1956 to 1985. Landings data are not comparable to earlier data because of restrictive seasonal and size regulations. Unfortunately, effort data are not available for the commercial fishery in Albemarle Sound. Based on examination of available data, it is apparent that the Albemarle-Roanoke stock of striped bass is much smaller at present than during the peak period from the 1960s through the mid-1970s.

Menhaden do not support major fisheries in the Albemarle-Pamlico estuarine system; however, the area is a major nursery area for menhaden harvested in the ocean off North Carolina and elsewhere. Several million pounds of menhaden are harvested annually from the Albemarle-Pamlico system for reduction to fish meal and oil and for bait. Since only one company fishes for reduction, data are confidential. Much of the bait landings (menhaden caught as bait) come from by-catch (incidental catch) of the long haul seine and summer pound net fisheries, although some purse seine sets are made for bait, especially in Core Sound.Vaughan and Smith (1988) recently completed a stock assessment for Atlantic menhaden of the entire Atlantic coast. The authors concluded that the stock has recovered from poor reproduction and over-fishing that occurred from the mid-1960s through the mid-1970s. Population sizes at present compare favorably with those estimated for the late 1950s.

D. 2. Commercial Fisheries

The Albemarle-Pamlico estuarine system currently yields about 62 million pounds per year of commercial landings which represent about 54% of the total North Carolina catch of edible seafood. Table IV-6 shows the catch for the three sound areas (Albemarle, Pamlico, and Core) for the 19 year period of 1972-1990. The area probably produces far more seafood, which is harvested all along the Atlantic Coast. Tagging studies on croaker, summer flounder, and Spanish mackerel, among other species (Ross et al. 1986; Monaghan et al. 1989), demonstrate that the Albemarle-Pamlico estuarine system contributes to harvests in a number of other areas. Producing 32% of the state's total landings, the Pamlico Sound area was the most productive, while the Albemarle area accounted for 14%, and Core Sound, almost 9%. The commercial fishing industry in the area is dependent upon a diversity of species and fisheries. Few fishermen depend on only one fishery or a limited geographic area. Most fishermen vary their practices depending on the season, market conditions, and other factors (Maiolo et al. 1980; Street and McClees 1981; Maiolo et al. 1985a). For example, a summertime shrimp trawler may fish for crabs in the spring and fall and for oysters in the winter. This diversity of fisheries accounts for the resiliency and the viability of the industry by allowing for flexibility in fishing practices and target species.

Table IV-6. Total commercial landings for principal fishing gears by sound area for 1974-1990 (in thousands of pounds). (DMF, unpublished data).

	Long haul seines			Pound nets			Gill nets			Crab pots			Shrimp trawl		
	Albml	Pmlco	Core	Albml	Pmlco	Core	Albml	Pmlco	Core	Albml	Pmlco	Core	Albml	Pmlco	Core
1974	553	3,370	5,844	7,119	845	696	1,388	837	391	1,812	6,833	2,239	44	3,871	2,949
1975	666	8,680	6,666	6,632	1,267	424	1,467	732	325	1,190	4,730	1,679	0	2,245	1,316
1976	603	6,421	2,422	7,219	3,412	419	1,697	644	80	813	5,036	1,854	0	3,792	1,448
1977	234	9,925	2,994	9,253	1,519	285	1,404	467	263	1,046	7,059	1,181	0	4,168	1,097
1978	175	14,159	2,204	6,493	2,463	298	3,983	1,544	649	2,798	11,274	2,757	4	1,954	1,315
1979	1,678	17,559	3,290	5,570	1,900	840	2,059	1,937	764	2,683	13,886	2,580	0	3,584	2,065
1980	1,359	16,277	4,800	7,265	6,501	586	2,188	1,525	1,349	1,888	22,730	2,629	49	7,010	2,454
1981	388	11,887	2,345	4,902	4,418	435	2,460	1,415	807	3,774	23,043	2,741	5	2,340	986
1982	1,576	11,277	2,497	9,197	4,545	353	3,047	1,134	512	6,076	21,884	2,335	15	4,947	1,867
1983	1,108	8,737	3,291	5,505	2,486	448	3,140	1,323	648	6,033	20,808	1,667	62	3,582	2,388
1984	1,035	8,470	2,171	5,616	3,216	713	3,855	1,584	935	2,620	21,760	2,098	73	1,241	1,881
1985	318	6,337	2,187	11,925	3,999	302	3,086	1,560	864	5,576	18,812	2,323	101	9,666	1,593
1986	628	6,795	2,602	7,519	2,276	500	2,517	1,927	989	8,001	11,936	1,070	2	4,057	1,689
1987	377	5,339	2,136	4,193	4,466	509	2,934	1,972	760	10,501	17,896	1,439	0	1,903	1,631
1988	440	6,273	2,405	3,825	5,276	1,217	3,513	2,245	1,043	6,118	24,131	1,764	0	3,901	2,155
1989	318	6,664	1,660	1,751	3,959	963	2,635	1,457	702	10,307	19,752	1,687	14	5,180	1,912
1990	172	8,378	2,583	1,720	3,449	841	4,053	1,299	942	7,702	24,924	1,183	6	5,137	903
Mean	684	9,205	3,064	6,217	3,293	578	2,673	1,383	707	4,643	16,265	1,955	22	4,034	1,744
Percent	4.9			45.3			17.2			27.0			0.2		
of Area		25.2			8.6			3.7			41.2			10.4	
Total			33.6			5.6			7.3			21.3			18.8

The diversity of fishing gears also greatly complicates the task of relating harvest data to actual stock abundance.

Commercial fishermen of the Albemarle-Pamlico estuarine system rely predominantly on five types of gear: long haul seine, pound net, gill net, crab pot, and shrimp trawl. These gears produce, on average, about 95% of the catches in the Albemarle Sound area, 89% of the Pamlico Sound area catches, and 87% of the Core Sound area catches. Table IV-6 gives the landings by these gears from each area from 1974 to 1990. While certain species, such as blue crabs, are important throughout the region, each area contains characteristic fisheries. Albemarle Sound, for example, produces about 99% of the river herring, 93% of the catfish, 68% of the striped bass, and 95% of the white perch caught statewide. Pamlico Sound produces 45% of the croaker, 42% of the shrimp, 78% of the blue crabs and 59% of the oysters commercially landed in North Carolina. Fifty percent of the hard clams in the state are harvested from Core Sound. This difference in fisheries is due to the difference in habitat types. Generally, Albemarle Sound has low salinities; Core Sound is a shallow, high salinity area; and Pamlico Sound contains broad expanses of moderate salinity.

Almost all of the commercial landings from the Albemarle Sound area come from fixed gear: pound nets and gill nets for finfish, and pots for crabs. Pound nets and gill nets have become increasingly important in taking finfish in the Pamlico and Core Sounds area, while long haul seines, a moveable gear, have become relatively less important. Long haul seines now harvest only limited amounts of finfish in the eastern portion of the area, however, while declining, long hauls are still the single most important finfish gear in the Pamlico-Core area. Crab pots account for the highest landings of any gear in the Albemarle-Pamlico estuarine system, especially in the Pamlico Sound area, the center of the blue crab fishery. The shrimp trawl, a moveable gear, accounts for about 95% of the shrimp harvest in the Albemarle-Pamlico area, as well as a substantial finfish by-catch, which is usually discarded at sea.

The use of various fishing methods is controlled by a variety of factors, principally natural conditions. Moveable gears require large, unobstructed areas. Areas containing fixed gear generally preclude the use of moveable gear. In order to maintain use of trawls and long haul seines and availability to the public of their products), state regulations restrict crab pots to specified areas during much of the year. On a local basis, fishermen usually determine use of areas among themselves, although conflicts do occur.

The following is a brief description of the five major fisheries (Copeland et al. 1983; Copeland et al. 1984).

<u>D. 2. a. Shrimp Trawl Fishery.</u> The trawl fishery for shrimp began shortly after the turn of the century in the southern part of North Carolina. Although some trawling occurred in Pamlico Sound during the 1930s, it did not become significant until the late 1940s or early 1950s (Maiolo et al. 1980). The North Carolina shrimp fishery, unlike that of other states, is dependent on estuarine trawling (Street 1987). The Pamlico Sound area is the northernmost area with commercial quantities of penaeid shrimp and is the major shrimping area in the state (Calder et al. 1974) (Figure IV-5). Harvest occurs from May through September or October and depends primarily on brown shrimp, although pink shrimp and white shrimp are also caught. Pamlico Sound is unique among southeastern estuaries in that it consistently produces large shrimp (16-20 tails per pound or larger). Maiolo et al. (1980) described the socio-cultural aspects of the North Carolina shrimp fishery. Other shrimp studies in the estuary have centered around biological and fishery management investigations (Broad 1950; Williams 1964; McCoy 1968; Purvis and McCoy 1972; Purvis and McCoy 1974a,b; Purvis et al. 1977; Hunt et al. 1980; Wicker et al. 1988). The resident shrimp trawl fleet often trawls for crabs and flounder in the estuary during the fall, winter, and spring.

Three general types of vessels normally fish in the Pamlico Sound shrimp fishery: (1) large vessels (50-90 ft) which fish part of the year in Pamlico Sound and the rest of the year in other southern areas (North Carolina and other states), mostly for shrimp; (2) large vessels, usually constructed of steel, which

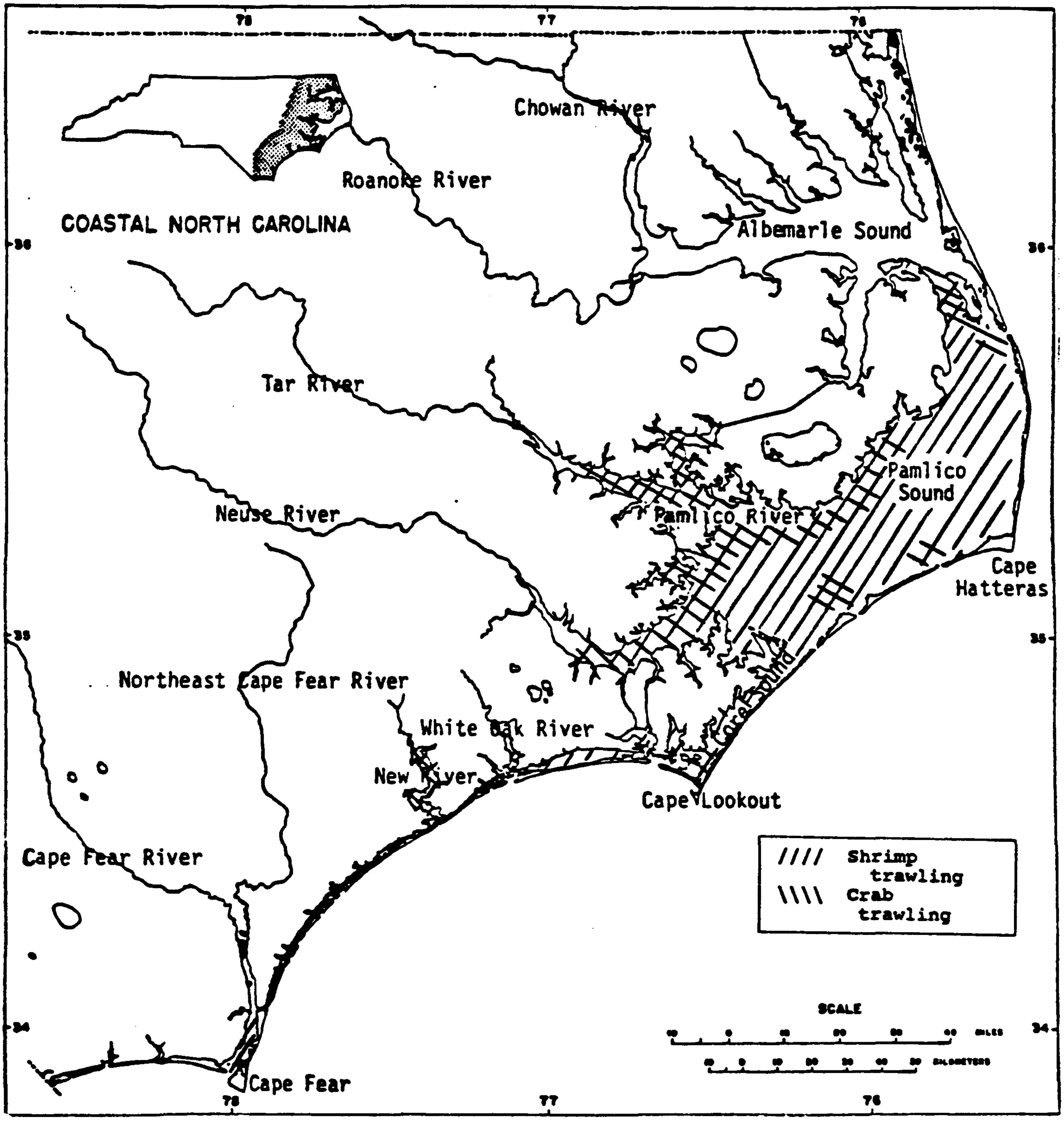


Figure IV-5. Shrimp and blue crab trawling areas in North Carolina's estuarine waters.

work most of the year in the mid-Atlantic and New England areas for finfish and/or sea scallops, shrimping in Pamlico Sound only at the peak of the season; and (3) small vessels (40 ft or less) which fish the entire year in Pamlico Sound, primarily trawling for shrimp, but often converting to oyster dredging, crab trawling, or other fisheries. The large vessels generally remain on the fishing grounds several days at a time, while the small vessels usually make one-day trips.

Shrimp trawling is also of major importance to the Core Sound area but is of little importance to the low salinity Albemarle Sound area. Most Core Sound vessels are small and work only at night. In Pamlico Sound, shrimping is usually conducted around the clock.

Because of the high use of fixed gear, all trawling is illegal in Albemarle Sound to minimize user and fishing gear conflicts; directed trawling in the Pamlico and Core Sound areas is restricted to shrimp, blue crabs, and flounder (while crab trawling). Shrimp provide the vast majority of the landings in this fishery. Catches vary widely from year to year since they depend on three annual species whose abundance is controlled by environmental factors. Technological advances in the shrimping industry have significantly increased the catching effort of larger boats, particularly in Pamlico Sound. Most boats in the 1940s and 1950s pulled a single trawl; presently, the majority of boats in Pamlico Sound are "four-barrelled" (they utilize four nets).

D. 2. b. Long Haul Seine Fishery. The long haul fishery is unique to the Albemarle-Pamlico estuarine area. It began in the Neuse River and Albemarle Sound area in the early to mid 1800s (Goode 1887). At that time the nets were limited in size to about 80-100 yards because they were hauled by sail skiffs. By 1925, the methods of long hauling from engine-powered boats had become almost identical to today's practices (Higgins and Pearson 1928). The modern-day seine, approximately 1,500 yards long, is pulled between two boats (long hauling) or from one boat (swipe netting) to a shoal area where the net is brought together around a stake. The fishermen "foot" the net while they are overboard. Methods of footing the net in deep water (up to 18 feet) have been developed and are now used by some fishing crews in northern Pamlico Sound and Croatan Sound. Guthrie et al. (1973) described in detail the methods used. In addition to an early study by Higgins and Pearson (1928), the DMF has been conducting studies since the 1970s to characterize the long haul fishery and to monitor the catch composition of the long haul fishery (Sholar 1979; DeVries 1980; DeVries 1981; DeVries and Ross 1983; Ross and Moye 1989; Ross et al. 1986). Harvest generally occurs from April through October and catches primarily Atlantic croaker, spot, weakfish and Atlantic menhaden. As shown in Table IV-7, these four species comprised over 87% of the long haul catch sampled by DMF in 1987. Table IV-6 indicates an average catch exceeding 9 million pounds for long hauls in the Pamlico Sound area, while they account for about one-third of Core Sound's total landings. The fishery generally occurs throughout the estuarine system (Ross et al. 1986).

The long haul seine fishery operates from Bogue Sound to Croatan Sound (Figure IV-6) and has been present in North Carolina since the early 1900s. This fishery peaked during between 1977 and 1983 when roughly 50-60 different crews made landings (Ross et al. 1986). The harvest has declined from an average of 17 million pounds annually during that period, to about 9.5 million pounds annually between 1984 and 1988. By 1987-88, the number of fishing crews was down to fewer than 30 (West 1989). Probable reasons for the decline are complex but include competition for space with fixed gear (crab pots and pound nets) and an apparent reduction of availability of target species. As noted earlier, stocks of several important species probably peaked during the late 1970s and early 1980s; several of these species (croaker, weakfish, spot) are important to the long haul fishery.

The centers of activity for the fishery are in northern Pamlico Sound/Croatan Sound and southern Pamlico Sound/Core Sound. The southern fishery utilizes the traditional method of fishing in relatively shallow waters near shoals (4-9 feet) and harvests primarily spot. The northern fishery has developed

Table IV-7. Species composition and abundance for the long haul seine fishery, Albemarle-Pamlico Estuaries, North Carolina, 1987 (adapted from Ross and Moye 1989). (% Freq. of occur. is the percentage of long hauls containing this species).

Common name	Species	Total number	% of total	% Freq. of occur.
Atlantic croaker	Micropogonias undulatus	962,604	36.1	94.5
Spot	Leiostomus xanthurus	752,636	28.2	100.0
Weakfish	Cynoscion regalis	308,851	11.6	92.7
Atlantic menhaden	Brevoortia tyrannus	305,175	11.5	61.8
Pinfish	Lagodon rhomboides	168,401	6.3	72.7
Silver perch	Bairdiella chrysouara	44,872	1.7	57.3
Pigfish	Orthopristis chrysoptera	38,373	1.4	63.6
Bluefish	Pomatomus saltatrix	24,915	0.9	78.2
Southern kingfish	Menticirrhus americanus	12,084	0.5	50.9
Spotted seatrout	Cynoscion nebulosus	7,997	0.3	56.4
Lookdown	Selene vomer	4,791	0.2	17.3
At. thread herring	Opisthonema oglinum	3,211	0.1	10.0
Blue crab	Callinectes sapidus	3,674	0.1	63.6
Crevalla jack	Caranx hippos	2,665	0.1	10.9
Flounder	Citharichthys spp.	2,363	0.1	1.8
Harvestfish	Peprilus alepidotus	2,302	0.1	24.5
Southern flounder	Paralichthys lethostigma	2,241	0.1	35.5
Summer flounder	Paralichthys dentatus	2,018	0.1	28.2
Atlantic spadefish	Chaetodipterus faber	1,806	0.1	7.3
Butterfish	Peprilus triacanthus	1,574	0.1	10.9
Others		12,338	0.5	

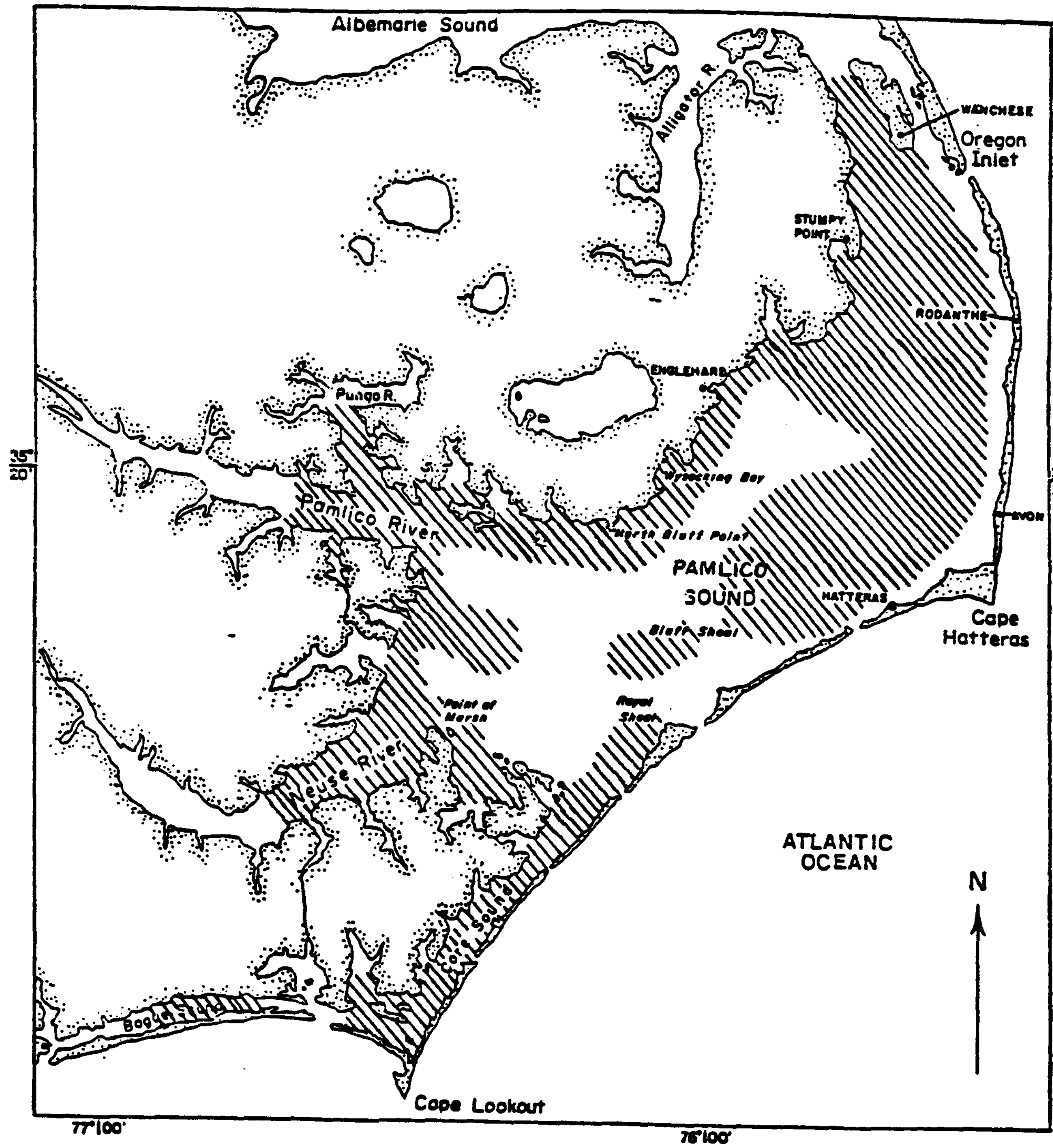


Figure IV-6. Fishing grounds (hatched areas) of North Carolina's long haul fishery.

the capability to fish the nets in relatively deep waters (12-18 feet) and harvests primarily Atlantic croaker.

The DMF has had an ongoing stock assessment program for the long haul seine fishery since 1981 (Ross et al. 1986; Ross and Mayo 1989). Examination of catch-per-unit-effort (CPUE) data for the period from 1981 to 1988 reveals no statistically significant trend for the fishery as a whole or specifically for spot, Atlantic croaker, or weakfish (Figure IV-7).

D. 2. c. Pound Net Fisheries. Pound nets are large stationary devices which lead and trap fish. Forms of pound nets made of hedging were used by coastal Indians and early settlers. In the Albemarle-Pamlico estuarine system there are three major pound net fisheries conducted in different areas, during different seasons, to catch different species of fish (Figure IV-8).

During the spring, a major fishery using pound nets occurs in the Albemarle Sound area, especially the Chowan River (Cobb 1906; Street and Pate 1975; Johnson et al. 1977; Winslow 1989; Winslow et al. 1983, 1985). This fishery is directed toward adult river herring migrating to spawning areas. Historically, the fishery was the largest fishery in the area with a large processing segment (Wynns 1967). Landings have become variable in recent years; roughly 11 million pounds were landed in 1985 compared to less than 1.2 million pounds landed in 1990 (Table IV-6). In addition to herring, pound nets catch catfish and white perch (Keefe and Harris 1981). On the average, pound nets account for about 45% of Albemarle Sound's total landings (Table IV-6).

Another major pound net fishery harvests migrating flounder in the fall. This fishery occurs in eastern Albemarle Sound, in eastern Pamlico Sound behind the Outer Banks, and throughout Core Sound (Wolff 1977; Epperly 1984). The fishery is directed at southern flounder migrating from the estuary to the ocean. Although they are the major species landed in North Carolina, relatively few summer flounder are caught in the estuarine pound net fishery.

The third major pound net fishery occurs in the deeper waters of Pamlico Sound during the warmer months. This fishery primarily targets estuarine migratory species, including Atlantic croaker, spot, and weakfish. Numerous other species are also taken, including Atlantic menhaden, bluefish, harvestfish (Peprilus alepidotus), Spanish mackerel, and butterfish (Peprilus triacanthus) (Higgins and Pearson 1928; Ross and Moye 1989; Ross et al. 1986; Sholar 1979).

The pound net fishery for river herring in the Chowan River has experienced greatly reduced catches since its peak in the late 1960s and early 1970s (Street 1988). Area fishermen maintained that fish were available between 1986 and 1988 but that weather and conditions hurt the fishery (Winslow 1989). Juvenile abundance data indicate considerable variability from 1972 to 1988, with poor year classes from 1986 to 1988. However, landings are comprised mostly of fish four to six years of age (Winslow 1989), so a paucity of juveniles during 1986-88 would not affect the landings for several years. DMF data (unpublished) indicate that landings in 1989 were the lowest on record.

The flounder pound net fishery in the fall has experienced fairly stable or somewhat increased landings in recent years (DMF unpublished data). This fishery depends on southern flounder, a different species from that comprising the bulk of winter landings from the ocean. An assessment program for this fishery began in 1989 to provide data to guide its management. An increase in the minimum size limit for flounder in North Carolina (from 11 to 13 inches) effective in late 1988, should improve the yield in this fishery, as well as in the ocean fishery for summer flounder. Working with fishermen, DMF developed a modification to the pound net gear with a larger mesh size which can release undersize flounder, thereby reducing waste.

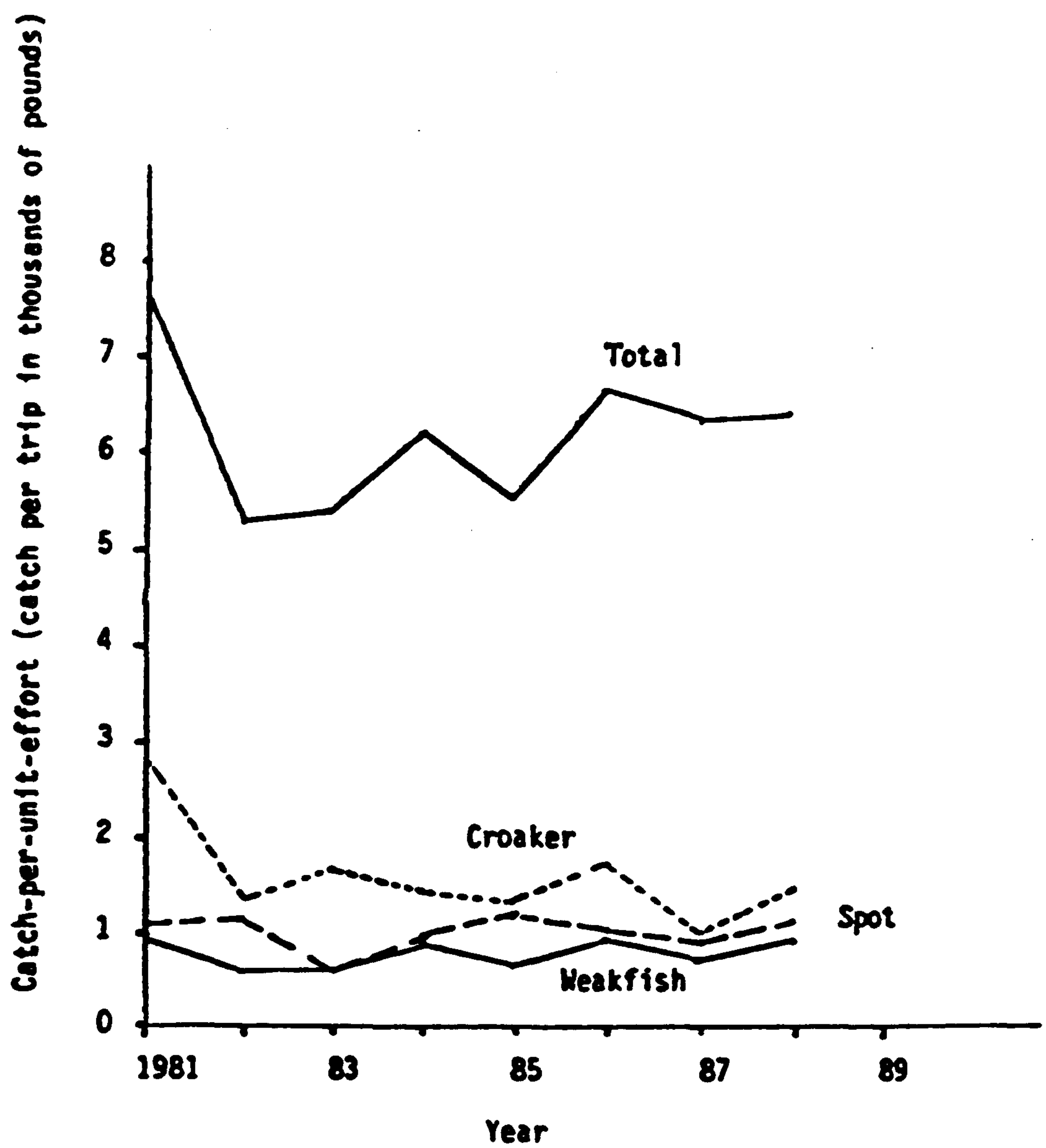


Figure IV-7. Catch-per-unit-effort (CPUE) for North Carolina's Long Haul Seine Fishery, 1981-1990 (DMF).

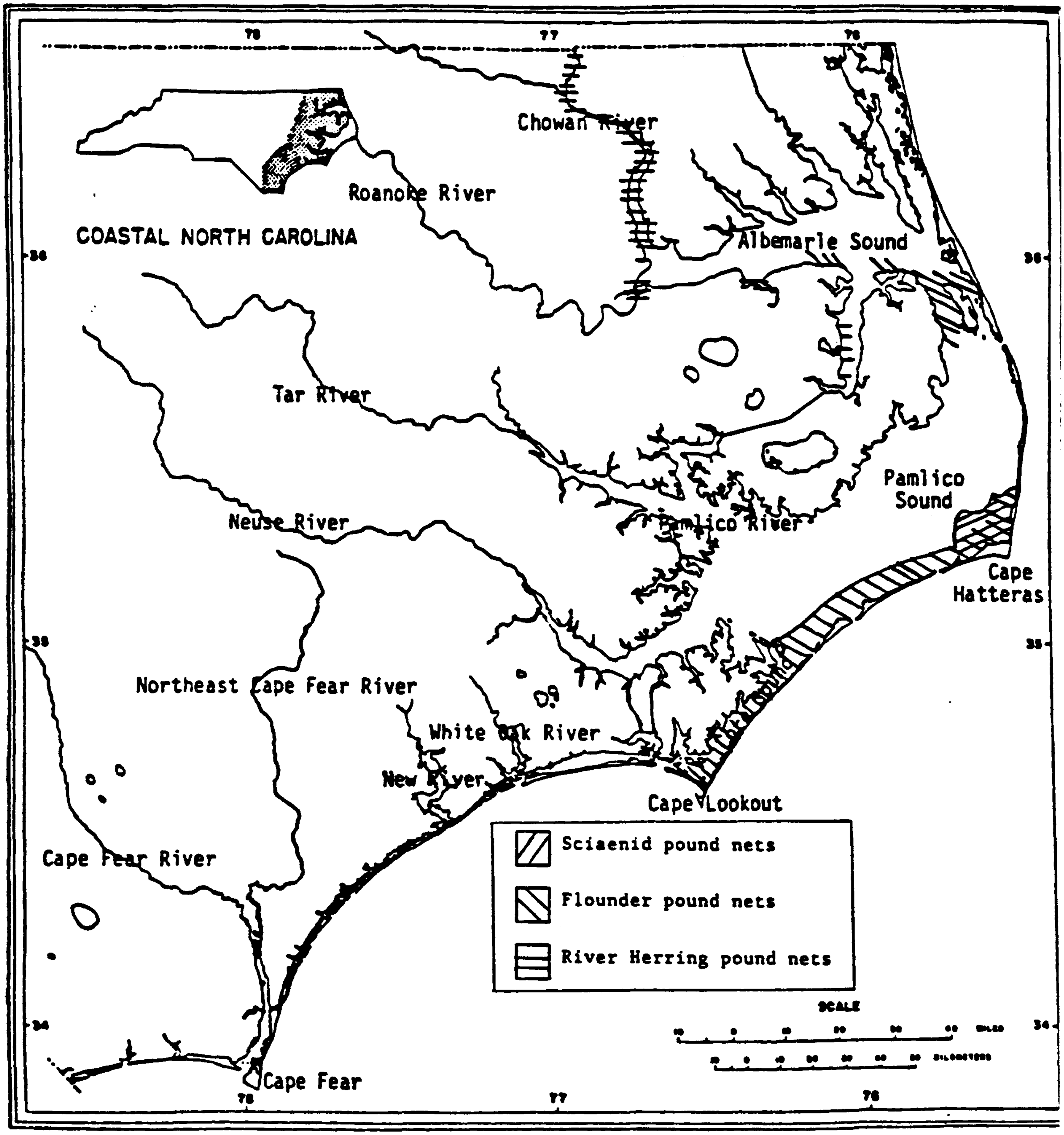


Figure IV-8. Fishing areas for North Carolina's three pound net fisheries: sciaenid, flounder, and river herring.

The summer pound net fishery, which targets spot, Atlantic croaker, weakfish (sciaenids), and harvestfish, has been a major commercial fishery in Pamlico Sound since the 1920s. The number of summer pound nets has fluctuated widely since the 1920s (Higgins and Pearson 1928). Sciaenid pound nets are no longer used in the Pamlico and Neuse River. The numbers in Pamlico Sound have decreased from a high of 30 stands in 1928 to 12-14 stands in 1987 (Ross et al. 1986; Ross and Moye 1989).

The DMF has had an ongoing stock assessment program for the sciaenid pound net fishery since 1982. Catch-per-unit effort data indicate that Atlantic croakercatches have not decreased, spot catches decreased but have become stable, and weakfish catches have decreased since 1982 (Table IV-6).

D. 2. d. Gill Net Fisheries. The estuarine gill net fisheries employ stationary nets of various mesh sizes, depending on target species. Estuarine gill nets produce about 17% of the annual Albemarle Sound landings (Table IV-6). Gill nets are the most widely used gear in the Albemarle Sound area and are the principal gear used for striped bass. Gill nets are used to catch anadromous species during their spring spawning runs, as well as mullet (Mugil cephalus), white perch, and southern flounder (Keefe and Harris 1981; Epperly 1984). Gill nets are used in other areas of the estuarine system to catch most other estuarine species, especially southern flounder. Large numbers of gill nets are also used by recreational fishermen to catch fish for home consumption.

Gill nets are set in much of the Albemarle-Pamlico estuarine system without being targeted at a specific species, especially during the summer when much of the gillnet effort is by recreational fishermen. The fishery is most directed in Albemarle Sound during the fall for white perch, during the winter for striped bass, and during the spring for American shad. Directed shad and southern flounder fisheries also occur in the Neuse and Pamlico Rivers and Pamlico Sound each spring. As noted earlier, the Albemarle-Roanoke stock of striped bass is depressed and landings have declined greatly, due both to reduced abundance and restrictive regulations designed to promote stock recovery. The Albemarle Sound gill net fishery has shifted to other species, especially in the fall. In recent years near-drought conditions have increased the salinity level in much of Albemarle Sound, bringing in species such as croaker, weakfish, and bluefish. As a result, total gill net landings have been relatively stable in Albemarle Sound (Table IV-6).

D. 2. e. Crab Pot Fishery. Blue crabs are the single most important commercial species in the estuary in terms of pounds landed, number of people involved in the fishery, processing volume, and total value. The Albemarle-Pamlico estuarine system produces about 95% of the blue crabs caught in the state, averaging over 25 million pounds per year. Pots catch around 95% of the crabs landed. Current estimates indicate that about 535,000 pots are in use (DMF unpublished data).

Limited studies have been conducted on the biology of, fishery for, and management of the blue crabs in the Albemarle-Pamlico estuarine system. Larval and juvenile abundance was investigated by Dudley and Judy (1971, 1973), and Wolff (1978). Fischler (1965) estimated the abundance of blue crabs in the Neuse River using catch-effort, catch data, and tagging. Tagging studies were also reported by Judy and Dudley (1970) and Sholar (1983). The blue crab fisheries were described by Pearson (1951), Wolff (1978), and DeVries (1981). In addition, Sholar (1982) described the Pamlico Sound area as "the major production area for the South Atlantic." Maiolo et al. (1985b) described the socio-economic aspects of the blue crab fishery in the estuary. Little stock assessment data exists for the crab pot or trawl fisheries.

The blue crab is North Carolina's most important species in terms of processed products. Table IV-8 indicates the number of processing plants and the processed products value by year for the Albemarle-Pamlico area. The decline from 1987 to 1988 was probably related to reduced catches and markets associated with the redtide episode of 1987-88. Although some other species and processes (river herring salting and canning, flounder filleting, and oyster shucking) are included in these figures, the majority of the value is attributable to blue crab processing.

Table IV-8. Seafood processing plants and processed product value for the Albemarle-Pamlico area, North Carolina, 1975-1988.

Year	No. plants	Processed products value
1975	75	$21,351,000
1976	69	21,558,000
1977	67	22,835,000
1978	68	21,065,000
1979	80	35,115,000
1980	83	32,481,000
1981	86	43,756,000
1982	90	41,360,000
1983	93	50,107,000
1984	98	54,663,000
1985	97	59,197,000
1986	103	65,894,000
1987	103	76,955,000
1988	98	64,760,000

For management purposes, blue crabs, like shrimp, can be considered as an annual crop of which a high proportion of the available stock may be harvested without affecting future production. Historic landings data (Street 1988; Chestnut and Davis 1975) show high production during the 1960s, reduced landings from 1971 to 1977, record landings each year from 1978 to 1982, decline through 1986, and return from 1987 to 1990 to levels of the record period. Effort data are poor, both for actual numbers of pots and the effectiveness of individual pots. Estimates of the number of pots provided voluntarily by fishermen on their vessel license applications and through DMF's statistics program's annual operating units survey vary widely. Many crabbers work on a part-time or seasonal basis. In specific geographic areas exploitation of blue crabs is high. Between 1980 and 1982, DMF personnel tagged several thousand blue crabs in various tributaries of western Pamlico Sound. Return rates for some groups of tagged crabs greatly exceeded 50% (DMF unpublished data), indicating the intensity of the existing fishery. Fishing effort is probably even greater at the present time.

The fishery along the Outer Banks and in Core Sound harvests large numbers of females, including egg-bearing ("sponge") females, while the catch in the western Pamlico Sound area and Albemarle Sound takes males and females, but relatively few egg-bearing females. This situation is due to the biology of the species; males stay in low salinity areas, while females migrate after mating to the inlets, extruding egg mass en route. There is no biological evidence that harvest of females at any stage of maturity has any effect on future stock size. Sponge crabs are, however, considered undesirable by crab processors since crabs are purchased by weight and the dealers get no return for the weight of the egg masses they purchase, and since the meat of egg-bearing females is of poor quality relative to non-sponge crabs. Consequently, there are periodic efforts to regulate the harvest of sponge crabs.

Of particular importance is the growth of the crab pot fishery in the Albemarle Sound area (Table IV-6), from a minor fishery during the 1970s, to the highest landings of any given year since 1986. This increase is probably attributable to two factors characterizing the Albemarle area: increased exploitation of previously under-utilized blue crab stocks in much of the Albemarle Sound area, and probable increased abundance of blue crabs in the Albemarle area due to increased general salinity in the area, as noted above in the "Gill Net Fisheries" discussion. Changes in the regulatory regime for finfish in the Albemarle Sound area have also encouraged some fishermen to change from finfish gill netting to crab potting.

As long as environmental conditions remain favorable for blue crabs (the controlling environmental factors are not known, specifically), the fishery will probably continue to be the most important in the coastal area. Conflicts will likely increase, however, as the presence of crab pots interferes with moveable gears (long haul seines and trawls) and as recreational boating continues to increase, and as the number of pots continues to increase. The DMF has recently initiated a blue crab stock assessment program to help determine harvest effects.

D. 2. f. Anadromous Fisheries. In general, populations of all anadromous species continue to decline in numbers throughout the A/P Study area (Table II-3). Over-harvest is one cause for decline of these populations, but degradation of available spawning habitat has contributed as well (Manooch and Rulifson 1989, Rulifson and Manooch 1990b). Only two species in North Carolina have undergone extensive stock restoration efforts through culturing. Striped bass and American shad, have been the focus of efforts by the US Fish and Wildlife Service and NC Wildlife Resources Commission, yet populations continue to decline.

During the late 1800s the North Carolina shad fishery reached its peak, at one time exceeding production in all other states (Smith 1907). In 1896 the Neuse River was regarded as the most important shad-producing stream between the James River, Virginia and the St. Johns River, Florida. After 1900, decline in numbers was attributed to over-harvest, so the NC Legislature enacted a law to protect shad from over-harvest.

Currently, commercial harvest of anadromous species is regulated by the State of North Carolina and the federal government. Regional fisheries councils have enacted management plans for the ocean harvest of anadromous alosids (shad and river herring) and striped bass. The shortnose sturgeon is protected as an endangered species; the Atlantic sturgeon management plan is currently underway. The NC Division of Marine Fisheries regulates commercial and recreational harvest of the estuaries, sounds, and 3 miles of coastal ocean. The NC Wildlife Resources Commission regulates recreational harvest in inland waters -- no commercial harvest is allowed in inland waters. North Carolina is the only Atlantic coast state that allows recreational harvest of striped bass in the spawning grounds. No comprehensive anadromous fish management plan exists at this time, but a cooperative agreement was reached in 1990 by the US Fish and Wildlife Service and two state agencies to manage striped bass in North Carolina.

D. 2. g. Other Commercial Fisheries. Many other commercial fisheries are also conducted in the area, including the oyster dredge fishery, the bay scallop dredge fishery, and the soft-shelled crab fishery. The economically productive bay scallop fishery was investigated by Spitsbergen (1979) and Kellogg et al. (1985). Another fishery, found principally in Core Sound, is mechanical clamming (Taylor et al. 1985). This fishery includes clam "kicking", which utilizes the wash from propellers and heavy trawls to catch buried hard clams, as described by Guthrie and Lewis (1982). Clams are also harvested with a variety of other gears in the Core Sound area including rakes, tongs, bull rakes, and hydraulic dredges.

D. 3. Recreational Fisheries

The recreational fisheries contribute substantially to the local economy in the form of pier use fees; charter fees; boat, bait, and tackle sales; marina use; and hotel and restaurant trade (Street and McClees 1981). In addition, the recreational fisheries are an important component of the overall fishery harvest. For a number of important species including bluefish, spotted seatrout, red drum, and Spanish mackerel, the recreational fishery harvest usually exceeds the commercial harvest. Recreational fishermen in the Albemarle-Pamlico estuarine system catch a wide variety of species (Table IV-9). The average number of fish per angler trip for the Albemarle-Pamlico estuarine system was higher than the statewide catch per trip during 1988 (Table IV-10). Atlantic croaker was the fish caught most frequently by recreational anglers. Eight species (Atlantic croaker, pigfish (Orthopristis chrysoptera), summer flounder, pinfish, weakfish, spot, spotted seatrout and bluefish) comprised 81% of the total catch (Table IV-10). In addition to recreational hook-and-line fishing, pleasure fishermen also utilize commercial techniques and equipment to catch a variety of finfish and shellfish for personal consumption. These gears include gill nets, pots, and shrimp trawls and hand gears such as rakes, dip nets, gigs and tongs. Pate (1977) attempted to quantify the recreational catch of shrimp with trawls. Although statistical data on the harvest of the fishery resources by recreational fishermen are limited, they are thought to take substantial numbers of finfish, as well as blue crabs, oysters, clams, shrimp, and scallops with commercial equipment. "Pleasure" vessels, those which use commercial gear for personal consumption, form the largest category of commercially licensed fishing vessels in North Carolina. Since 1980, such vessels have comprised 53% of the total licensed commercial fishing vessels in North Carolina (Table IV-11). Recreational fishermen utilize the Albemarle-Pamlico estuarine system to harvest the same resources as commercial fishermen. As a result, occasional competition and conflict exist between commercial fishing and recreational fishing interests seeking similar harvest opportunities.

D. 4. Summary of Trends

Following are a number of trends in the commercial fisheries which are apparent from the preceding discussions. Recreational data are insufficient to indicate any long-term trends (1987-present).

1. Landings of the major finfishes, most of which have fairly similar life histories and are taken by the same fishing gears, reached historic peaks in the late 1970s and early 1980s and have since declined. Reasons for the peak are unknown. Weakfish, Atlantic croaker, and summer flounder landings have declined significantly. The landings of these species have also declined throughout the Atlantic coast. Weakfish and summer flounder have been determined to be in an over-fished status. Atlantic croaker are being growth over-fished (not maximizing yield).

2. Landings of anadromous fishes (fish which spawn in freshwater but spend most of their life in salt water -- striped bass, American shad, and river herring) have declined since the early 1970s, or before. The American shad fisheries in particular have declined in Pamlico Sound and the Neuse and Pamlico Rivers. The reasons for the decline of American shad in North Carolina are specifically unknown, however, Atlantic coast stocks have been affected by habitat degradation, loss of spawning areas, and over-fishing. River herring initially declined because of excessive catches by foreign vessels in the ocean, but recovery has probably been impeded by poor water quality in the Albemarle Sound spawning and nursery areas. Reproduction of striped bass in the Roanoke River has been unsuccessful since 1977, probably due principally to water quality and water flow problems. Reproductive success improved somewhat in 1988 and 1989, but fell in 1990 (DMF JAI data). Striped bass have continued to decline in the Pamlico River.

3. Shrimp landings fluctuate widely, depending on environmental conditions. The shrimp trawl fishery has developed more effective methods to harvest shrimp, such as the ability to use four nets per boat.

4. Landings of blue crabs, North Carolina's most important commercial species, reached peak levels in the early 1980s, declined, and have again increased. Factors controlling abundance are unknown. Blue crabs were harvested by trawls, but are presently harvested by pots. Effort, in terms of numbers of pots, has increased dramatically.

Table IV-9. Species Composition, Reported and Observed Catches by Area from the North Carolina Marine Recreational Fishery Statistical Survey, 1988. (Numbers indicate relative abundance of fish, but not the total catch for the area). (DMF)

Common name	Scientific name	Total	Albemarle Sound area		Pamlico Sound area		Core Sound area	
			Reported*	Observed	Reported*	Observed	Reported*	Observed
Croaker, Atlantic	*Micropogonias undulatus*	3578	814	1124	428	964	94	154
Pigfish	*Orthopristis chrysoptera*	1345	20	29	152	47	245	852
Flounder, summer	*Paralichthys dentatus*	925	119	44	312	423	1	26
Pinfish	*Lagodon rhomboides*	552			40	5	435	72
Weakfish	*Cynoscion regalis*	529	64	85	17	234	8	121
Spot	*Leiostomus xanthurus*	468	1	10	140	200	20	97
Seatrout, spotted	*Cynoscion nebulosus*	408	2	40	20	142	42	162
Bluefish	*Pomatomus saltatrix*	326		24	93	142	26	41
Lizardfish, inshore	*Synodus foetens*	273			211	4	57	1
Mullet, striped	*Mugil cephalus*	268			9	247	7	5
Sea Bass, black	*Centropristis striata*	190	5		80	25	68	12
Toadfish, oyster	*Opsanus tau*	133	20		67		42	4
Sheepshead	*Archosargus probatocephalus*	105		3			15	87
Drum, red	*Sciaenops ocellatus*	105			14	28	31	32
Killifish, striped	*Fundulus majalis*	98			30	68		
Puffer, northern	*Sphoeroides maculatus*	89			33	10	21	25
Kingfish, southern	*Menticirrhus americanus*	71	7	6	1	36		21
Kingfish, northern	*Menticirrhus saxatilis*	69				2		67
Skates	Rajidae	64	47		15		2	
Mackerel, Spanish	*Scomberomorous maculatus*	54			2	8	1	43
Flounder, southern	*Paralichthys lethostigma*	52		3	5	44		
Bass, striped	*Morone saxatilis*	43	32	11				
Searobins	*Triglidae*	43			8		32	3
Perch, silver	*Bairdiella chrysoura*	38		7	6	4	3	18
Flounder, lefteyed	Bothidae	38			5		21	12
Searobin, northern	*Prionotus carolinus*	25			22	1	2	
Sharks	Squaliformes	20	3		5		12	
Stargazer, southern	*Astroscopus y-graecum*	14	2		12			
Toadfishes	Batrachoididae	12					12	
Sunfishes	Centrarchidae	12	12					
Skate, clearnose	*Raja eglanteria*	11			11			
Puffers	Tetraodontidae	11			11			
Perch, white	*Morone americana*	8		8				
other species		69						

* - Reported - Number reported by fishermen but unconfirmed by intercept agent.

x - Observed - Fish observed, identified, and recorded by intercept agents.

Table IV-10. Number of Interviews, Angler Trips, Total Fish Caught, and Mean Fish Per Angler Trip for the Albemarle, Pamlico and Core Sound areas, 1988. (Angler trips and Total fish represent only those included in the field samples and are not estimates of total trips or fish for the year). DMF, unpublished data.

	Number of interviews	Angler trips	Total fish	Mean fish per angler trip
Albemarle Sound area	166	169	2,649	15.7
Pamlico Sound area	636	658	4,431	6.7
Core Sound area	241	292	3,080	10.5
Albemarle-Pamlico Estuarine System	1,043	1,119	10,160	9.1
All State waters	8,215	6,830	51,797	5.9

Table IV-11. Numbers of Licensed North Carolina Commercial Fishing Vessels by License Categories, 1980-1990. (DMF)

	Commercial			
Year	Full-time vessels	Part-time vessels	Pleasure and hire vessels	Total vessels
1980	3,792	8,162	13,282	25,236
1981	4,090	7,765	13,596	25,428
1982	4,217	7,283	14,599	26,099
1983	4,021	6,334	14,411	24,766
1984	3,950	5,913	11,277	21,140
1985	4,228	5,632	11,472	21,332
1986	4,159	5,671	11,366	21,196
1987	4,391	5,694	10,815	20,899
1988	4,566	5,746	10,216	20,659
1989	4,730	5,719	10,119	20,731
1990	4,780	5,402	10,017	20,199

5. The hard clam fisheries of Core Sound and other areas are probably producing near their maximum potential, given the existing regulatory controls and mix of harvest methods used.

6. Oyster landings have declined to the lowest levels on record. Harvest pressure, loss of habitat, the pathogens MSX and Dermo, and water quality degradation (as measured by fecal coliform and anoxic and hypoxic events) have contributed to the decline. Intensive management measures have been utilized to maintain/enhance the oyster resource.

7. Certain water quality associated concerns which have the potential to negatively affect fisheries in the A/P area are becoming more severe, such as fish and crab diseases and losses of shellfish habitat. Reports of fish kills, algal blooms, and hypoxia are becoming more frequent.

8. Downward trends in total commercial landings of edible finfish species continue and may indicate declining stocks. Current or increasing levels of fishing pressure on such stocks will likely lead to increased social conflicts among all fishermen (commercial and recreational) for access to the available resources, and resultant calls for the state to "solve" such problems.

9. Continuing stock declines, initially attributable to pollution, environmental conditions, or natural variations in abundance, will likely be magnified by fishing mortality caused by commercial and recreational fishermen. Such a situation will result in the need for restrictions on fishing. Such restrictions on harvesters, when biologically justified, are necessary and must be undertaken in concert with actions aimed at improving environmental conditions.

E. EFFECTS OF FISHING PRACTICES ON HABITAT

Virtually all of the current fishing practices of the Albemarle-Pamlico estuarine system have been used for generations. A brief history of commercial fishing in North Carolina was provided by Godwin et al. (1971). Pound nets were introduced in the Albemarle Sound area in 1870 (Earll 1887). This gear is similar to devices used by Indians and illustrated by John White of the Roanoke colony in the 1580s (Wilder 1963). Gill nets were in use by the latter third of the 19th century (Wilder 1963). Oyster dredges were extensively used in Pamlico Sound in the 1880s (Godwin et al. 1971). Long haul seines have been used in North Carolina since the early 1800s (Earll 1887). Trawls were first used in North Carolina before World War I, and have been the major gear for shrimp since at least 1918 (Chestnut and Davis 1975). In contrast to the older gears, crab pots were introduced from the Chesapeake Bay in the early 1950s and became the dominant gear by 1959 (Chestnut and Davis 1975). "Clam kicking" refers to the use of vessel propeller wash to dislodge hard clams so they can be caught by a heavily weighted trawl towed behind the boat. The practice began in the 1940s and changed little until the late 1960s or early 1970s (Guthrie and Lewis 1982) when a number of innovations were implemented. Hydraulic escalator dredges have been used to harvest clams since the 1960s. Various other gears are used for commercial fishing in the Albemarle-Pamlico estuarine system including hand gears such as rakes and tongs for clams and oysters, toothless dredges for bay scallops, channel nets (anchored trawls held open by the ebbing tide) for shrimp, and eel pots.

Fixed gears generally have little or no significant effect on the habitat. Such gears include gill nets, crab and eel pots, and pound nets. Pots may create some turbidity when dropped to the bottom or from interactions with bottom currents. Stakes and anchors used with gill nets may have very minor, temporary effects. Channel net anchors are similarly benign. Pound net stakes have a one-time impact during the setting procedure, with negligible habitat effect thereafter.

Movable gears are generally assumed to have greater impact on the habitat than fixed gears. As a conservation practice, most movable gears are banned from use by the MFC in designated primary nursery areas. For most of the gears, little or no information on effects is available. Hand rakes and tongs used to harvest oysters and clams dig into the bottom and stir surficial sediments. When rakes and tongs are used in seagrass beds, some vegetation is lost, however, effects are judged to be so minor that the MFC allows their use in primary nursery areas. Bay scallop dredges are toothless steel and netting devices dragged over seagrass beds to catch scallops. A leading bar prevents them from digging into the bottom, but considerable amounts of grass are broken loose. Fonseca et al. (1984) concluded that scallop dredges have a negative effect on eel grass meadows. Unfortunately, peak meat weight (thus, desirability for harvest), peak juvenile attachment, and low seagrass biomass occur at the same time. Research is underway on the effects of use of scallop dredges for adult harvest on juvenile bay scallops.

Long haul seines herd their catch as they are pulled across the bottom. While it depends on the bottom type and the weight of the bottom line (lead line) of the seine, this gear seems to have a minor effect on the bottom. In grass beds, some damage undoubtedly occurs. To the degree that the seine may dig into the bottom and/or catch in the grass, additional energy must be expended to haul the net, costing the fishermen time and money. The lead line must, however, stay very close to the bottom to prevent fish from escaping under the net. No research is known on the effects of long haul seines on the bottom.

Hydraulic escalator dredges are used in North Carolina and South Carolina for hard clams, in Maryland for soft clams, and in New York for oysters. These gears dig trenches of varying depths and widths in the bottom, so their use is strictly regulated by the MFC, with limited areas available only during the winter (December-March). Physical effects on the bottom and its infauna are probably similar to those of clam kicking (Peterson et al. 1987), but hydraulic escalator dredges do not appear to hurt hard clams. The DMF has regulated the use of hydraulic dredges in New River below the North Carolina highway 172 bridge since the mid-1970s. This area is quite unique, with depths of 12-18 ft, which are beyond the harvest ability of all but the largest hydraulic dredges. No research has been conducted on the effects of the fishery on the habitat in this area. The area is opened to harvest every other year. Harvest is intensive, with declining catches within a few weeks of the opening of the harvest. After "resting" for a season (actually about 18 months), abundance of harvestable clams has returned to that at the opening of earlier seasons. Thus, recruitment of hard clams does not seem to be hurt by this practice.

Clam-kicking is most prevalent in Core Sound, at the southern end of the Albemarle-Pamlico estuarine system study area. Although fairly shallow (depth not exceeding 10 ft), Core Sound is generally more than two miles wide. Due to prevailing winds and such an expanse of open area, the use of hand gears, such as tongs or bull rakes (used in Chesapeake Bay and New England in depths much greater than 10 feet), is extremely difficult, if not impossible. Thus, mechanical harvest gear is necessary if the clams are to be harvested in much of Core Sound. In order to minimize negative effects on habitat, only open sand areas are made available for mechanical harvest. Adjacent seagrass meadows (eelgrass and shoalgrass) are not opened to mechanical harvest. This management approach is supported by the research of Peterson et al. (1987). Illegal harvest does, however, occur in the grass beds, sometimes resulting in significant local impacts. The high unit price of clams provides an incentive for current harvest, regardless of consequences. The legal harvest of clams by mechanical gears probably has minimal negative effects.

The overall effect of mechanical clam harvest on the habitat is unknown and cannot be determined relative to the period prior to use of mechanical gear because virtually the entire Core Sound area was subjected to clam-kicking during the 1970s, before the MFC enacted restrictive rules. No data are available on the productivity of the area for the period prior to heavy use of kicking and hydraulic dredging, so comparisons of past productivity with present productivity cannot be made.

The use of trawls to harvest shrimp and crabs in Pamlico Sound has become very controversial in recent years. Shrimp trawls operate by dragging across the bottom behind a trawl vessel. Water pressure spreads the "doors" or "otter boards" which are attached to the leading edge of the funnel-shaped net, holding the net open. The bottom line (lead line) of the trawl maintains contact with the bottom. Usually a chain (tickler chain) is attached to the trawl doors ahead of the net. The tickler digs slightly into the bottom to cause the shrimp to jump off the bottom and so be captured by the trawl. Thus, the doors, tickler chain, and trawl leadline all stir the bottom to some extent. The larger the rig, the greater the resulting disturbance. Throughout the 1980s, North Carolina shrimp trawlers have converted their rigs from one or two large nets to four nets, which are believed to take less by-catch, and require less fuel.

Since 1918, trawls have been the principal gear for the harvest of shrimp in North Carolina, accounting for more than 96% of the harvest during recent years (unpublished DMF data), with an average dockside value exceeding $13.6 million annually. On average, the Albemarle-Pamlico estuarine system accounts for about 70% of North Carolina's annual commercial harvest of shrimp (Street 1987). Thus, shrimp trawling is extremely important economically. Prior to the early 1970s, trawling was allowed anywhere within the estuary once the season opened in that area. Trawling occurred in marsh creeks small enough that the trawl boards were in the marsh grass on each side of the creek. As the DMF primary nursery area surveys were being conducted between 1970 and 1976, trawling was prohibited in the designated areas. Since 1977, MFC regulations have prohibited trawling in all designated Primary Nursery Areas. Trawling has been restricted in many estuarine bays since the late 1970s. Most of these areas were formally designated as Secondary Nursery Areas in 1986 by the MFC, with a prohibition on trawling. The Albemarle Sound area was also closed to trawling in 1987 by the MFC because of the overwhelming long-term use of fixed gears in that area. Trawling in the Albemarle-Pamlico estuarine system is generally restricted to the open waters of Pamlico Sound, Neuse River, Pamlico River, Bay River, and Core Sound.

Brown shrimp provide the majority of shrimp landings in North Carolina, generally comprising about two-thirds of the total. In Pamlico Sound, they are even more important (unpublished DMF data). In Pamlico Sound, brown shrimp grow to very large sizes, usually exceeding 165 mm in length by early fall, when large catches of shrimp in the "16-20" range (16-20 tails per pound) may be taken in the Sound. Brown shrimp of such a size are only rarely found elsewhere along the Atlantic coast, and are not found again until the Gulf of Mexico shrimping grounds off Louisiana and Texas.

No studies have been conducted in North Carolina to examine the effects of trawling on the estuarine habitat. A South Carolina study examined trawl effects on sediments and benthic organisms in two South Carolina estuaries with bottom types and fauna generally similar to those found in the Albemarle-Pamlico estuarine system. The authors concluded that shrimp trawling "did not have a significant adverse effect on the benthic community parameters measured" (Van Dolah et al. 1988). Those parameters included sediment composition, hydrographic conditions, and benthic community structure (diversity, evenness, and richness).

F. DISEASE PROBLEMS

F. 1. Introduction

Very little is known of the actual consequence of disease on populations of aquatic organisms, however, the potential damage that disease can inflict is considerable. Disease may be important in fisheries populations for several reasons. First, the potential impact of diseases upon the amount of biomass of the stock is great. An accurate determination of this value is of great concern to both fishery managers and fishermen, as it influences decisions about the amount of finfish or shellfish that can be harvested. With the sensitivity of present methods, usually only massive, catastrophic acute mortalities are detectable due to the wide degree of natural biological variation (Munro et al. 1983; Vaughan et al. 1986). It is the chronic deterioration in water quality, however, that may affect fishery stocks most significantly. Unfortunately, such chronic effects are often the most difficult to discern (Green 1984; Wedemeyer et al. 1984). Chronic problems are a major dilemma for fisheries managers, since the immediate impacts of the problem may be relatively small and, thus, may be considered relatively unimportant. By the time that the true impact of the pollutant has been fully realized, the population may already have suffered great harm.

Second, disease is important from the standpoint of aesthetics. This phenomenon may have more economic impact than previously thought. Visibly diseased fish are unsalable "in the round". If fillets are affected, they may be totally rejected, thus excluding them from the commercial fishery, regardless of the risk they pose to human health. In addition, people do not like to see sick fish or other animals in the wild. Thus, appearance may reduce the attractiveness of fishing in affected areas, and so could have considerable impact on the valuable recreational fisheries. Such problems often become politicized. Political pressure placed on managers may be somewhat beneficial, by focusing attention on these problems, but it can also be detrimental if it tends to emphasize short-term, stop-gap solutions that fail to recognize or address the problems' inherent complexity (Perry et al. 1987).

Third, is the potential relationship of aquatic animal health to human health. Fish exposed to contaminants such as carcinogens and other toxins often respond in a manner similar to that of mammals and develop neoplasia and other organ dysfunctions (Sindermann 1983). Toxin-producing phytoplankton can accumulate in the edible tissues of marine animals, especially bivalve molluscs, posing potential risk to humans. Also, some pathogens that cause disease in fish (e.g., certain Vibrio bacteria) can be pathogenic to humans. Thus, it is never advisable to consume any animal having lesions that may have high concentrations of such pathogens.

Finally, fish health may be an indicator of general ecosystem health (Sindermann 1988). In aquaculture, high levels of disease are frequently a reflection of sub-optimal environmental conditions that allow pathogens to overwhelm a population's defenses (Plumb 1984; Wedemeyer et al. 1976). It is tempting to extrapolate such findings to natural aquatic populations, but such cause and effect relationships have not been proven.

F. 2. Finfish Diseases

Epidemic disease was first reported in the Albemarle-Pamlico estuarine system in the 1970s, when there were massive kills of largemouth bass (Micropterus salmoides), white perch, and other species in the Albemarle Sound area (Esch and Hazen 1980a). Dying fish frequently had extensive skin lesions, which were referred to as "**red-sores**" (DEM et al. 1976). During certain periods of the summer of 1975, 50% of all the commercially harvested fishes in Albemarle Sound were found to be affected with red sore disease (DMF 1975).

In the 1970s, epidemics of red-sore disease were also reported in a number of freshwater lakes in North Carolina (Miller and Chapman 1976) and in other parts of the southeastern US (Esch and Hazen 1980b). Unfortunately, the term "red-sore" soon became synonymous with any red lesion seen on fish in North Carolina. General use of this term added considerable confusion to the attempts to determine the true cause of these lesions, since red skin lesions on fish can be caused by many factors.

True red-sore disease has been described as a skin infection due to the presence of both a bacterium, Aeromonas hydrophila, and a protozoan, Epistylis (also known as Heteropolaria). Huizinga et al. (1979) stated, based upon experimental infection studies, that the presence of a skin ulcer having only A. hydrophila should be considered as a diagnosis of "red-sore." The utility of this criterion may, however, be questionable since A. hydrophila is probably the most common secondary invader of skin wounds in freshwater fishes and so, more often than not, can be isolated from any skin wound regardless of its cause.

During the massive fish kills in Albemarle Sound and the Chowan River, the affected fish apparently had red skin lesions (DMF 1976). Presumably, many of these fish had Aeromonas-Heteropolaria infections, although the true prevalence of such pathogens in the lesions was never documented. However, based upon the serious fish disease problems being experienced in the Albemarle drainage, a series of studies was initiated by Esch and Hazen (1980b) to study the microbial ecology of A. hydrophila. Using monthly sampling, they found a positive correlation between A. hydrophila concentrations and the levels of fecal and total coliforms, dissolved oxygen, turbidity, chlorophyll a, pheophytin a, sulfate, ammonia, total Kjehldahl nitrogen, total phosphorus, phosphates and total organic carbon.

In previous studies, Esch, Hazen, and co-workers had correlated the increased prevalence of red-sore disease in Par Pond, a freshwater reservoir in South Carolina, with high temperature. An attempt was made to equate hematological parameters of physiological stress to body condition of largemouth bass sampled from Par Pond (Esch and Hazen 1980a). Based upon these previous studies in Par Pond, they concluded that lowered body condition of fish, an indicator of poor health and a result of various stressors in the water: (1) perturbs parameters of physiological stress in the fish, thereby increasing their susceptibility to and the occurrence of red-sore disease, and (2) increases the abundance of the causative agent, A. hydrophila.

The model that Esch and Hazen (1980b) presented relating water quality, A. hydrophila densities, and the stress-related occurrence of red-sore disease is intuitively appealing, especially since high levels of organic matter have been felt to increase the risk of infection by A. hydrophila (Wedemeyer et al. 1976). However, their conclusions largely rested on inference, not on definitive research. Esch and Hazen's (1980b) studies in the Albemarle drainage area focused entirely on the relationship between water quality and bacterial densities. There was no examination of how these two parameters related to the prevalence of fish disease. Instead, they studied the prevalence of red-sore lesions in a body of fresh water (Par Pond) and then attempted to extrapolate this work to an estuarine system (Albemarle Sound). Aside from the inherent dangers in making any such extrapolations, a comparison of these two systems is especially questionable, since the most common pathogens in marine environments are not the same as the ones most commonly found in freshwater systems, even though many may appear clinically similar.

For example, there is some question as to whether Esch and Hazen (1980b) were accurately measuring A. hydrophila densities, since the medium they used for enumeration, Rimmler-Shotts, does not differentiate between A. hydrophila and Group F or EF6 vibrios (Kaper et al. 1981), bacteria which are widely distributed in estuarine environments. Thus, many of the bacteria being counted as A. hydrophila may actually have been Vibrio species. The actual importance of A. hydrophila in the pathogenesis of skin lesions in the Albemarle drainage area is also in question due to the more recent studies which demonstrated that early skin lesions from largemouth bass in the Chowan River had a variety of bacteria present (Noga 1986b). A. hydrophila was not the predominant organism (as defined by colony type) in most cases, and no other bacterium was consistently predominant. Microscopic examination revealed that 31% of all early lesions were associated with Lernaea cruciata infection. This copepod was the most commonly identified agent in early skin lesions. Over 60% of all lesions had no identifiable pathogens, but the histological appearance of most lesions was similar to that seen in L. cruciata infection, suggesting that this parasite may be the primary initiator of skin lesions in largemouth bass of the Chowan River. Examination of other species from the Chowan River and Albemarle Sound also revealed that "red-sore" lesions were associated with many other pathogens, including monogenean trematodes, digenean trematodes, fungi and (rarely) Heteropolaria (Noga 1986b; Noga Unpublished Data). Most of the lesions examined were small, presumptively early stages of disease.

Between November 1986 and May 1987, an epidemic of severe **ulcerations of the tongue and buccal cavity of largemouth bass** was seen in Currituck Sound (Noga et al. 1990). No other external clinical signs were present. Reports from fishermen suggested that as many as 90% of large bass (over 300 mm) were affected at certain times. Older fish were the most commonly affected. The leech Myzobdella lugubris was consistently present on or near the lesions. Lesions were heavily infected with several different bacteria that were apparently secondary invaders. Stressfully high salinity or an interruption in the normal migratory cycle of the parasite were considered as possible causes for the condition.

Recently, other types of diseases have been recognized in Pamlico Sound and its tributaries. In the winter of 1981, the North Carolina DMF investigated **lesions on southern flounder** from the Pamlico and Pungo Rivers that had been captured by the estuarine winter trawl fishery. Affected individuals appeared predominantly in the tributaries between Blount's Bay and Rose Bay. The prevalence of flounder with lesions appeared to significantly decrease when water temperatures increased during spring. From November 1983 to March 1984, more flounder with skin lesions were seen. Exhaustive water quality sampling failed to reveal any obvious abnormalities. Although a virus was isolated from some fish (McAllister et al. 1984), subsequent studies failed to reproduce the disease with this agent.

One of the most common diseases presently affecting fishes in the Albemarle-Pamlico estuarine system is **ulcerative mycosis** (UM), a fungal infection primarily affecting Atlantic menhaden. This disease was first reported in April 1984. First seen in the Pamlico River, it was also reported in the Neuse River as well, with isolated reports from the New River and Albemarle Sound.

Since 1984, repeated outbreaks of UM have occurred that in some instances has resulted in up to 100% infection rates in randomly sampled schools of Atlantic menhaden in the Pamlico River (Levine et al. 1990(b)). In North Carolina, outbreaks are most common in the Pamlico River. The severity of epidemics in other estuaries in the state, like the Neuse River, appears to parallel the severity of the condition in the Pamlico River. During especially virulent episodes, millions of fish may die of the infection (J. Hawkins, DMF, Personal Communication).

The overwhelming majority of fish that acquire the UM infection are young-of-year (age 0) Atlantic menhaden. A similar disease has been observed on southern flounder, striped bass, weakfish, Atlantic croaker, spot, silver perch, gizzard shad (Dorosoma cepedianum), hickory shad, hogchoker (Trinectes maculatus), pinfish, and bluefish (Noga et al. 1991). The prevalence of skin lesions on these other species seems to be greatest during the peaks of the menhaden epidemics (Levine et al. 1990(a)).

In the Pamlico River, where UM has been best studied, outbreaks exhibit a bimodal annual cycle, with peaks in disease prevalence usually occurring between April and June and again between September and December (Levine et al. 1990(b)). The highest prevalence rates occur in low to moderate salinity (about 2-8 ppt). Observations of lay-observers and empirical evidence from sampling surveys (Levine et al. 1990a, 1990b) strongly indicate that the fish are probably acquiring the infection in parts of the estuary exhibiting this salinity range. This conclusion is also supported by the spatial shifting of the focus for high concentrations of infected fish from downriver in the spring-summer epidemic, to farther upriver during the fall-winter peak, corresponding to rising salinities late in the year (Noga et al. 1989a).

UM has several characteristic features that help to distinguish it from other diseases that cause sores on fish. First, and most obvious, are very deep, penetrating, aggressive lesions which commonly perforate the body wall nd expose internal organs. Once dead tissue sloughs off, a crater-shaped lesion is left. Lesions are commonly infected with many different types of bacteria and protozoa. The large numbers of microorganisms present in advanced cases probably contribute to the death of the fish.

The fungi in UM lesions are water molds of the genera Aphanomyces and Saprolegnia (Noga and Dykstra 1986; Dykstra et al. 1986; Dykstra et al. 1989). These organisms have previously been considered to be almost exclusively freshwater pathogens and have rarely been reported to cause disease in estuarine fishes. These water molds or "oomycetes" are common freshwater inhabitants that usually form fuzzy, cottony growths on the skin of freshwater fishes. In contrast with UM, typical oomycete-caused lesions usually do not penetrate deeply into the body. Fishes' inflammatory response to UM is unusually severe; this may reflect the aggressive fungal growth into the tissue. The disease appears to have a high mortality rate, since few fish with evidence of previous infection are seen after an outbreak subsides.

The growth of an Aphanomyces sp. isolated from Atlantic menhaden with ulcerative mycosis was enhanced in the presence of low concentrations of salt (Dykstra et al. 1986). Such growth is very unusual, for this type of water mold is usually inhibited by salt. This finding, however, correlates with the highest prevalence of the disease in waters of low to moderate salinity. Salinity tolerance may also explain how these fungi penetrate deep into fish tissue, which has a high salt content. The tissue of freshwater fish also has a high salt content. While fungi are consistently present in UM lesions, there is now evidence that a bacterium or some other infectious agent is also needed to cause UM (Noga et al. 1989b).

While UM is by far the most common disease affecting Atlantic menhaden in the Pamlico River, many other diseases have been seen in lower prevalence since 1984 (Table IV-12). Among the most important of these problems is an ulcerative disease of American eels (Anguilla rostrata) caused by the bacterium Aeromonas salmonicida (Noga et al. 1989a). The only feature that all of these maladies have in common is that an infectious agent is involved, which is often an opportunistic pathogen. Neoplasia (i.e., cancer) is extremely rare.

Kills of fish without obvious gross lesions are also common in the Albemarle-Pamlico estuarine system, especially in the Pamlico River during late summer and fall. The cause of the majority of these kills is unknown, but where causes have been determined, hypoxia is by far the most important factor (Rader et al. 1987). Hypoxic conditions are usually created by salinity stratification, however, it now appears that hypoxic conditions can develop in unstratified waters (Noga, Markwardt, Berkhoff 1989). Toxins produced by algae have also been suspected of causing mortalities in flounder and other fishes (Paerl 1987). Evidence accumulated through the statewide fish kill monitoring network suggest that more fish may die in acute mortalities in the Albemarle-Pamlico estuarine system than in the rest of North Carolina combined. The number of kills may be increasing (Rader et al. 1987).

Finfish diseases do not appear to be a problem in Core Sound, as evidenced by the lack of observations of diseased finfish by both fishermen's reports and the DMF state-wide trawl survey for juvenile fish and crustaceans, which notes general skin diseases on individuals.

F. 3. Shellfish Diseases

While lesions on finfish have been most intensively studied in the Albemarle-Pamlico estuarine system problems with shellfish have also recently become a concern. In the summer of 1987, fishermen in the Pamlico River began to report blue crabs with shell disease (McKenna et al. 1990). During the course of the outbreak, up to 90% of crabs in individual crab pots were affected (S. McKenna, DMF, Personal Communication). Since crabs with significant amounts of shell disease are unsalable, there is considerable worry among commercial fishermen.

Shell disease (also known as rust disease, black spot, or brown spot) is a common syndrome in both freshwater and marine decapod crustaceans (Johnson 1983). It is considered an infectious disease, and a number of pathogens have been found in the lesions. The most commonly isolated pathogens are gram-negative bacteria, including Vibrio and Pseudomonas (Johnson 1983). Vibrio and Pseudomonas were among the pathogens isolated from shell disease lesions in Albemarle-Pamlico estuarine system blue crabs (McKenna et al. 1990). Other agents including mycobacteria, psychrophilic luminescent bacteria, and fungi have also been associated with some cases.

The lesions seen in the Pamlico River blue crabs are a very aggressive form of shell disease that frequently penetrates the carapace or causes massive disintegration of the shell (Engel and Noga 1989). These lesions are much more severe than those classically described by Rosen (1970).

In June 1987, DMF sampling of crab pots of commercial fishermen suggested that the highest prevalence of shell disease was on the south side of the river between Durham and South Creeks near the Texasgulf, Inc. phosphate mine. This conclusion was supported by the observation of the same distribution after a trawl survey of 60 stations between Mauls Point and Indian Island (McKenna et al. 1990).

Clinically normal crabs obtained from Rose Bay were placed in cages in the river in order to determine if there was any increased risk of developing shell disease in certain areas. Cages were placed at Core Point, Indian Island, Long Point, and adjacent to the Texasgulf, Inc. phosphate mine. Crabs that were wounded by scraping the carapace developed what the authors considered to be early stages of shell disease (i.e., punctiform brown marks with reddish-brown depressed centers) as soon as one day after wounding. While shell disease lesions developed from the wounds of most crabs at all locations, crabs at Long Point and Texasgulf developed lesions significantly ($p < 0.05$) faster (mean = 4.2 days) than crabs at Core Point and Indian Island (mean = 8.1 days).

McKenna et al. (1990) speculated that toxic sediments originating from Texasgulf, Inc. may be responsible for the increased risk of disease development, since the Division of Environmental Management had determined that cadmium and fluoride, both of which might affect skeletal integrity, were highest on the south side of the river at the Texasgulf, Inc. facility.

Problems have also recently been reported in oysters. During the annual DMF oyster shoal survey of fall 1988, high mortalities were observed in Core and Pamlico Sounds. Examination revealed that many oysters were infected by **Dermocystidium** (Perkinsus marinus) or MSX (Minchinia nelsoni), two diseases that can be highly fatal to oysters. These two pathogens were later found throughout much of North Carolina's oyster stocks (DMF Unpublished Data).

Toxic dinoflagellate blooms in the fall of 1987 resulted in considerable mortalities of bay scallops (Summerson and Peterson In Press).

F. 4. Evaluation of Trends in Diseases

There is a very limited temporal database on the prevalence of disease in the Albemarle-Pamlico estuarine system. Before 1974, investigations of fish diseases had been sporadic and short-term. Since 1974, North Carolina has had an extensive coastal finfisheries monitoring program conducted by DMF. It includes sampling of several hundred estuarine stations up to 10 times per year (currently March through November) as well as sampling of commercial catches year-round. The field survey is directed at determining the relative abundance of juvenile bottom fishes and crustaceans, such as sciaenids, flounders, and shrimp, but incidentally includes pelagic species, such as menhaden and anchovies. Temperature and salinity are recorded at each station, and dissolved oxygen is measured at some locations. Presence of diseased fish is routinely recorded on data sheets. In 1986, a more comprehensive diseased fish recording system for skin disease problems was instituted that included detailed data on the types of lesions seen (Noga 1986a). Representative samples of all lesions are preserved for later histological diagnosis. All disease data are stored on computer files for future retrieval and analysis. While potentially useful in health monitoring, the ground fish survey is biased towards juvenile bottom fishes and often does not efficiently collect the pelagic fish populations (Atlantic menhaden) that are most heavily affected by disease at the present time.

Based on data from this survey, sampling by the North Carolina Wildlife Resources Commission, and fishermen's reports, the prevalence of disease in the Albemarle Sound estuary appears to be considerably less than during the epidemics of the mid- to late- 1970s. The last major epidemic of skin lesions appears to have been in 1982 (H. Johnson, J. Kornegay, DMF, Personal Communication). Since that time, the prevalence of skin lesions appears to have declined. Interestingly, decreased disease has coincided with a noticeable reduction in the number and severity of blue-green algae blooms that were also prevalent during this time. On average, from 1983 to 1988, salinities have been higher than the average in the Albemarle drainage area, due to lesser rainfall. In 1982, the Chowan River basin was designated as nutrient-sensitive by the North Carolina Environmental Management Commission as part of an effort to improve water quality of the river.

Prevalence of fish disease in the Pamlico River estuary has increased dramatically since 1984. Based on data from the DMF trawl survey and fishermen's observations, ulcerative mycosis (UM), which is the most common problem, was not seen before 1984. However, since its dramatic appearance, it has remained highly prevalent. While comparable data are not available for all years, it appears that the largest disease outbreaks occurred in 1984, 1989, and possibly, 1988. Interestingly, 1984 and 1989 were unusually wet years, resulting in depressed salinities in the Pamlico River, indicating the relatively greater importance of nonpoint sources of pollution.

Prospective studies to determine possible water quality conditions that may be responsible for fish disease were initiated in the Pamlico River in 1985. An intensive field survey examined the prevalence of UM in the Pamlico River from May 1985 to April 1987. Temperature, salinity, and dissolved oxygen (DO) were measured simultaneously at monthly intervals, in concert with a trawl survey to determine disease prevalence (Noga et al. 1989a). None of the water quality factors measured showed a correlation with UM. However, a more intensive cast net survey of UM prevalence that focused on the high-risk (low salinity) area of the Pamlico River demonstrated that there was a positive correlation between UM and temperature and bottom DO during the fall 1988 outbreak (Levine et al. 1989). This finding was supported by the observation of several hypoxic episodes in the same area just prior to the UM outbreak (Noga et al. 1989b). Also, large diurnal fluctuations in DO and pH were common. These fluctuations were similar in magnitude to seasonal fluctuations that had been reported previously (D. Stanley, ECU, Personal Communication).

A data management program known as the Ulcerative Disease Regional Database (UDRDB) was developed to both retrospectively and prospectively determine the relationships between water quality parameters and the presence of ulcerative lesions on fish in the Pamlico River estuary (Levine et al.

1987). The data bank combined fisheries, physical, and water quality data with skin ulcer prevalence. Values for more than 20 water quality and sediment parameters monitored by the North Carolina Division of Environmental Management were compared with UM prevalence. The monthly proportion of fish affected was regressed on total nitrogen, phosphorus, temperature, dissolved oxygen, BOD, pH, chloride, and heavy metals. No significant relationship was observed between these parameters and the occurrence of disease. Statistical evaluation was limited by the lack of available historical water quality data. During or preceding three outbreaks of UM, however, total nitrogen concentrations were elevated at one station. Similar concentrations were observed at a second site during two outbreaks. Chloride levels were also elevated during three outbreaks. Minimal changes in phosphorus levels were evident during or preceding UM outbreaks. In 1985 and 1986, disease appeared to increase following periods of dry weather and decline during periods of rainfall (Levine et al. 1987; Noga et al. 1989a).

Fish disease does not appear to be a major problem in Core Sound, although the importance of bivalve pathogens such as MSX or Perkinsus (Dermo) are uncertain. In general, there is considerably more knowledge about the disease problems affecting the finfish populations of the Albemarle-Pamlico estuarine system than those affecting invertebrate species.

F. 5. Cause of Disease Problems: Current Status of Knowledge

An overall assessment of the number and magnitude of diseases affecting the finfish and shellfish populations of the Albemarle-Pamlico estuarine system suggests that the populations are being exposed to abnormally high stresses. Whether such stresses are due to pollution or are entirely natural events has yet to be scientifically proven. There are several lines of evidence, however, that suggest that these problems are not entirely due to natural phenomena.

First, is the very high prevalence (and possibly incidence) of many different diseases. For example, overall prevalence of UM in the Pamlico River was 15% from May 1985 to April 1987 (Levine et al. 1990a; Levine et al. 1990b); during outbreaks, prevalence frequently exceeded 90% of sampled populations. In the Chowan River, some studies, designed to be representative of the population at large, have shown that over 50% of the largemouth bass population can have skin lesions during the summer (Noga 1986b). Disease prevalence in fish populations in unpolluted environments rarely exceeds 10% (Brown et al. 1977; Couch 1985).

While shell disease does not appear to affect more than 5% of the Pamlico River crab population (McKenna et al. 1990), the extremely aggressive lesions on affected animals suggest that the mortality rate may be especially high, compared to other blue crab populations that usually have been reported to have a milder form of the disease (Rosen 1970). High (and probably rapid) mortality is characteristic of UM. These features suggest that the incidence of these diseases (i.e., the number of new cases of disease developing at any particular time) would be great and make their impact more severe than less virulent problems with a similar prevalence.

Second, many of the most common diseases are often associated with polluted environments. Skin ulcers, for example, are considered to be one of the best pathological indicators of pollution (Sindermann 1983). Shell disease is increasingly being considered as the invertebrate analogue of finfish skin ulcers as an indicator of environmental quality (Sindermann 1989). Shell disease has been reported in many natural populations of crustaceans (Sindermann 1989), but the prevalence has usually been very low. Stressful environments, however, seem to increase the risk of disease.

Third, the tremendous number of affected species from diverse habitats and niches is indicative of widespread environmental perturbation.

The overwhelming majority of diseases facing the fishery populations of the Albemarle-Pamlico estuarine system have some infectious component. No strong evidence linking any infectious disease in wild fisheries populations to a specific pollutant currently exists, due largely to the myriad of possible variables ("contaminants") which may influence fish health. Factors which lead to the development of an infectious disease can be very complex. Exposure to a pathogenic organism will not result in disease unless the proper conditions in the host are met (i.e., suppressed immune system). The conditions responsible for this immunosuppression may not be easily determined.

If a toxin responsible for reducing immunity accumulates in host tissues, determination of body burdens in affected individuals may provide clues to the cause of the problem. Infectious diseases may also, however, be initiated by environmental factors which leave no detectable residues. Perturbations, such as increased nutrient levels, alterations in salinity gradients, or changes in suspended solids may not be directly toxic to aquatic animals. Instead, their second and third order consequences (e.g., changes in dissolved oxygen or carbon dioxide due to eutrophication) may stress fish (Plumb 1984). The rather ephemeral and temporally variable nature of such factors make them especially difficult to study. Thus, it is important to realize that infectious diseases are secondary manifestations of physiological and/or environmental changes that allow infectious agents to colonize a host. The need to identify those primary effects ultimately responsible makes research very complicated.

F. 6. Information Needed for Developing Management Strategies

Determining the factors that are responsible for an epidemic in a fishery population requires close examination of the three principal components that interact to produce disease: the host, the pathogen, and the environment (Snieszko 1974). It should be recognized that disease is a normal process in any animal population. Thus, we are concerned not so much with the presence of disease, but instead, with the anthropogenic factors that may affect its prevalence.

Many diseases can look very similar to the naked eye and thus may mistakenly be lumped into one category (Table IV-12). It is important to differentiate and identify the most important disease problems because distinct risk factors are associated with the development of different diseases. Once putative pathogens have been isolated, the disease must be successfully induced in the laboratory, and then the same organism must be re-isolated. The meeting of such criteria, termed Koch's Postulates, is essential because reproducible induction of a disease provides an experimental model which can be used to determine which environmental conditions are most influential on disease development.

It is also necessary to determine factors that may influence the pathogenicity of the infectious agent causing the disease. Many fish pathogens, such as water molds and many bacteria, are capable of a free-living existence in water and do not require a fish host for survival. Temperature, dissolved gases, salinity, pH, and various nutrients may influence the abundance and, possibly, the virulence of such agents.

There always exists the possibility that newer, more virulent strains of pathogens may be responsible for an epidemic. The introduction of new agents into susceptible host populations has frequently resulted in catastrophic effects, however, this is unlikely to be responsible for problems in the Albemarle-Pamlico estuarine system fisheries, since there are so many different agents causing lesions.

Field studies should include identification of zones of high and low risk for infection in an effort to focus on those sites in which fish are becoming infected. Correctly identifying such sites is critical to determining which water quality parameters may be responsible for the disease. One approach is to narrow the suspected region of high risk by using progressively more precise methods of detection.

Table IV-12. Pathogens associated with skin diseases ("red-sore") from fishes in the Albemarle-Pamlico Estuarine System (from Noga 1986b and Noga et al. In Press).

VIRUSES

Lymphocystis

BACTERIA *

Aeromonas hydrophila
Aeromonas salmonicida

FUNGI

Saprolegnia spp.
Aphanomyces spp.

PARASITES

Henneguya sp.
Heteropolaria sp.
Monogenean trematodes
Digenean trematodes
Argulus sp.
Lernaeid copepods

NOTE: Only skin pathogens associated with grossly evident inflammatory lesions are included. Many of these pathogens are also found asymptomatically on healthy skin.

* Numerous other bacteria which have been identified from lesions and which do not appear to be primary pathogens are not included.

At the same time, one must try to correlate specific water quality factors with high and low risk sites. The success of this stage of study depends upon the ability to precisely identify high risk sites for infection. At present, there is very little information about the relationship between water quality and infectious disease development in natural environments. However, experience with disease problems in aquaculture situations can be helpful in formulating a list of probable risk factors. Two major types of factors should be considered. First, are those environmental conditions universally essential to fish health: dissolved gases (oxygen, carbon dioxide, etc), salinity, temperature, nitrogenous compounds (ammonia, nitrite, nitrate), and pH. Deciding which to examine depends upon their past variability in the particular system under study. Second, are toxins (heavy metals, etc.) that may be present above "normal" limits. With the myriad of possible factors that may affect fish health, this list should also be based upon any historical trends of anthropogenic inputs into the system. The time scale of monitoring to be performed will obviously depend upon the range of system variability for the water-quality criteria examined (Livingston 1982). For example, previous studies in the Pamlico River indicate that monthly water quality sampling is insufficient to accurately assess the actual water quality changes that are occurring (Levine et al. 1989; Noga et al. 1989b).

As mentioned previously, most pollution-disease investigations have focused on the possible cause and effect relationship between an anthropogenic substance and its effect on aquatic animal health. A direct causal relationship, however, may not exist. Instead, the pollutant may act indirectly on fish health by causing other changes in environmental quality. More difficult to assess, yet potentially very important, are ecological changes that may affect trophic dynamics, and thus food quality or quantity or the presence of various chemical constituents in the water (toxins, etc.).

In summary, while many factors have the potential of making fish more susceptible to disease, there needs to be a rational prioritization of the factors that are most likely to be responsible. While such a list may vary somewhat depending upon data available on the disease, it should focus on most probable conditions based upon data from more well-studied systems (e.g., aquaculture). Cost is always an important consideration, and thus an attempt should be made to use indicators that will provide the most information about a broad range of conditions. Once correlates are found, the study should become progressively more focused as more specific variables are identified.

In the Albemarle-Pamlico estuarine system, conditions which appear to merit special consideration as possible risk factors for fish disease include low dissolved oxygen, demonstrated to be responsible for acute mortalities of both finfish and shellfish in the Albemarle-Pamlico estuarine system, and phytoplankton-produced toxins, potentially able but never proven to cause mortalities. The presence of such acute effects suggests that sub-lethal effects leading to increased disease susceptibility may also be operative. If this is true, changes in the quality and/or quantity of phytoplankton communities will require further investigation. Physical-chemical factors which might be important in influencing these end results include the volume and temporal-spatial distribution of water entering the estuary. Depressed salinities appear to increase the risk of disease outbreaks, although other factors are probably also required.

A final step required in proving that certain water quality conditions are responsible for a disease is to reproduce the disease using the specific water quality risk factors. If differences in water quality have been detected between high- and low-risk sites, one must decide which of those differences are most likely to be causing the disease. This decision implies that reliable information exists on factors influencing fish health in natural systems. Unfortunately, environmental requirements for fish health are based mainly on studies of a few species, primarily salmonids and catfishes. Even in these species, the relationship between specific environmental conditions and disease resistance is poorly understood. Nonetheless, one must demonstrate that specific water quality features increase the risk of disease under experimental conditions in order to prove a cause-and-effect relationship.

The ultimate goal of these studies is to present to managers the major water quality factors that are responsible for the development of the disease. With this information and a knowledge of the anthropogenic contributions to a pollutant's loading, an administrative decision can be made concerning acceptable levels of that pollutant in the environment. It is important to realize that the acquisition of this information requires a long term effort. Since not all the data that are desired will be acquired at once, new information should be incorporated into management plans.

Thus, adaptive management should be encouraged, allowing managers to proceed with the best available information and to implement corrective actions as research produces new information. An assessment also needs to be made of the true impact of these diseases on the Albemarle-Pamlico estuarine system. This assessment should include not only catch data, but also less tangible effects such as socio-economic effects of the disease. At the same time, attempts should be made to determine how causes of fish disease may also be linked to other deleterious changes in the environment (loss of submerged aquatic vegetation, increased noxious algae blooms, etc.), which may also have adverse effects on fishery productivity. Thus, there needs to be a commitment to determining the impact of these diseases on the Albemarle-Pamlico estuarine system, so that rational judgments can be made before irreversible changes occur.

F. 7. Summary

Fishes in the Albemarle-Pamlico estuarine system have a very high prevalence of skin diseases. The only apparent similarity among the diseases is an infectious component (i.e., virus, bacterium, fungus, or parasite). Although diseases are very common in this estuarine system, there are insufficient data to support or refute pollution as their cause. One unknown, but crucially important, variable is the influence of natural environmental perturbations on the expression of these diseases. Disease is certainly not restricted to fish populations in polluted environments, and significant disease outbreaks have been documented in fish populations far from any pollutant sources.

One must first determine the major environmental factors that increase the risk of the fish population to disease before specific pollutants can be implicated. Thus, the question of "pollutant" or "natural stressor" is initially irrelevant; instead, the focus should be on those factors most important to fish health. It is important to understand how natural environmental fluctuations may affect the susceptibility of fish to disease. Only with this knowledge can we understand how anthropogenic activity can influence and accentuate those environmental stressors.

Finding those risk factors requires a multifactorial approach that includes examining the host, the pathogen and the environment. It is obvious that this task is not easily done, but will require considerable effort with no guarantee that answers will be found. The decision to attempt such undertakings will ultimately depend upon the economic and intrinsic value which we place on our fishery resources.

G. FISHERIES MANAGEMENT ISSUES

For various species, regulations of the North Carolina Marine Fisheries Commission (MFC) directly control seasons, gear parameters, size limits, and quantity of daily harvest. The Coastal Resources Commission (CRC) regulations help maintain estuarine habitat and water quality. Rules promulgated by the North Carolina Environmental Management Commission (EMC) are designed to maintain water quality. Because North Carolina has a federally approved coastal zone management plan, the activities of federal agencies which may affect coastal fisheries or habitat are subject to review for consistency with that plan. Many species of importance in the Albemarle-Pamlico estuarine system spend a portion of their life in the federal Exclusive Economic Zone (EEZ), that area extending from the state's three-nautical mile Territorial Sea to 200 nautical miles offshore. Some of these species, such as summer flounder, are harvested in the EEZ and so the fisheries are subject to federal fishery management plans and regulations under the Fisheries Conservation and Management Act (FCMA). Many other species migrate in the near-shore ocean and are harvested principally in areas under the control of the coastal states. Under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC), coastal states may join together to prepare fishery management plans for such species, implementing needed regulations under their individual authorities. Some of the species for which such plans have been prepared and implemented include Atlantic menhaden, bluefish, striped bass, river herring and shad, weakfish, spotted seatrout, and red drum.

The responsibility for regulation of the fisheries in the estuary (inland waters) lies with the MFC under General Statute 143B-289.3. This 15-member body, created by the North Carolina General Assembly and appointed by the Governor, is delegated the responsibility "to manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (NCGS 143B-289.4). The MFC and the management agency, the Division of Marine Fisheries (DMF), deal directly with fishery conflicts (people problems) and stock problems (biological issues). In approaching these types of problems, the DMF seeks to promote conservation of the fisheries resources for the long term. In this context, conservation means "wise use." Management is not intended to seek short-term economic or social benefits at the expense of long-term benefits to the resources and those who use the resources.

The fisheries resources cannot be directly controlled by regulations. Regulations affect the fishermen utilizing the resource by controlling gears, seasons, areas, size limits, and quantities harvested. Most efforts of DMF involve the collection of statistical information, monitoring the various stocks, conducting needed research, and enforcing fishing regulations. In addition, some enhancement efforts, such as planting oyster clutch material for spat settlement and construction of artificial fishing reefs, occur within the estuary.

It is important to note that the MFC has no direct authority to regulate or control activities which affect the overall fisheries habitat or water quality, except those impacts resulting from use of fishing gears. Although DMF works closely with agencies with environmental regulatory authority and comments on habitat alteration permits, the agency which is responsible for managing the fisheries has no direct authority to protect that habitat from adverse environmental impacts. Habitat and water quality degradation are believed to be major threats to the long term fishery productivity of the estuary. Strong actions by all responsible state agencies is requisite.

A fishery management issue which needs immediate attention concerns the collection, assimilation, and analysis of the fisheries database to determine the true status and trends of the fisheries resources. As mentioned earlier, landings statistics are often improperly used to indicate resource trends. Unfortunately, they do not accurately reflect the true stock trends over time. As a result, differing opinions arise over the true status of the resources in the estuary. Much alarm has been raised in recent years about declines in the fishery resources. It is unclear, however, whether the resources have, in fact, declined. No doubt certain species, valuable to the estuary, have declined, such as striped bass. In many cases, individual fishermen's catches have decreased due to a number of factors, some of which may be competition from other fishermen and increases in total fishing effort. However, no comprehensive analyses have been conducted to accurately determine the overall status of the stocks. Until improved information and analyses are available to determine the status and trends of the fisheries resources, there will be constant debate about what direction management actions should take. Clearly, an effort must be made to determine the true status of the resources.

Compared to other states, North Carolina allows a wide variety of fishing activities with relatively little regulation. Access to the resource is not only unlimited, but in many respects is encouraged. As a result, the Albemarle-Pamlico estuarine system is fished very intensively, often resulting in conflicts over resource utilization or fishing space. Large numbers of people fish both commercially and recreationally for a wide variety of species utilizing diverse types of gear. In addition, many people fish commercially on a part-time basis to supplement their regular income. All of this activity occurs in an estuary which also serves as a highly productive nursery habitat for fisheries resources. Such intense utilization, combined with the need to protect essential habitats and resources, can result in highly volatile management situations, both perceived and real.

As discussed earlier, the principal fisheries in the estuary involve both fixed gears, such as crab pots, pound nets, and gill nets, and movable gear, such as shrimp trawls and long haul seines. Intense use of crab pots in an area precludes trawlers or seines from working the same area. Often, prime fishing with different gear for different species involves the same area; this often results in conflicts over allocation of the space available to each fishery. Towed gear has been displaced in some areas by fixed gear and fixed gear is occasionally destroyed by towed gear; real conflicts have ensued. As utilization of the estuary increases, these conflicts will probably intensify. Efforts to resolve gear conflicts center around negotiating with the user groups rather than imposing new regulations. When necessary, however, regulations to separate gears spatially with areal restrictions have been enacted by the MFC.

User conflicts sometimes occur among different commercial harvesting sectors of the same fishery. Crab potters compete with crab trawlers for the same resource, while conflicts among shrimp trawlers sometimes involves competition between large boats and small boats for both resource and area. Such conflicts are also likely to become more numerous as the use of the estuary increases. This situation leads to a growing concern over how many users and how much effort can be supported by the estuary's resources. Very few restrictions or limits are placed on the various commercial gears used and, for a modest fee, commercial access to the resource is unlimited. There are no fees at all for recreational fishing with hook-and-line. Can the estuary continue to support an ever-increasing level of fishing effort and still produce economically viable harvests and quality recreational experiences? Clearly, limits on the amount of gear or effort, or possibly limited entry to commercial fisheries, must be considered for the future.

There is a growing conflict between recreational and commercial fishermen. As noted earlier, recreational fishermen and commercial fishermen fish for many of the same species. Recreational interests are becoming concerned over the large harvests by commercial fishermen and over the use of fishing methods which may negatively affect the habitat as well as. Conflicts between fishing groups and property owners or businesses have also intensified in recent years. Citizens have complained that fishing gears near their property impede access to their property, damage their property, or decrease aesthetic values. Piers and docks, on the other hand, may take space formerly utilized for commercial or recreational fishing. As use of the coastal area increases, these conflicts will intensify.

Public policy-makers must recognize that, like agriculture, commercial fishing is a basic food producer, providing products for consumers and productive employment for thousands of North Carolinians and, like agriculture, commercial fishermen are being severely impacted by environmental degradation, loss of productive areas, and economic factors. Specific policies have been developed at the state and federal levels addressing protection and maintenance of the "family farm." Similar policies may be appropriate for North Carolina's commercial fishermen, especially those who rely so heavily on the estuarine resources. If developed, such policies must consider the needs of the recreational sector and ensure fair allocation of fishing opportunities.

North Carolina's estuarine system can continue to produce resources for sport and commercial fishermen alike, but harvest quantities and access may have to be restricted. Tourists flock to coastal seafood restaurants to eat "fresh local seafood." Without clean, productive waters fished by local commercial fishermen, "fresh local seafood" will not be available to consumers. To maintain commercial fishing and its way of life, commercial fishermen must adopt modern technology to harvest target species and release non-target fish. Policy-makers must seriously consider limiting entry to the commercial fisheries in order to ensure: (1) the availability of stocks for harvest by all fishermen, (2) the economic viability of commercial fishing, (3) the continued supply of seafood for consumers, and (4) allocation of fishing opportunities and resources for anglers. Commercial fishermen will have to approach their work much more as regulated small businessmen, realizing that success cannot be guaranteed in a competitive environment. At the same time, recreational fishermen must emphasize the sporting aspects of their avocation and place less importance on harvesting large numbers of fish. Catch-and-release and quality aspects of fishing will have to become more important.

North Carolina's appointed and elected officials must critically examine the coastal fisheries in the very near future and make informed, conscious decisions on the future of the fisheries. Change is underway, and, if not guided, will likely result in future conditions which do not satisfy commercial fishermen, anglers, consumers, or government officials.

Another major management issue involves the use of fishing gears such as trawls, clam kicking, long haul seining, and dredging, which may damage or degrade the habitat and/or result in significant by-catches. Towed gear sweeps the bottom and suspends sediments, potentially impacting benthic organisms. Methods, such as oyster and clam dredging and clam kicking, dig directly into bottom sediments, disturbing the bottom habitat, especially such habitats as seagrass meadows. Regulations of the MFC prohibit use of dredges and kicking gear in grass beds, but enforcement is extremely difficult. The catch by such methods is largely non-selective and can produce large amounts of by-catch if care is not taken. The by-catch issue has been studied for many years (Higgins and Pearson 1928; Lunz et al. 1951; Roelofs 1950; Fahy 1965a,b; Brown and McCoy 1969; and Wolff 1972). In estuarine areas, the by-catch may be composed largely of juvenile fish and crustaceans utilizing the estuary as a nursery area. Fish naturally suffer high mortality as larvae and juveniles, and the impact on overall stock levels of mortality of juveniles from fishing is unknown. Stationary methods of fishing, such as gill nets and pound nets, generally have a by-catch component, as well. Mounting public concern will require that these issues receive careful consideration; fishing practices will have to become more selective and reduce by-catch.

An important concern of managers and fishermen alike is the ability of the fisheries habitats to sustain production of the resource. Clearly, without such productive habitats the fisheries would not exist. Another problem concerns identifying the major factors controlling overall production of the resources. Fishermen (both commercial and recreational) are relatively easy to regulate and are often blamed for problems with the resource. Fishermen, in turn, often contend that pollution and other habitat and environmental problems are responsible for declines in the fisheries. Yet, eliminating sources of pollutants throughout the 30,000 square mile watershed is extremely difficult, expensive, and time-consuming. All users must assume responsibility for their actions and be willing to take necessary steps to limit their impacts rather than continuing unproductive "finger pointing."

H. CONCLUSIONS AND RECOMMENDATIONS

H. 1. Habitat Protection

A healthy productive habitat is absolutely essential for providing fisheries resources for commercial and recreational harvesters alike. The North Carolina Marine Fisheries Commission (MFC) is responsible for harvest regulations, while the North Carolina Coastal Resources Commission (CRC) and the North Carolina Environmental Management Commission (EMC) regulate land use and water use, respectively, which determine the quality of the aquatic habitat. In order to ensure that CRC and EMC policies and regulations contribute to a healthy coastal environment, formal coordination among the three commissions should be established on a continuing basis. Similarly, formal coordination to protect and improve coastal habitat should be initiated among the three state agencies which conduct the day-to-day work of the three commissions: Division of Marine Fisheries (DMF), Division of Coastal Management (DCM), and Division of Environmental Management (DEM).

H. 2. Data Collection

Analysis of the DMF data gathering programs by Street and Phalen (1990) indicates that DMF conducts strong programs to collect biological fisheries-dependent data. Environmental data collection is minimal. Collection of fisheries-independent data is increasing with the survey in the Albemarle-Pamlico estuarine system and the cooperative interstate SEAMAP program in the ocean. Landings statistics are probably adequate at the state level for commercial data, but are weak at the waterbody level, the level of accuracy often needed for analysis. Reliable data for the marine recreational fishery, on a coast-wide basis, have been collected since 1987. The survey primarily directs sampling efforts at marine anglers and, as a result, sampling in upper estuarine areas, such as the Pamlico River, Neuse River, and Albemarle Sound, is very limited. Collection of effort data is improving for both commercial and recreational fisheries.

Changes in commercial licensing would greatly improve collection of statistically valid data at every level. Licenses or permits for specific quantities of gear would provide much-needed estimates of effort. Use of trip tickets for all initial landings sales by commercial fishermen (with copies sent to the DMF) would provide accurate data on catch, water body, gear, and effort. Initiation of gear licenses or permits and commercial trip tickets are recommended and are within the authority of the MFC.

A recreational license would provide a reliable sampling frame for the general recreational survey and for special surveys aimed at specific fisheries not adequately sampled by the general survey. Institution of an individual recreational permit or license for hook-and-line recreational fishing and personal use of commercial gear is also recommended, but would require legislative action.

H. 3. Stock Status

Most of the requisite data for stock assessments are collected (Street and Phalen In Press), the DMF data management system adequately processes the data, and computerized analytical programs are available through the Statistical Analysis System (SAS). The DMF should produce, on a continuing basis, a series of reports on the status of the species of principal concern to recreational and commercial interests in North Carolina for which adequate data do exist. Assessment programs should begin on those important species where data are lacking (blue crabs, white perch, hard clams, etc.).

H. 4. Nature of Commercial Fishing

As total pressure on the habitat and fisheries resources increases, each harvester's potential share of the finite resources diminishes. Commercial fishing is more than a means of making a living for most commercial fishermen; it is a way of life handed down through many generations. Marine recreational fishing has become a major economic factor in the coastal area, as well as an integral part of the lifestyle of a large segment of North Carolina's population. Conflicts between the two segments are growing, along with conflicts within the segments. Both groups must recognize their shared need for healthy habitats and stocks. Commercial fishermen must recognize the angler's need for access to fishing grounds and accept as reasonable his expectation of a quality fishing experience. Anglers must recognize that commercial fishermen must make reasonable economic returns on their investments of time and equipment in order to support their families and that consumers demand a choice of fishery products in the marketplace.

Commercial fishermen need to emphasize product quality and efficiency, and eliminate waste in their harvest practices. They must conduct themselves as small, independent businessmen. In recognition of the importance of commercial fishermen as basic food producers for consumers, similar to farmers, the General Assembly should consider enacting policies to protect commercial fishermen and commercial fishing, similar to those protecting family farmers.

For most fisheries, the effort employed probably greatly exceeds that needed to harvest the amount a given stock can annually produce and still remain productive. Such over-capitalization potentially endangers the biological integrity of the stocks and are economically inefficient. Because commercial fishermen have no guarantee of future stock availability, they often seek short-term harvest advantages with little or no consideration of the future. Conflicts and economic hardship are the inevitable result. The General Assembly should grant the MFC the authority to institute licensing regulation, including systems for limiting entry into selected fisheries in order to promote stock stability, economic stability, and reasonable allocation among competing commercial and recreational fishing interests.

Imposition of limited entry would be a drastic approach to solving various problems within target fisheries. Other, more conventional means should be utilized prior to use of limited entry, such as size limits, creel limits, quotas, seasonal closures, gear restrictions, and areal closures.

H. 5. Selective Fishing

Neither the fish stocks nor the harvesters can afford wasteful harvest practices. Excessive by-catch represents economic waste in harvesting, handling, energy use, and wear-and-tear on gear and vessels. To an unknown degree, excessive by-catch also represents biological and economic waste in that some portion of the discarded catch could have been captured later when larger in size and/or could have contributed to stock maintenance or growth through reproduction. In cooperation with commercial fishermen and the University of North Carolina Sea Grant College Program, DMF should institute a long-term program aimed at development of fishing gear which captures target species and sizes while releasing unharmed non-target species and/or sizes of fish. Work is needed on trawls, gill nets, pound nets, long-haul seines, and pots.

H. 6. Recreational Fishing

Just as commercial fishermen must change their historic behavior patterns in light of the realities of stock availability, environmental conditions, the needs of other resource users, and changing economic conditions, so, too, must anglers change some of their approaches to their sport and methods of fishing. The "sport" of fishing must receive greater emphasis among all anglers. Assuming commercial fishermen are placed under the types of controls discussed above, anglers must accept their share of the responsibility for maintenance of stocks and habitat. Their numbers, both of individuals and vessels, greatly exceed those of commercial fishermen. Collectively, recreational fishermen probably have greater impacts on many stocks and habitats than any other group. Success in harvesting fish will have to receive less emphasis, while catch-and-release fishing should receive much greater emphasis.

Sale of their catch by many recreational fishermen creates competition and ill-will among many commercial fishermen. Recall again the food-producing role of commercial fishing and farming, nd recognize that hunters are not allowed to sell game in competition with livestock and poultry farmers. Hunters do not recoup costs of their recreation through sales; neither should anglers be allowed to do so.

H. 7. Aquatic Resource Education

Some public schools provide brief introductions to marine science at various grade levels. The North Carolina Aquariums provide excellent programs at their three facilities for visitors from the general public and organized groups, they hold workshops for teachers, and tey conduct some other outreach activities. The staff of the North Carolina Maritime Museum also conducts educational activities in their area of expertise. The most ambitious aquatic resources work is the new education program of the North Carolina Wildlife Resources Commission (WRC), designed to encompass a number of activities aimed at school children, resource users, and the general public. However, coastal resources are not emphasized. The DMF published a bimonthly newsletter, presents educational displays at the annual North Carolina State Fair, and assigns staff to give talks to various groups on request. There is, however, no coordination in presentation of educational services concerning coastal resources.

The DMF should initiate a coordinated, coherent aquatic resources education program emphasizing coastal resources. The program should include activities aimed at resource users and the general public, including displays, videos, pamphlets, and slide programs. Assistance should be provided to the WRC, the Aquariums, and the Maritime Museum to enhance the existing education programs aimed at teachers and students.

For all target groups, emphasis is needed on conservation, ethics, man's impacts on natural resources, impacts of solid waste and pollution on the habitat, and similar topics.

H. 8. Fishery Management Plans

The DMF and MFC conduct their management work on a very wide range of species and problems. Many decisions are made in short time frames with much less information available than the DMF and MFC would like to have. Although the various DMF research and monitoring programs are quite comprehensive, information is not always available in a timely manner or presented in a comprehensive fashion. The reasons for regulatory actions of the MFC and the DMF are frequently controversial, and seem unjustified to various interest groups. The roles of various state and federal agencies are frequently unclear to the public. Neither the MFC nor the DMF has issued general statements of goals and objectives for overall management, nor for any specific fishery or species.

In order to bring together coherent statements of goals, objectives, available and needed information, problem definition, and regulatory needs, the DMF and MFC should conduct a continuing program of preparing, publishing, and revising state fishery management plans for the species of importance to North Carolina's commercial and recreational fishermen.

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