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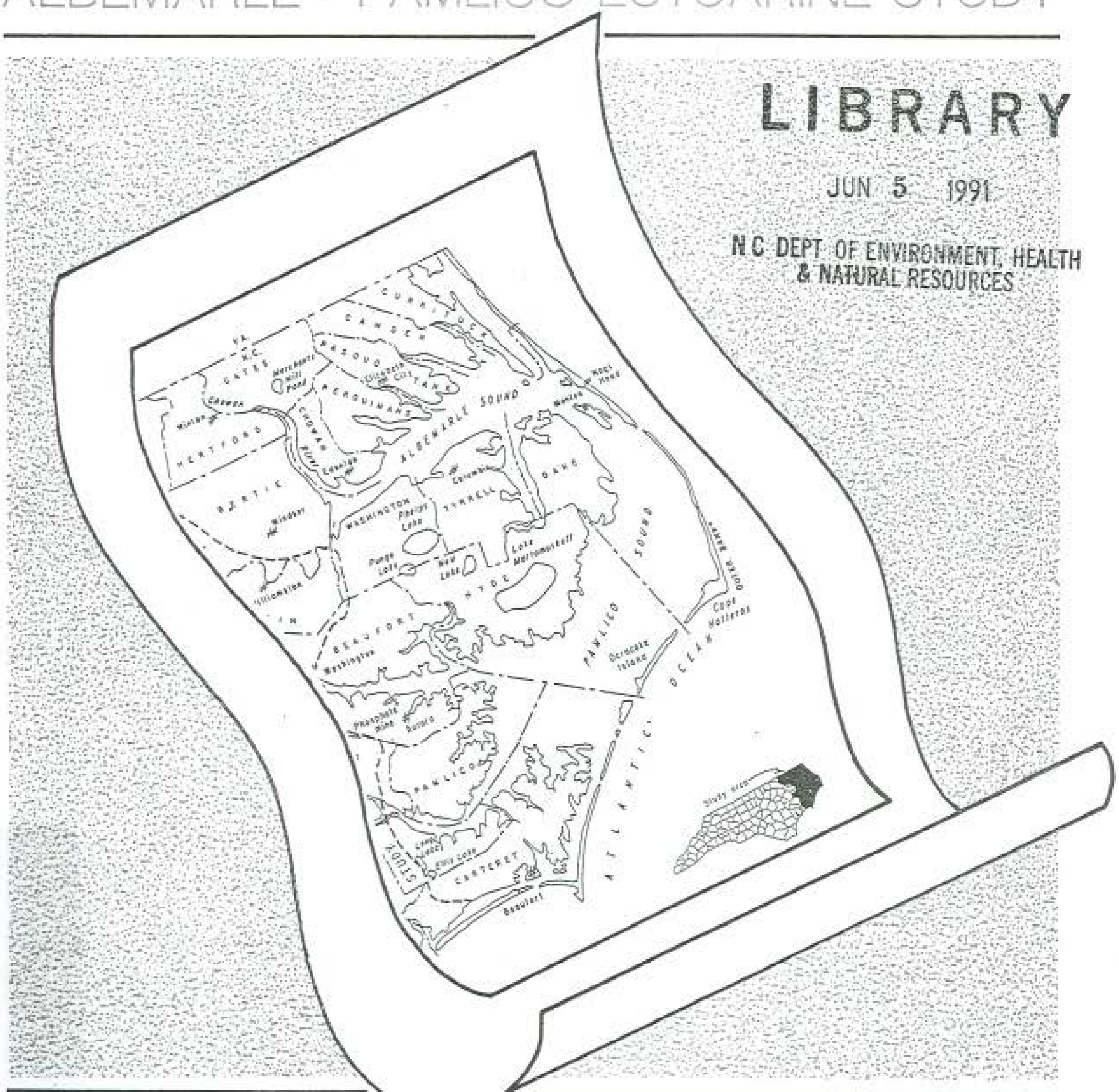
Classification of Pamlico Sound Nursery Areas: Recommendations for Critical Habitat Criteria

ALBEMARLE - PAMLICO ESTUARINE STUDY



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ALBEMARLE-PAMLICO

CLASSIFICATION OF PAMLICO SOUND NURSERY AREAS:

RECOMMENDATIONS FOR CRITICAL HABITAT CRITERIA

By

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ABSTRACT

A monitoring program of the Pamlico Sound estuarine complex was initiated in 1971 by the North Carolina Division of Marine Fisheries. This long-term database includes environmental variables and juvenile finfish and crustacean relative abundance and diversity. Classification analysis of over 300 stations by abiotic variables and percent composition of sixteen target species produced distinct station groupings.

Salinity was the key abiotic factor. Low salinity group stations were located in the Pamlico, Pungo, and Neuse rivers, and also the eastern portion of Albemarle Sound (including Roanoke Island). Dominant species were Atlantic croaker, brown shrimp, blue crab, and southern flounder. Intermediate salinity stations were found in the bays surrounding Pamlico Sound. In addition to the four species present in the low salinity areas, spotted seatrout, weakfish, and silver perch were most abundant in the Pamlico Sound bays. The next highest salinities were present in those stations behind the Outer Banks. Pinfish, pink shrimp, black sea bass, gag, pigfish, red drum, and gulf flounder were characteristic species of this area. Those stations located behind Core Banks had the second highest salinities and species compositions similar to the Outer Banks. Stations in the bays and tidal creeks of mainland Core Sound had the second highest salinities. Summer and southern flounder and brown shrimp were most abundant in this area. There were also good numbers of pink shrimp, blue crab, pinfish, and Atlantic croaker.

Based on core group characterizations, recommendations for critical habitat criteria were made. It was recommended that the North Carolina Marine Fisheries Commission recognize those high salinity areas behind Core Banks and the Outer Banks as critical habitats and nursery areas. It was also recommended that the Commission consider the relative abundance of species other than the traditional spot, Atlantic croaker, southern flounder, Atlantic menhaden, blue crab, and brown shrimp when making determinations for potential nursery area designations. In the high salinity areas of the Pamlico Sound estuary, this would include pink shrimp, pinfish, and pigfish. Consideration of the importance of less abundant species such as juvenile gag, black sea bass, and red drum was also recommended.

Results will be utilized by resource managers to better define and protect critical habitats which function as nursery areas for economically important finfish and crustaceans in North Carolina.

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1.0 INTRODUCTION

The Pamlico-Albemarle Sound estuarine complex is the largest semi-enclosed estuarine system on the Atlantic Coast. It consists of more than 3,000 square miles of sounds, marsh, tidal creeks and rivers. There are 125 miles of barrier islands separating the Sound from the Atlantic Ocean (Figure 1). Oregon, Hatteras, and Ocracoke inlets connect Pamlico Sound with the ocean. Drum and Barden inlets connect Core Sound with the ocean.

This immense estuarine complex supports substantial commercial and recreational fisheries. Most of the species that are economically important are also estuarine-dependent, spending part of their life cycle in the system. Estuarine nursery areas are key components of the system. Table 1 gives North Carolina commercial landings of the more abundant estuarine-dependent species for 1987 and 1988. Estuarine-dependent species comprise more than 95% of North Carolina's annual commercial fisheries landings. In 1988, over 156 millions pounds with an ex-vessel value of 64 million were landed.

A monitoring program of the Pamlico Sound estuarine complex was initiated in 1971 by the North Carolina Division of Marine Fisheries (DMF). The resulting long-term database includes environmental variables, juvenile finfish and crustacean relative abundance and size, and species diversity. This data-base is used by DMF to identify nursery areas. Nursery areas are defined as habitats, "in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season" (15 North Carolina Administrative Code (NCAC) 3B .1402). This regulation was adopted in 1977 by the North Carolina Marine Fisheries Commission (MFC) after estuarine trawl surveys (Spitsbergen and Wolff 1974, Purvis 1976, Wolff 1976) found large numbers of juvenile spot, Atlantic croaker, flounders, shrimps, blue crab and other species present in the shallow upstream areas of estuaries throughout the coastal area.

The basic criteria presently used by DMF to determine if an estuary is a primary nursery area is the abundance of juvenile organisms relative to existing designated nursery areas within similar ecological systems. Juvenile species most often used are spot, Atlantic croaker, blue crab, Atlantic menhaden, brown shrimp, and southern flounder. Historically, nursery area designations were based on data collected during estuarine trawl surveys conducted from 1970 through 1976. Catch-per-unit-effort (CPUE) data for all samples collected during major finfish and crustacean recruitment were computed. Values were ranked from low to high and plotted against stations. The point at which the CPUEs tended to level off was selected as that minimum value which warranted the designation at that area as a nursery area for the species concerned. In recent years, consideration is also given to species diversity, size composition, salinity, bottom type, depth, and surrounding land type. Based on the information gathered, DMF staff make a recommendation to the MFC to designate the waterbody as a primary nursery area. The recommendation is subsequently carried through the public hearing process prior to regulatory action.

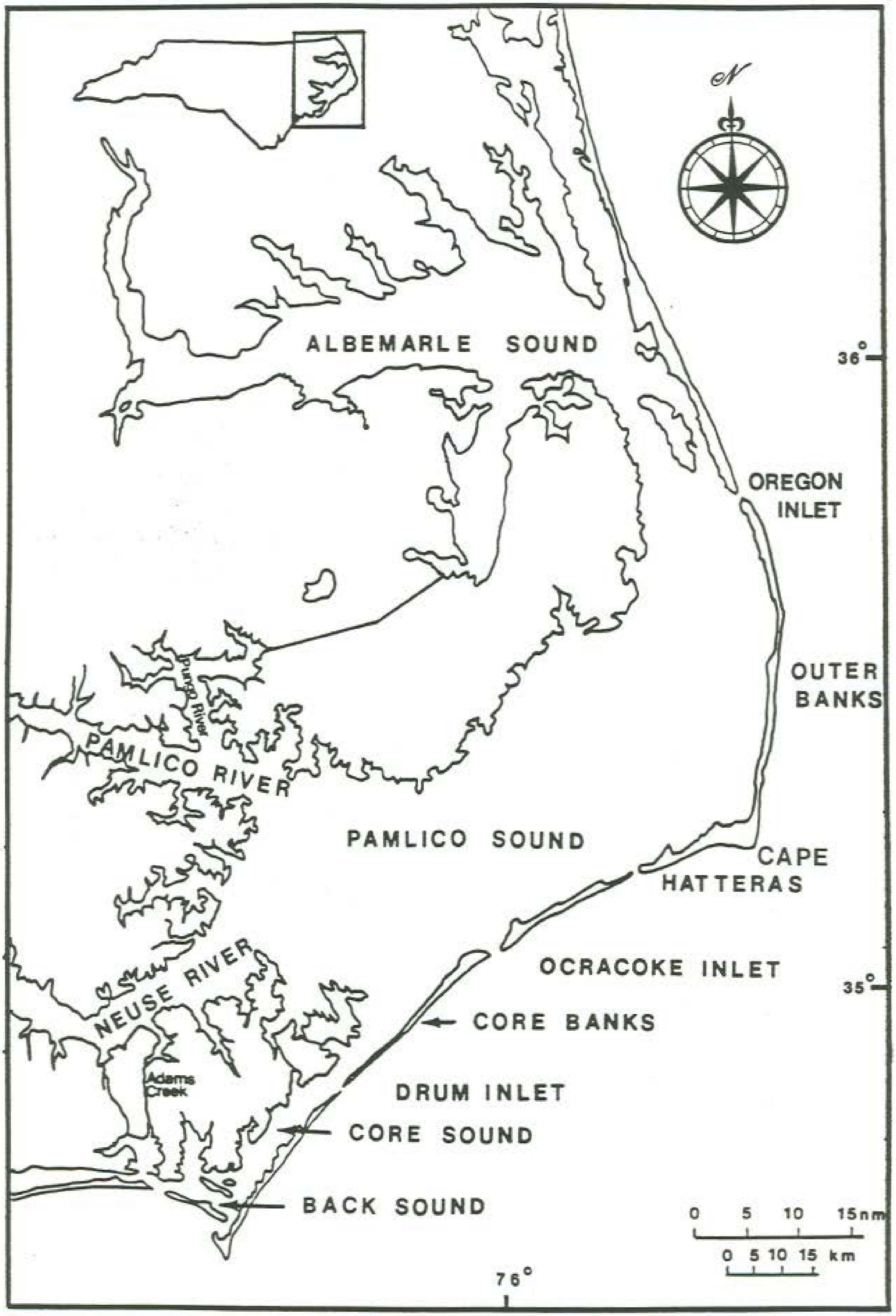

Figure 1. The Albemarle - Pamlico estuarine system

Table 1. Commercial landings in North Carolina of major non-sedentary estuarine-dependent species, 1987-88 (North Carolina Division of Marine Fisheries).

Species	1987		1988	
	Pounds	Value	Pounds	Value
Atlantic menhaden	55,498,571	$ 1,624,511	73,715,713	$ 2,566,832
Blue crabs	32,423,604	$ 9,608,647	35,604,423	$11,133,064
Weakfish	11,882,362	$ 4,423,164	15,091,878	$ 5,220,475
Flounders (unclassified)	7,983,973	$ 9,489,956	10,265,776	$10,737,091
Atlantic croaker	7,289,191	$ 2,956,025	8,434,415	$ 3,542,549
Shrimps	4,416,636	$ 8,178,180	8,139,190	$16,509,108
Bluefish	4,561,101	$ 818,046	5,039,039	$ 683,232
Spot	2,806,041	$ 648,742	3,080,258	$ 682,260
Mullets	2,590,360	$ 654,536	3,060,829	$ 1,634,408
Spanish mackerel	504,063	$ 145,141	438,222	$ 140,815
Spotted seatrout	315,380	$ 261,455	296,538	$ 247,852
Red drum	249,657	$ 148,205	220,271	$ 125,289
Pigfish	140,206	$ 21,844	172,735	$ 27,473
Total	130,661,145	$38,978,452	163,559,287	$53,250,448

There are 2,044,375 acres of estuarine waters in North Carolina (NC Division of Marine Fisheries unpub. data). The 1977 regulation designated 76,000 acres in North Carolina's coastal waters as primary nursery areas. Since 1977, additional primary nursery areas have been designated by the MFC, bringing the total (as of December 1988) to 80,165 acres. Secondary and special secondary nursery areas are also designated by the MFC as those areas in the estuarine system where later juvenile development takes place. A total of 128,878 acres of coastal waters have been designated by the MFC as either primary, permanent secondary, or special secondary nursery areas (Table 2). This figure represents only 6.3% of the State's estuarine waters. Figures 3-7 show the designated nursery areas in the Albemarle-Pamlico (A/P) study area. Table 3 gives nursery area acreage by county for the Albemarle-Pamlico (A/P) study area. Nursery area nomination and designation is an on-going process. There are many waterbodies in the A/P area that function as nursery areas, but are not yet designated as such.

MFC regulations mandate that nursery areas be maintained as much as possible in their natural state and that juvenile finfish and crustaceans present there be allowed to develop with as little interference from man as possible. Use of most bottom disturbing fishing gears such as trawl nets, swipe nets, long haul seines, dredge or mechanical harvest of clams or oysters is prohibited in primary nursery areas. The MFC also recommends that excavation and/or filling activities be severely restricted or prohibited.

The NC Division of Coastal Management and the North Carolina Coastal Resources Commission (CRC) administer the State's coastal zone management program in the 20 coastal counties under the authority of the Coastal Area Management Act (General Statute 113A-118) and the Dredge and Fill Act (General Statute 113-229). Regulations have also been established by the CRC to specifically protect designated primary nursery areas. Navigation channels, canals and boat basins must be aligned or located so as to avoid primary nursery areas. New marinas that require dredging cannot be located in primary nursery areas or in areas which require dredging through primary nursery areas for access. Maintenance dredging for existing marinas must be limited to periods of minimal juvenile abundance.

Local governments can also protect primary nursery areas through their Land Use Plans, which are required by the Coastal Area Management Act. Some local governments prohibit locating marinas in primary nursery areas, and/or require a one acre lot minimum in subdivisions adjacent to primary nursery areas.

The objectives of this study were to consolidate DMF's information on nursery areas in the A/P study area and document their importance to allow more efficient management and better protection of these critical habitats. From the classification analysis of stations in the A/P estuary (using biotic and abiotic variables), species habitat utilizations and core group characterizations were determined. The two principal methodologies used were cluster analysis and discriminant function analysis. To help resource managers identify new areas for nursery area designation, recommendations for critical habitat criteria were developed. Recommendations for future research

Table 2. Designated nursery area acreage in North Carolina's coastal waters as of December 1988.

Nursery area type	Acreage	Percent of state's estuarine waters
Primary Nursery Areas	80,165	3.9%
Permanent Secondary Nursery Areas	35,355	1.7%
Special Secondary Nursery Areas	13,358	0.7%
Total	128,878	6.3%

Table 3. Nursery area acreage by county in the Albemarle-Pamlico estuary.

County	Primary nursery area	Secondary nursery area	Total
Beaufort	578	165	793
Carteret	7,244	9,868	17,112
Craven	335	376	711
Dare	376	2,231	2,608
Hyde	4,300	23,559	27,859
Pamlico	4,666	8,939	13,605
Total	17,499	45,138	62,688

include identification of impaired or impacted areas and any causal relationship to human activities that might exist.

2.0 NURSERY AREA RESEARCH AND MONITORING

The majority of DMF data applicable to this project is found in the juvenile stock assessment program (designated as Program 120). Sampling for this program has been ongoing in the A/P study area since 1971. This long-term database contains over 900,000 collections. Other DMF programs that have data on nursery areas are listed in Table 4. Data used in this project were only from Program 120. Program 120 objectives have remained consistent; however, sampling methods and materials have varied. Documentation of the program's procedures was written as part of this project and is available from DMF. This documentation includes a historical perspective, sampling methods and gears used, changes or deviations in sampling or coding procedures, species lists, and station locations.

Reports on early estuarine monitoring programs by DMF include Spitsbergen and Wolff (1974), Purvis (1976), and Wolff (1976). Other reports by DMF for the juvenile stock assessment program include Carpenter and Ross (1979), Hawkins (1982), and Ross and Carpenter (1983). Other publications utilizing DMF survey data include Street and Pate (1975), Epperly (1984), DeVries (1985), and Ross and Epperly (1985).

Other North Carolina studies on the utilization of nursery areas by juvenile finfish and crustaceans have been conducted in the Cape Fear River (Copeland et al. 1979, Weinstein 1979, Weinstein et al. 1980, Hodson et al. 1981), South River off the Neuse River (Kirby-Smith et al. 1987, Kirby-Smith et al. 1988), Pamlico River (West 1988), and in the bays and tidal creeks of the Albemarle-Pamlico Peninsula (Gerry 1981, Woodward 1981, Currin 1984). Miller et al. (1984) stated that a few species dominate the biomass of these estuaries, and that, for the most part, these species are juvenile life stages.

Work was conducted by Ross and Epperly (1985) on the utilization of estuarine nursery areas by fishes in the Pamlico Sound estuarine complex. They found species composition, seasonal abundance and fish distribution in these shallow estuarine nurseries to be similar to those reported for other temperate east and Gulf coast estuarine systems. Ross and Epperly (1985) also addressed relationships among various abiotic and biotic factors using numerical classification techniques, discriminant analysis, and other statistical tests.

3.0 STUDY AREA

The study area (Figure 2) included the Pamlico Sound estuarine complex and Core Sound. Only two stations, KHB2 and BB4 from Albemarle Sound were used in the analyses. These were located in Kitty Hawk Bay and Buzzard Bay, respectively. Other Albemarle Sound stations were sampled with a larger net; thus, resulting data could not be compared with that from Pamlico and Core sounds.

Table 4. North Carolina Division of Marine Fisheries nursery area monitoring programs.

Program name	Program number	Dates	Study area
Nursery area juvenile stock assessment	120	1970-present	Estuarine nursery areas coastwide
Vandemere Creek study	125	1982	Vandemere Creek
Orchard Creek study	126	1983	Orchard Creek
Juvenile anadromous study	100	1972-present	Albemarle and Currituck sounds
Anadromous adult spawning area sampling	150	1972-1983, 1987-present	Albemarle and Currituck sounds
Anadromous egg and larvae sampling	160	1973-1984, 1987-present	Albemarle and Currituck sounds
Freshwater intrusion study	130	1977-1980	Rose and Swanquarter bays
Nursery area gear tests	925	1988, 1989	Neuse River, South Creek, Pamlico River, Rose Bay, Spencer Bay

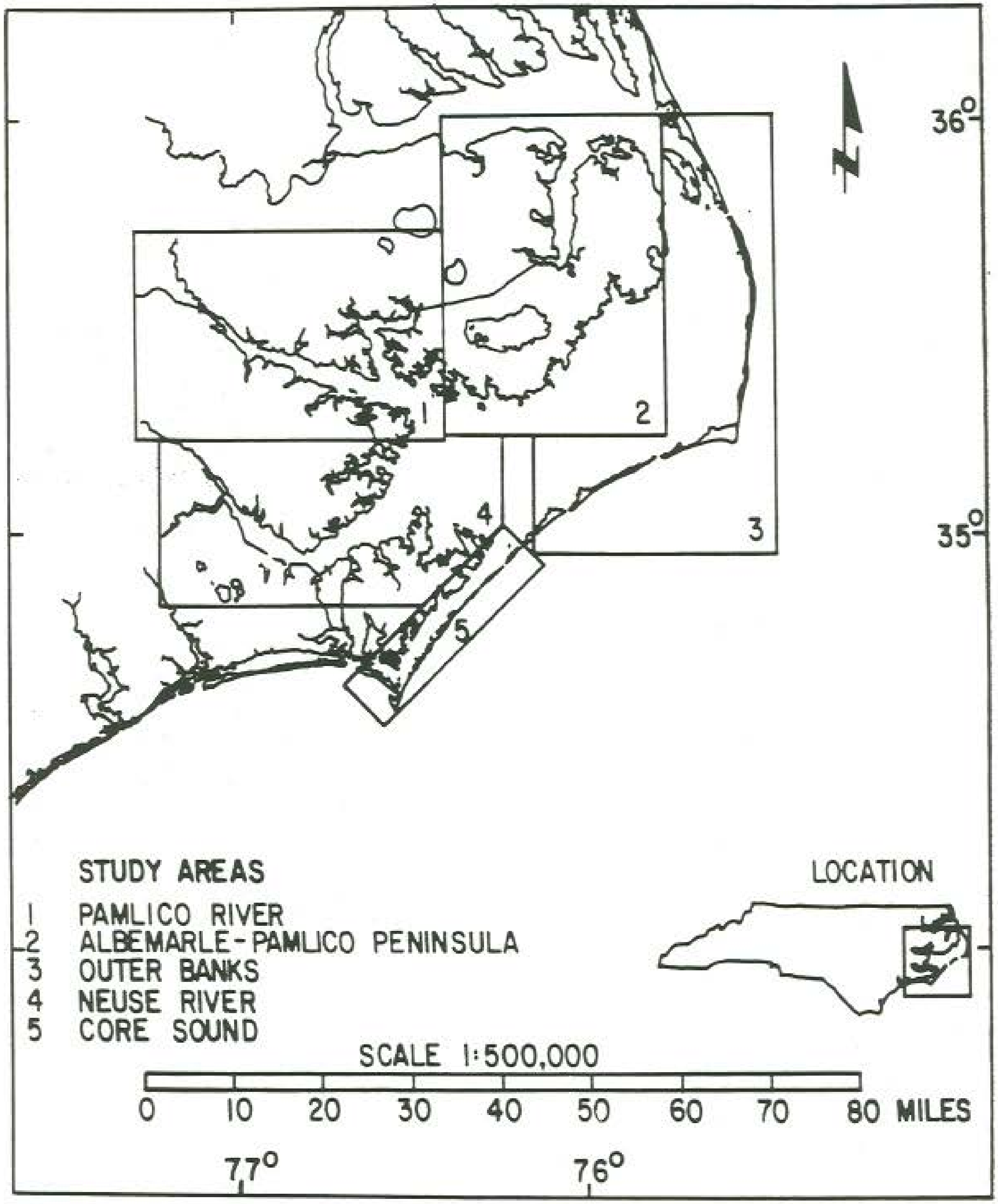

Figure 2. Study area for the analysis of Albemarle-Pamlico Sound nursery area project.

Pamlico and Core sounds are 5,335 square kilometers in area. With a mean depth of only 4.9 meters, Pamlico Sound is 326 x 10^8 cubic meters in volume (Giese et al. 1979). This system is physically controlled by tides near the inlets and by wind-generated flow elsewhere. Core Sound, also a shallow water body, receives little freshwater inflow, and with its proximity to the ocean, is dominated by lunar tidal flow (Epperly and Ross 1986).

Stations were located over a large geographic area and are influenced by a variety of hydrological conditions and habitat types (Figures 3-7). These habitats included shallow areas of Core Sound, open water behind the Outer Banks, estuaries around Roanoke Island, bays of the Albemarle-Pamlico Peninsula, the Pungo, Pamlico and Neuse rivers, and also the bays along the southwest perimeter of Pamlico Sound. Those stations behind Core Banks and the Outer Banks were generally located in sandy habitats with eelgrass (*Zostera marina*) and shoalgrass (*Halodule wrightii*) beds present. The stations around Roanoke Island were generally located in sandy-mud bottom sediments with widgeon grass (*Ruppia martima*) present. Pamlico Sound and adjoining river system stations were in tidal creeks and small bays with muddy, detrital bottom sediments surrounded by saltmarsh cordgrass (*Spartina alterniflora*) or black needlerush marsh (*Juncus romerianus*).

4.0 CLASSIFICATION ANALYSES

4.1 Methods

4.1.1 Sampling

Various gears and methodologies have been used by DMF in the study area since 1971. The gear used most consistently over the long-term for sampling shallow upstream areas of creeks and bays was a two-seam otter trawl with 3.2 m headrope, 6.4 mm bar mesh wings and body, and 3.2 mm bar mesh cod end. The net was towed with 46 cm x 76 cm doors by outboard boats. Only one replicate per station was taken. Since 1971, 470 different stations have been sampled in the study area with this gear (Appendix). Only samples collected with this gear were used in analysis. In 1978, tow times were standardized. The net was towed for one minute at approximately 1.1 m/sec. Prior to 1978, tow times varied from 30 seconds to 30 minutes (Table 5). Samples collected prior to 1978 with tow times between one and five minutes were included in analyses. These were not standardized to one minute tows. One daylight tow was made at each station per month in the spring, summer, and fall and at some stations in the winter. Time of day varied. Data from sporadic night sampling over the eighteen year period were not included in analyses. Three hundred and twenty-five stations out of the 470 met these sampling criteria and were included in the analyses. All areas did not have equal sampling. The Pamlico River estuary had 74 stations, the Pamlico-Albemarle Peninsula had 76, the Outer Banks and Roanoke Island had 26 stations, the Neuse River estuary had 74 stations, southwestern Pamlico Sound had 53 stations, and Core Sound had 17 stations (Figures 3-7).

All economically important species were identified, counted, and measured to the nearest millimeter. A subsample was measured when large numbers of

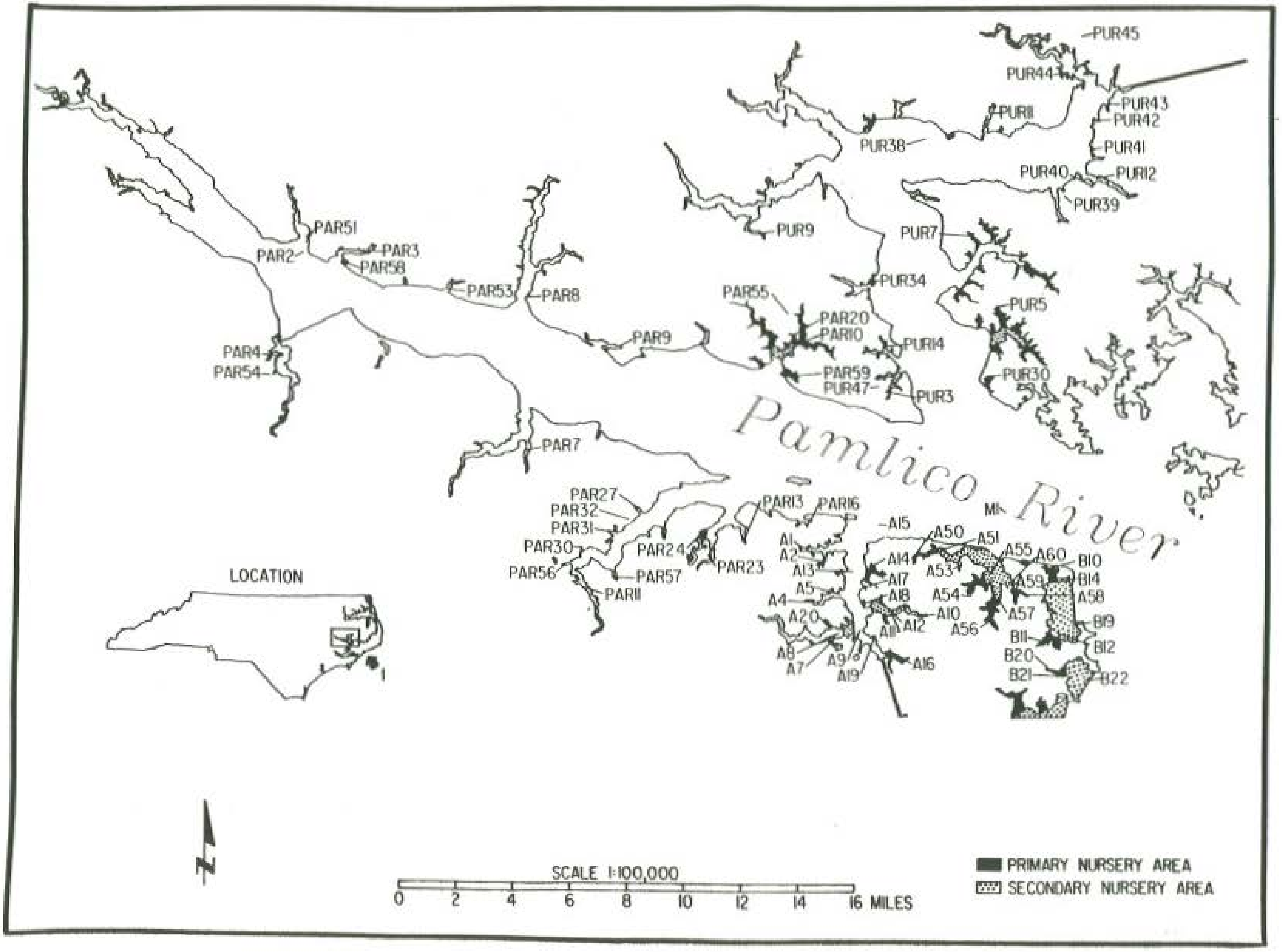

Figure 3. Pamlico River designated nursery areas and stations used in analysis.

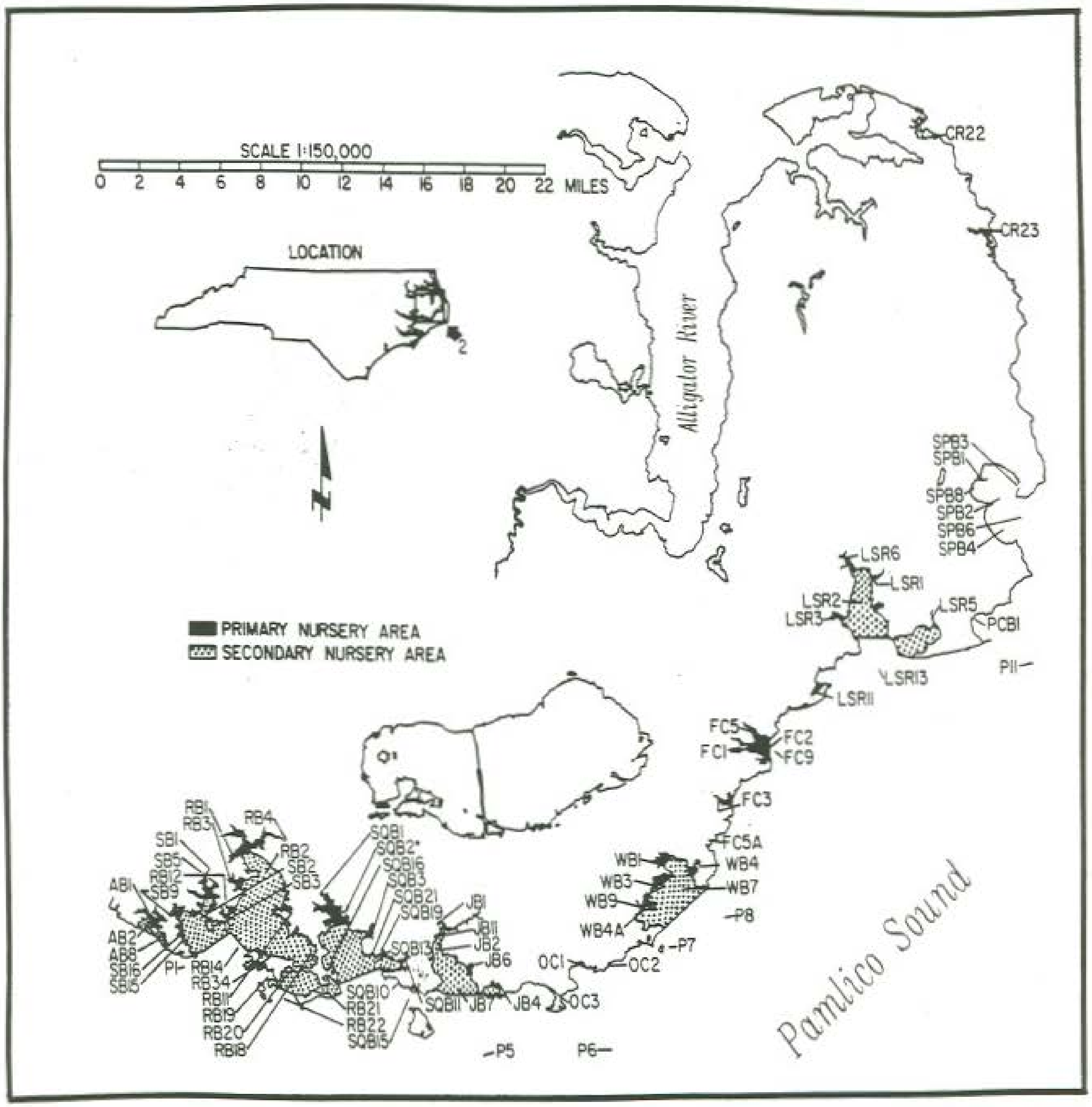

Figure 4. Albemarle-Pamlico peninsula designated nursery areas and stations used in analysis.

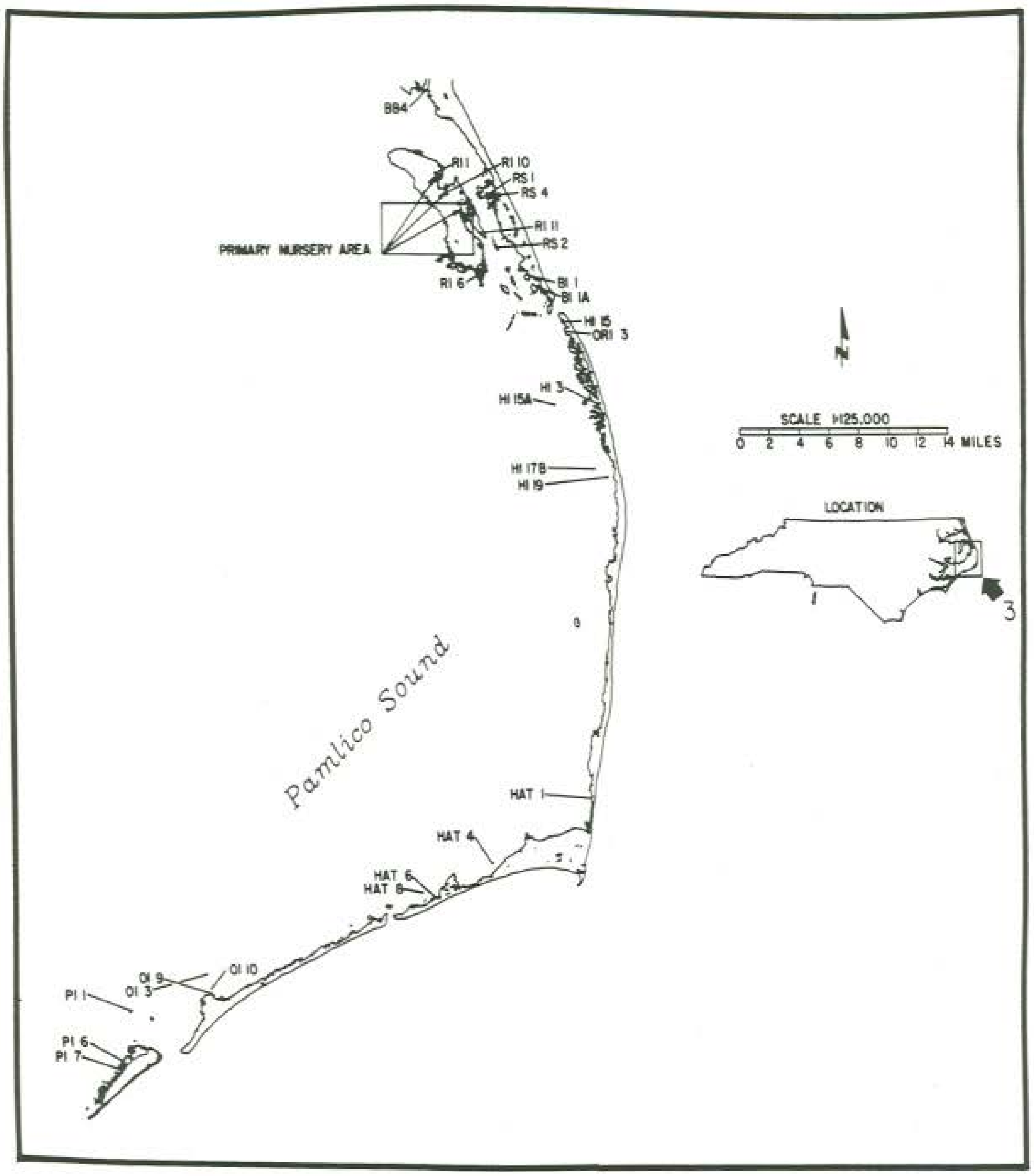

Figure 5. Outer Banks designated nursery areas and stations used in analysis. Station KHB2, located north of station BB4, was used in the analyses, but is not shown on this map.

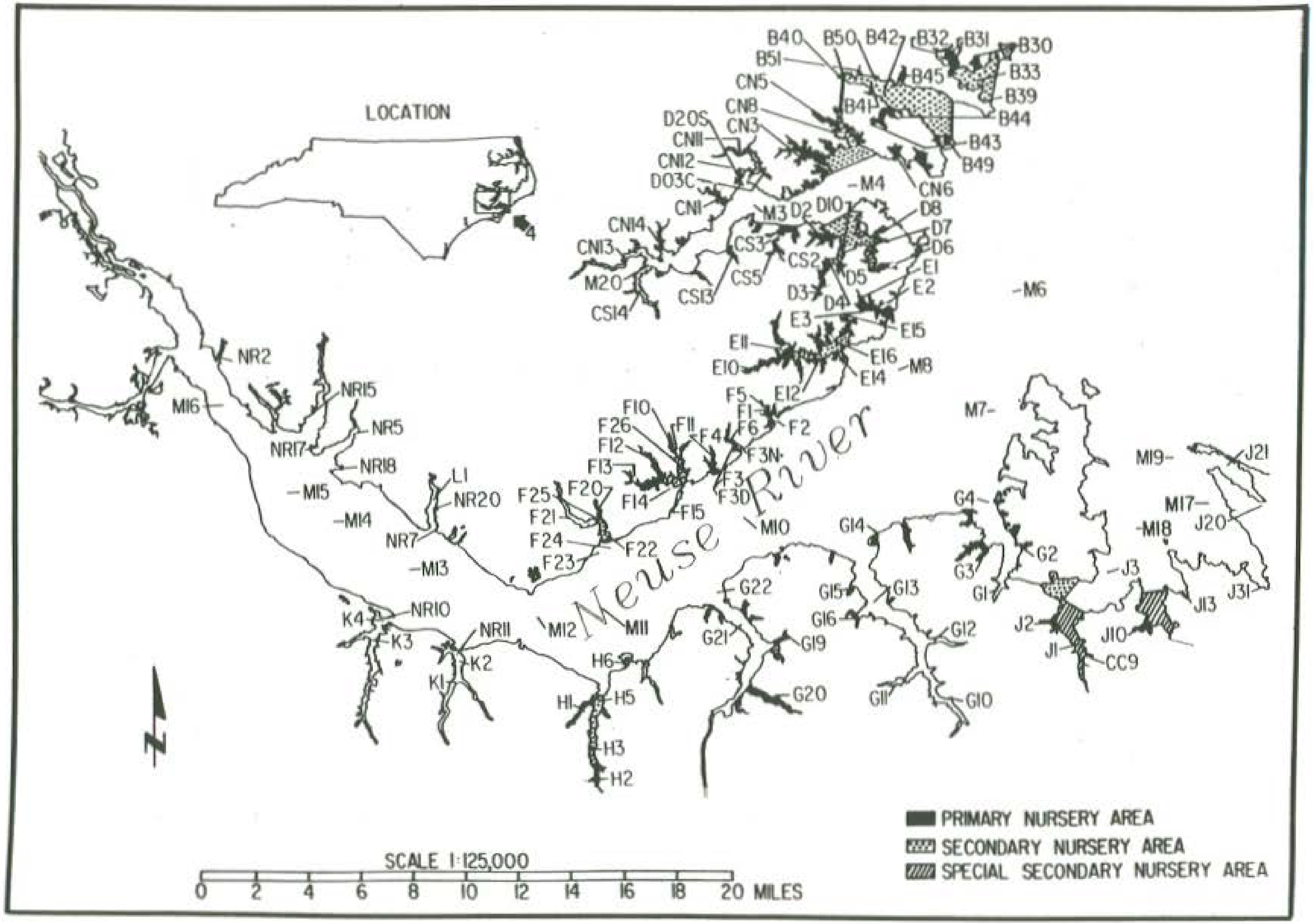

Figure 6. Neuse River and southwestern Pamlico Sound designated nursery areas and stations used in analysis.

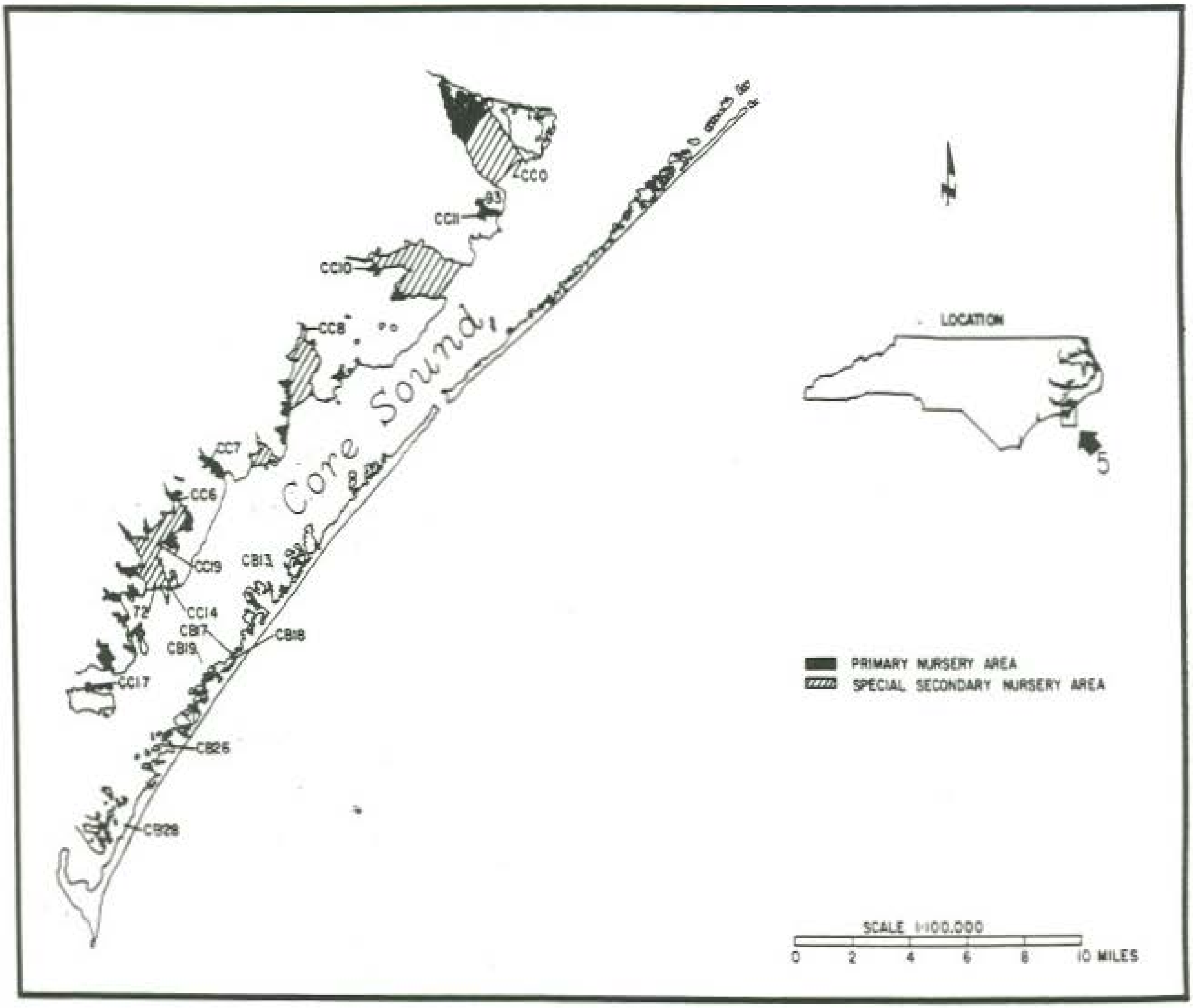

Figure 7. Core Sound designated nursery areas and stations used in analysis.

Table 5. Tow times for 32 m foot otter trawl used in the North Carolina Division of Marine Fisheries estuarine monitoring program. Number of times this trawl was pulled at these durations each year is also given. A total of 224 samples were taken with no duration noted.

Duration (minutes)	Year																		Total
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	
0.5			5	1	80	29	28	63	119	3									328
0.75						2			4										6
1			56	193	269	214	121	114	480	833	879	933	1,145	1,052	1,098	1,116	808	821	10,132
1.25								1											1
1.5			1	1	2		1		1										6
2		5	149	378	321	179	56	81	175	4	1			2		1			1,352
2.5		1	405	171	124	107	54	43	31										936
3	1	12	384	397	382	303	70	20	47										1,161
3.15				1															1
3.5									1										1
4			10	22	9	3	1		4	2									51
5	98	762	1,621	525	396	321	250	82	42	13	21	16	1			3	3	1	4,155
6				1			1				2								4
7			4															1	5
8			1	1															2
8.5			1																1
10	41	201	81	2	4		1												330
12		3																	3
13		2																	2
15	126	250	5		4														385
20		6																	6
30				1	3														4
Totals	266	1,242	2,723	1,694	1,594	1,158	583	404	904	855	903	949	1,146	1,054	1,098	1,120	811	823	19,327

individuals were sampled. Surface and bottom salinities and temperatures were taken for each tow. Depth was also recorded. Bottom composition and sediment size data have been collected from some stations.

4.1.2 Database Construction

4.1.2.1 Target Species Selection

Twenty-three species were originally chosen to be included in the analysis based on the classification of stations done by Ross and Epperly (1985). Of these, only economically important species were selected. This included spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), brown shrimp (*Penaeus aztecus*), blue crab (*Callinectes sapidus*), silver perch (*Bairdiella chrysoura*), southern flounder (*Paralichthys lethostigma*), pinfish (*Lagodon rhomboides*), pigfish (*Orthopristis chrysoptera*), pink shrimp (*Penaeus duorarum*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), white shrimp (*Penaeus setiferus*), summer flounder (*Paralichthys dentatus*), and gag (*Mycteroperca microlepis*). Other economically important species originally included were striped mullet (*Mugil cephalus*), crevalle jack (*Caranx hippos*), gulf flounder (*Paralichthys albigutta*), white perch (*Morone americana*), black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), Atlantic menhaden (*Brevoortia tyrannus*), and red drum (*Sciaenops ocellatus*). Sheepshead (*Archosargus probatocephalus*) was also included.

After preliminary analyses, several species were omitted. Five species were deleted based on very low percent species composition, and after analysis of variance, very low F values ($P > 0.9$). These were white shrimp, white perch, crevalle jack, striped mullet and sheepshead. Atlantic menhaden, a surface schooling species, was also omitted because of extreme variability in catch due to patchy distribution and gear selectivity. Spot was omitted because it is so ubiquitous in the nursery areas of the Pamlico Sound estuarine complex that its value in creating station groupings was minimal. This species "diluted" between-station differences in species composition. Thayer et al. (1984) and Weinstein (1985) found spot to be a dominant species in eelgrass habitat, *Spartina* marsh, channels, and intertidal sandflats. In fact, it was the only dominant species common to all four habitat types. Heck and Thoman (1984) also found high densities of juvenile spot in their four Chesapeake Bay sampling areas (eelgrass, widgeon grass, and two unvegetated). When they included spot in their analyses, grass beds did not support larger numbers of fish than unvegetaged areas. However, without spot included in station totals, vegetated habitats supported much larger fish numbers than unvegetated sites did (Heck and Thoman 1984).

The sixteen species used in the final analysis are listed in Table 6. Adult specimens were eliminated from the analysis by designating maximum lengths for each species for each month (Table 7). Maximum lengths were determined from individual species length-frequency analysis by month of nursery area data. Although some species were less vulnerable to the gear, each species was equally vulnerable at all stations throughout the study area.

Table 6. Target species used in classification analysis of Albemarle-Pamlico Sound nursery area data.

Common name	Scientific name
Atlantic croaker	*Micropogonias undulatus*
Weakfish	*Cynoscion regalis*
Spotted seatrout	*Cynoscion nebulosus*
Red drum	*Sciaenops ocellatus*
Silver perch	*Bairdiella chrysoura*
Summer flounder	*Paralichthys dentatus*
Southern flounder	*Paralichthys lethostigma*
Gulf flounder	*Paralichthys albigutta*
Pigfish	*Orthopristis chrysoptera*
Pinfish	*Lagodon rhomboides*
Bluefish	*Pomatomus saltatrix*
Black sea bass	*Centropristis striata*
Gag	*Mycteroperca microlepis*
Blue crab	*Callinectes sapidus*
Brown shrimp	*Penaeus aztecus*
Pink shrimp	*Penaeus duorarum*

Table 7. Maximum lengths (mm) by month for target species used in classification analysis of Albemarle-Pamlico Sound nursery area data.

	Lengths (mm)		
Species	April	May	June
Atlantic croaker	100	125	150
Silver perch	75	75	75
Southern flounder	100	120	130
Pinfish	50	75	100
Pigfish	50	50	75
Weakfish	100	100	100
Spotted seatrout	50	50	50
Summer flounder	100	100	120
Gag	150	150	150
Gulf flounder	100	100	100
Black sea bass	150	150	150
Bluefish	225	225	225
Red drum	225	225	225
Brown shrimp	*	*	*
Pink shrimp	*	*	*
Blue crab	50	50	50

* Annual crop, all specimens sampled were juveniles.

4.1.2.2 Time Period and Depth

Initially, data were analyzed by season (winter, spring, summer, fall). Over the 17 year period, the greatest number of stations sampled and the most consistent sampling methods were found during April, May, and June. These months also coincide with peak abundance of most of the target species. Final analyses used environmental and biological data from only April, May, and June. Future analyses should look at later months (July, August, September) when peak abundance of pink shrimp, spotted seatrout, and red drum occur.

Initial classification analyses showed that depth had very little discriminatory ability in separating station clusters because the majority (82%) of the stations had depths <2 m. Therefore, depth was eliminated from the analyses.

4.1.2.3 Databases

Three distinct databases were constructed for this study.

1. <u>Abiotic</u> - Temperature and salinity records were available for 307 stations for the months of April, May, and June. The values of bottom temperature and bottom salinity averaged over all years produced a six variable set for classification. Data on sediment size and bottom composition were scattered and historical information was sporadic. However, both of these data sources were used qualitatively in core group characterizations described later.

2. <u>Biotic</u> - Species abundance data on the 16 target species were available for three or more consecutive years for 204 stations. The total number for each species for each station was calculated for each month over all years, giving a monthly sum for each target species for each station. A total sum of the 16 target species for each station by month over all years was also calculated. The monthly percentages were computed for each species for each station over all years, and the percentages for each species for each station averaged over three months. Analysis was done on these percentages after using the angular transformation,

   $$y = \arcsin \sqrt{\text{percentage}}$$

   Sokal and Rohlf (1969) state that arcsin transformation is especially appropriate for percentage data. The transformation stabilized the variances across the range 0-100% and further minimized the possibility of linear dependencies occurring which might cause computing difficulties.

3. <u>Abiotic-biotic</u> - Both abiotic and biotic variables were complete for 180 stations These data produced a 22 variable set for classification. Data used in this combination clustering were again by station and by month.

4.1.3 Statistical Analysis

The two principal methodologies used were cluster analysis and discriminant function analysis. The basic sampling unit was a station. The cluster analysis produced groups of stations with similar abiotic and/or biotic characteristics. Classification analysis is an appropriate method for mapping species distributions (Goodall 1978). Using the cluster classification, the discriminant function was used to reclassify and, in a sense, support the original classification. The discriminant function analysis was also used to investigate the DMF classification of primary, secondary, and unclassified nursery areas.

4.1.3.1 Cluster Analysis

Numerical classification groups entities (stations) based on the resemblance of their attributes according to mathematically stated criteria. Clustering methods form these groups on the basis of interentity similarity. The particular method chosen in any given instance depends on a variety of factors including relative weights desired for species abundance and species diversity, as well as the availability of computer hardware and software. In this study, species composition was used to reflect the species diversity as a preferred measure of nursery habitats. The criterion used to cluster variables in this study was the average linkage (or group average) method, which is the most widely used in ecological studies and extensively employed in aquatic biology (Sokal and Michener 1958, Boesch 1977). The method uses unweighted pair group averages for each variable and is exclusive, intrinsic, hierarchical, and agglomerative. The hierarchical nature of this method permits easy transition from large-to-fine-scale group definition. It produces moderately sharp clustering, but introduces little distortion to the relationships originally expressed in the inter-entity resemblance matrix (Cunningham and Ogilvie 1972). The group average method is a space conserving strategy and is not biased towards group size dependence (Clifford and Stephenson 1975). The implementation used here is that of the Statistical Analysis System (SAS Institute, Inc. 1985).

Some preliminary analyses were done using the Lance-Williams flexible beta method (Lance and Williams 1967), but abandoned because the results were similar to those of average linkage and required no arbitrary choice of the beta parameter.

4.1.3.2 Discriminate Function Analysis

This method constructs a linear function of independent variables (abiotic and/or biotic) which will provide an index to maximize the distance between clusters obtained by the clustering procedure. Using this index, each station is classified into one of the clusters, and the results are presented as a reclassification table. A similar application to the stations classified by DMF as primary and secondary, and also unclassified nursery areas provided insight to the consistency of the DMF external classification and its compatibility with the groupings obtained by abiotic and/or biotic clustering. It is argued that if the discriminant function can reasonably reflect the same station grouping as the clustering procedure, the consistency of the clustering is supported.

4.2 Results

The cluster analyses identified station groupings based on species composition, salinity, and temperature. Output was in the form of similarity matrices and computer-generated dendrograms. The separation was by sampling site, not sampling period. Results show that physical differences between habitats are important factors in determining distribution patterns.

4.2.1 Abiotic Clustering

Following the recommendations of Milligan and Cooper (1983), Cooper and Milligan (1984), and Sarle (1983), the pseudo-F and pseudo T^2 statistics and the cubic clustering criterion appeared to best identify five clusters from the 306 stations. Cluster means for each of the six abiotic variables are given in Table 8. Eight stations did not fall into one of these five clusters. Table 9 lists these eight stations and their abiotic variable values. The relationship of the clusters to each other is shown graphically in Figure 8. Inspection of the figure show that clusters 1 and 2 had some overlap, and also contained most of the stations. A third representation of the clustering is the geographic location of similar stations in Figure 9. Similarities associated with salinities correlate well with the river, sound, and Outer Banks stations.

As would be expected, temperature differences are not great from cluster to cluster (Figure 10). April mean temperatures ranged from 16.6°C to 17.3°C, May was 21.6°C to 22.9°C, and June was all around 26.0°C. In the Pamlico Sound estuarine complex, seasonal variation in temperature is greater than spatial variation within a season.

Of the two abiotic factors, salinity had the greatest discriminatory ability (Figure 11). Cluster 2 is clearly a "low salinity" group (5.6 - 7.9 ppt) with clusters 1 (10.9-13.2 ppt) and 6 (14.7-18.6 ppt) in the moderate salinity range. Clusters 3 and 5 are "high salinity" groups with mean salinity ranges of 29.4-30.7 ppt and 21.0-26.7 ppt, respectively. Salinity increased over time in all five main station groupings.

The eight stations judged to be anomalous showed an erratic salinity pattern over the three months and did not fit any of the other cluster patterns. There were also exceptionally low April temperatures in clusters 4 and 9 which further segregated these stations from the main groups.

Table 10 contains the results of a discriminant function analysis with the same abiotic variables used in clustering. The linear discriminant function considers the clusters as externally classified groups and finds a linear function of the abiotic variables which best separates these groups. An index is computed for each station, and the station is assigned to the group having the highest posterior probability of membership in each group. The five major groups consisted of 298 (97%) of the 306 stations clustered.

Table 8. Variable means for the five major abiotic clusters of Albemarle-Pamlico Sound stations.

Cluster	N	Salinity (ppt) Apr	May	Jun	Temperature (°C) Apr	May	Jun
1	130	10.9	12.0	13.2	17.3	22.7	26.4
2	142	5.6	6.5	7.9	16.8	23.0	26.8
3	6	29.4	30.2	30.7	16.6	22.2	26.2
5	9	21.0	25.2	26.7	17.0	21.6	26.6
6	11	14.7	18.0	18.6	16.1	22.1	26.4
Total	298						

Table 9. Variable means for anomalous abiotic clusters of Albemarle-Pamlico Sound stations.

Cluster	N	Salinity (ppt) Apr	May	Jun	Temperature (°C) Apr	May	Jun
4	2	0.0	1.8	10.0	15.0	26.0	26.2
7	2	12.8	7.2	6.0	18.1	27.5	26.5
8	2	4.8	9.6	10.9	18.5	30.4	28.1
9	1	23.4	16.0	20.2	14.2	21.2	25.2
10	1	20.5	30.0	17.0	19.5	25.0	28.0
Total	8						

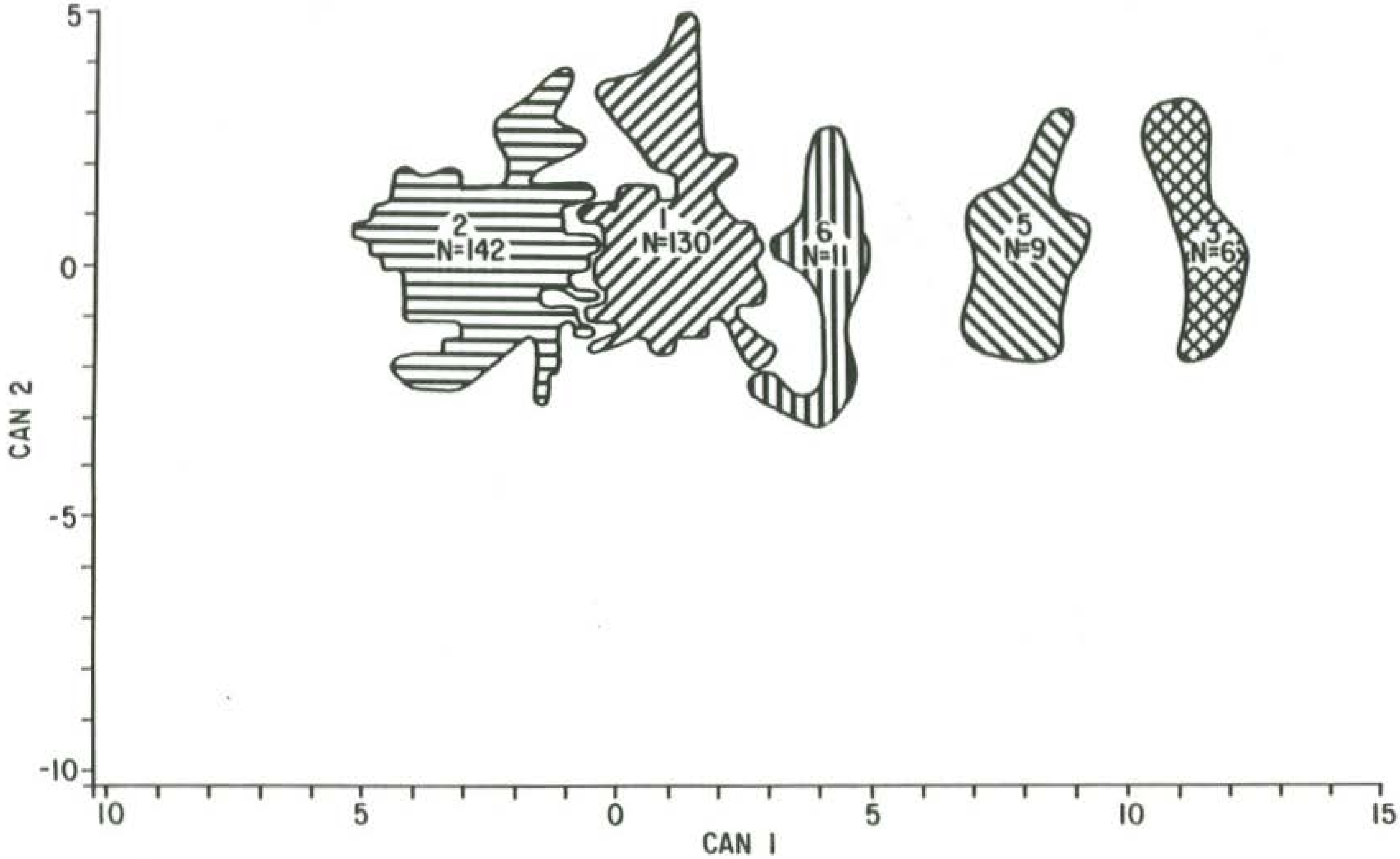

Figure 8. 298 Albemarle-Pamlico Sound nursery area stations grouped into similarity clusters according to the six abiotic variables.

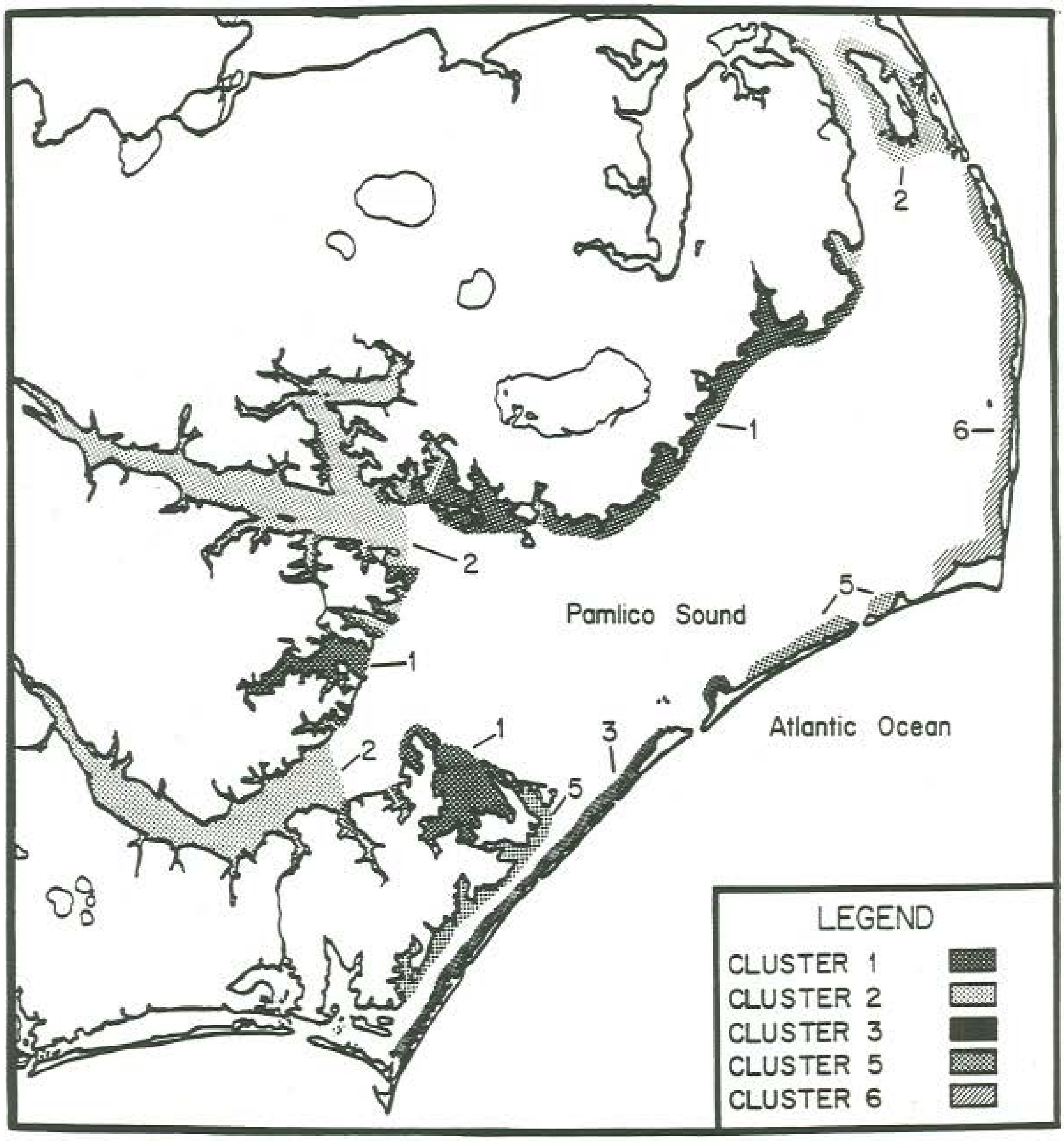

Figure 9. Map of areas defined by abiotic clustering of Albemarle-Pamlico Sound nursery area stations.

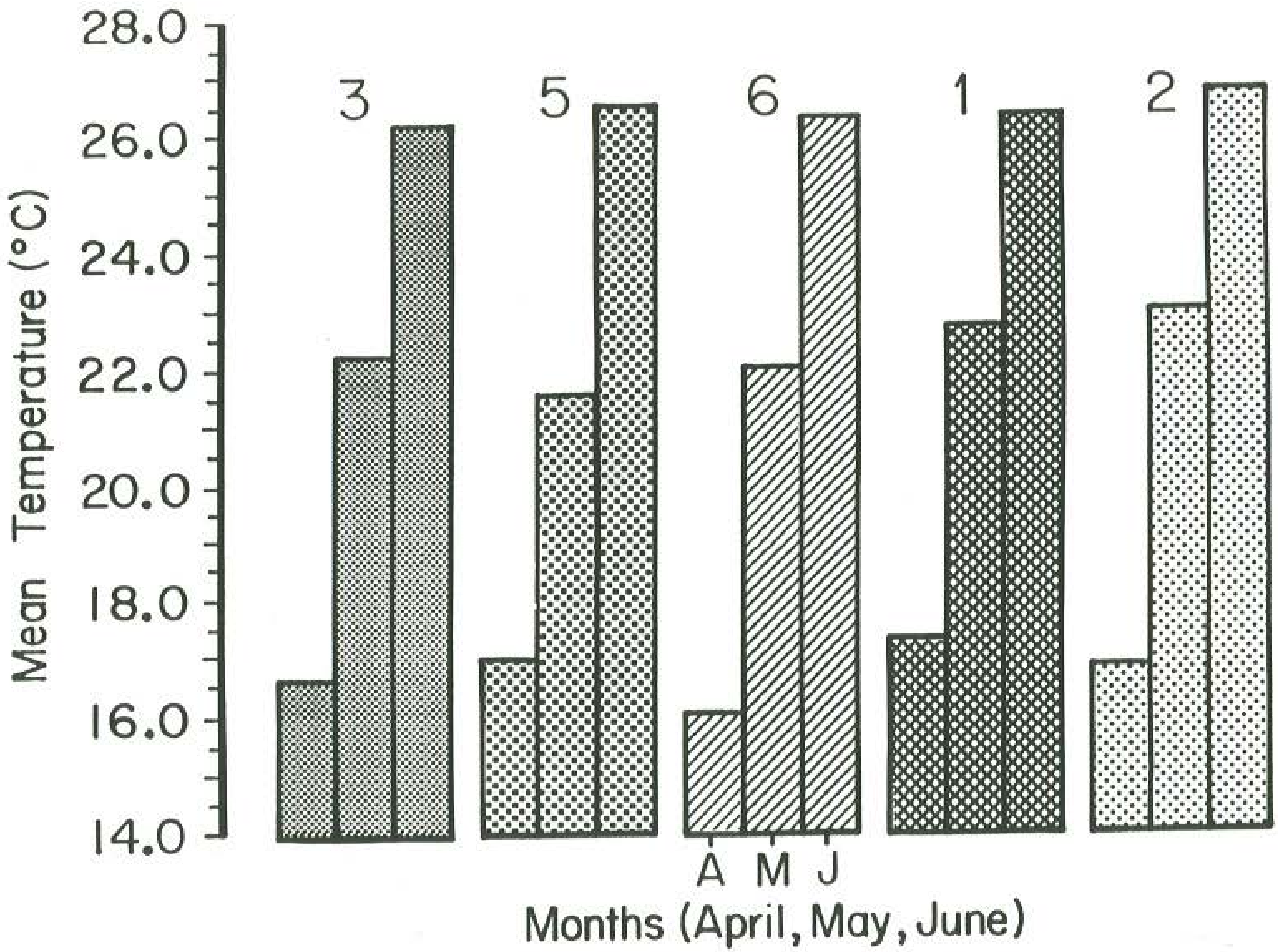

Figure 10. Mean monthly temperatures for abiotic clusters of Albemarle-Pamlico Sound nursery area stations.

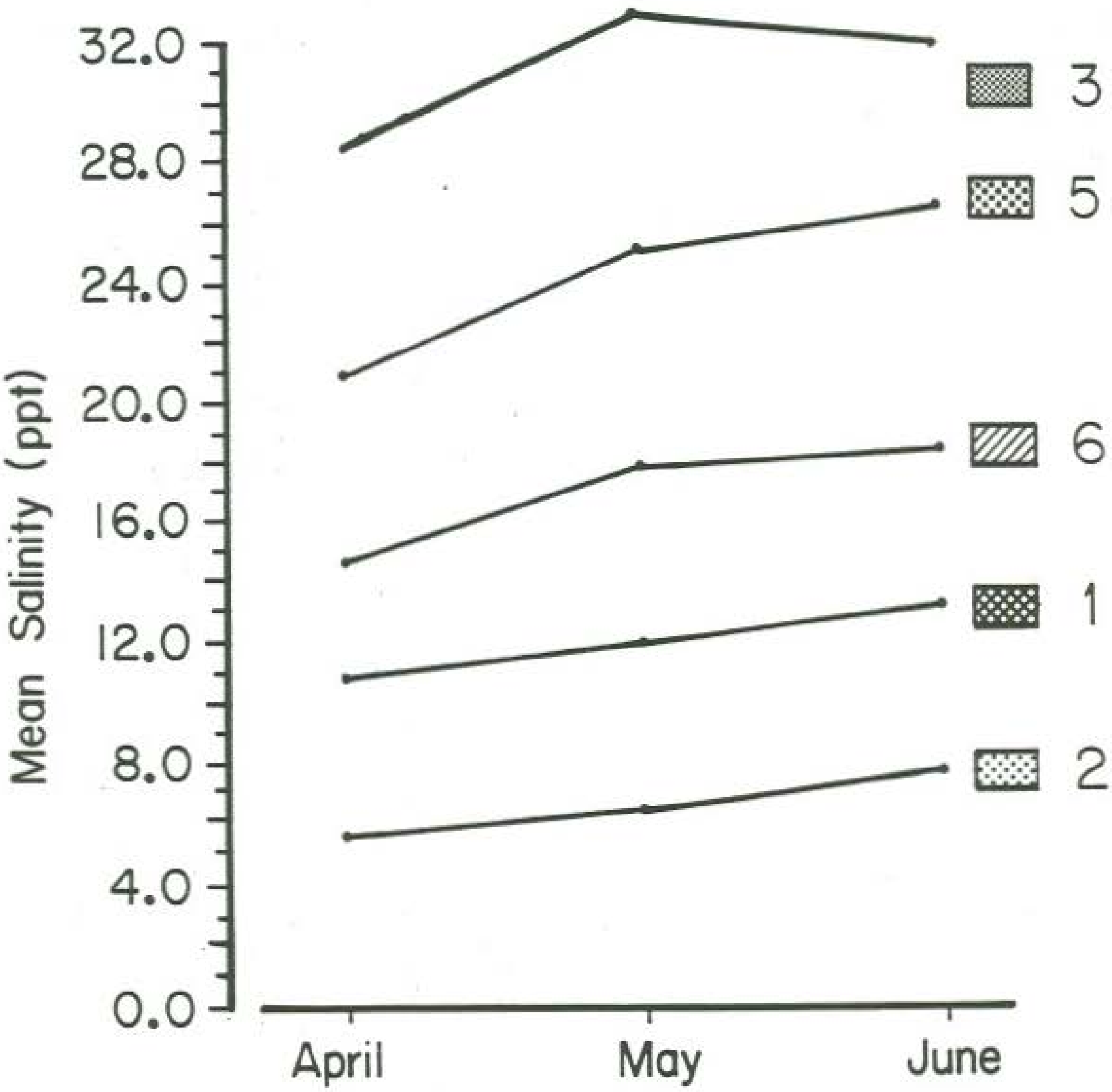

Figure 11. Mean monthly salinities for abiotic clusters of Albemarle-Pamlico Sound nursery area stations.

Table 10. Classification by an abiotic discriminant of Albemarle-Pamlico Sound station groups determined by abiotic clustering.

From cluster	Number of stations and percent classified into clusters					Original totals
	1	2	3	5	6	
1	121 93	1 1			8 6	130 100
2	8 6	126 89				142 95
3			6 100			6 100
5				9 100		9 100
6					11 100	11 100
Total classified	129	127	6	9	19	290/298
Percent	43	43	2	3	6	97

The remaining eight stations regarded as anomalous formed an additional five clusters. The linear discriminant classified 97% into the five major clusters, with the remaining 3% (eight stations) of cluster 2 being scattered among the five anomalous clusters. Some ambiguity exists in clusters 1 and 2, with eight stations in cluster 1 going to cluster 6, and eight stations of cluster 2 going to cluster 1. It appears that the linear discriminant classification supports strongly the original clustering using the average linkage method.

A second linear discriminant was constructed for these abiotic clusters using the available biotic variables (Table 11). It was hoped that some insight could be gained relating the abiotic similarities to the biotic ones. Only 183 stations of the original 306 contained biotic variables, and of those, 181 classified by the biotic discriminant were retained in the five major abiotic clusters. Only two stations remained anomalous with respect to the biotic variables. It is clear that more ambiguity exists between clusters 1 and 2 than was observed for the abiotic discriminant suggesting that the 16 target species represented were more nearly indifferent to the low salinities represented in these abiotic clusters. It is, of course, true that some sharpness of classification would decline using variables not included in the clustering process, but the fact that this decline is in the two lower salinity clusters appears to be significant support for the previous conjecture of low salinity indifference among the target species.

4.2.2 Biotic Clustering

Using the same statistical criteria as in the preceding section, the stations were clustered using the biotic (species composition) variables. The arcsin transformation of the mean percent for each species while stabilizing the variances also takes 0 percent to 0 degrees, 100 percent to 90 degrees with the mid-point of 50 percent going to 45 degrees (i.e., the zero points remain the same). Again, five major clusters were produced with nine stations forming six additional clusters, tentatively designated as anomalous. Suggested reasons for the separate cluster formations regarded as anomalous are given in Table 12. Tables 13 and 14 give the class means of the transformed species composition. Following the pattern of the preceding section, the cluster relationships are shown graphically in Figure 12 and geographically in Figure 13.

Whereas clusters 1, 2, 3, and 4 represented a specific geographic area, cluster 5 did not. Cluster 5 consisted of only six stations. Stations RI11 and RS2 are located in Roanoke Sound and KHB2 is in Albemarle Sound. Stations J13 and J20 are across Pamlico Sound to the south in West Bay. Station SQB10 is in Swanquarter Bay. Except for KHB2, salinities ranged between 8.6 and 15.5 ppt; for KHB2, the average salinity for April, May, and June was 6.0 ppt. These six stations had very high numbers of blue crabs relative to the five major clusters. Species absent at all six stations were black sea bass, gag, spotted seatrout, and gulf flounder. Percent species composition of blue crab was primarily responsible for this cluster formation. Stations are most similar to those in the bays of mainland Core Sound.

Table 11. Classification by a biotic discriminant of Albemarle-Pamlico Sound station groups determined by abiotic clustering.

From cluster	Number of stations and percents classified into clusters					Original totals
	1	2	3	5	6	
1	75 77	23 23				98 100
2	15 22	52 78				67 100
3			3 100			3 100
5				7 88	1 12	8 100
6					5 100	5 100
Total classified	90	75	3	7	6	181/181
Percent	50	41	2	4	3	100

Table 12. Reasons for separate cluster formation of six anomalous biotic clusters of Albemarle-Pamlico Sound stations.

Cluster No.	Station	Reasons
6	SPB2	Only five target species sampled.
	72	Greatest number of brown shrimp.
	LSR6	Greatest number of bluefish.
7	BI1A HI15A	Greatest number of blue crab, black sea bass, and gag.
8	B33	Only four target species sampled.
9	HI3	Only five target species sampled. Greatest number of pigfish and southern flounder.
10	RB11	Greatest number of red drum.
11	CC19	Greatest number of pink shrimp, silver perch, and summer flounder.

Table 13. Variable means of transformed percent species composition for major biotic clusters of Albemarle-Pamlico Sound stations[1].

	Cluster/Number of stations				
Species	1/74	2/86	3/16	4/13	5/6
Brown shrimp	7.54	22.79	2.43	33.28	12.26
Pink shrimp	0.62	1.20	9.71	8.21	1.89
Blue crab	6.25	15.40	9.36	21.48	43.18
Black sea bass	0.00	0.03	0.60	0.00	0.00
Gag	0.00	0.00	0.85	0.19	0.00
Bluefish	0.49	1.00	0.23	0.48	3.75
Pigfish	0.02	0.12	9.05	2.54	1.14
Pinfish	1.30	3.51	65.4	11.55	7.05
Spotted seatrout	0.02	0.27	0.21	0.00	0.00
Weakfish	0.84	2.90	0.00	1.10	4.32
Silver perch	1.10	3.30	0.61	1.71	1.38
Atlantic croaker	74.3	48.06	2.40	18.94	21.85
Red drum	0.06	0.15	1.16	0.26	0.41
Summer flounder	0.28	0.57	1.16	2.85	1.07
Gulf flounder	0.02	0.02	2.18	1.59	0.00
Southern flounder	4.98	10.94	1.60	15.85	9.57

1. The variable means are angles expressed in degrees. Species composition percentages can be obtained by finding the sine of the mean angle, squaring the result, and multiplying by 100.

Table 14. Variable means of transformed percent species composition for anomalous biotic clusters of Albemarle-Pamlico Sound stations[1].

Species	6/3	7/2	8/1	9/1	10/1	11/1
	Cluster/Number of stations					
Brown shrimp	70.02	3.69	0.00	0.00	6.99	9.81
Pink shrimp	0.00	1.83	13.28	7.40	0.00	53.21
Blue crab	2.92	73.47	15.00	19.36	20.11	9.16
Black sea bass	0.00	2.17	0.00	0.00	0.00	0.00
Gag	0.00	0.91	0.00	0.00	0.00	0.00
Bluefish	4.77	0.00	0.00	0.00	2.02	0.00
Pigfish	0.00	6.30	0.00	23.12	0.00	2.05
Pinfish	0.00	6.15	0.00	0.00	41.63	5.88
Spotted seatrout	0.00	0.00	0.00	0.00	0.00	0.00
Weakfish	0.00	0.00	0.00	0.00	1.90	0.00
Silver perch	0.00	1.57	0.00	0.00	0.00	3.56
Atlantic croaker	16.44	0.00	30.00	0.00	25.18	19.79
Red drum	0.00	0.00	0.00	0.00	2.68	0.00
Summer flounder	0.00	4.75	0.00	4.24	0.00	12.05
Gulf flounder	0.00	0.00	0.00	0.00	0.00	0.00
Southern flounder	3.61	1.23	31.72	45.00	24.60	5.59

1 The variable means are angles expressed in degrees. Species composition percentages can be obtained by finding the sine of the mean angle, squaring the result, and multiplying by 100.

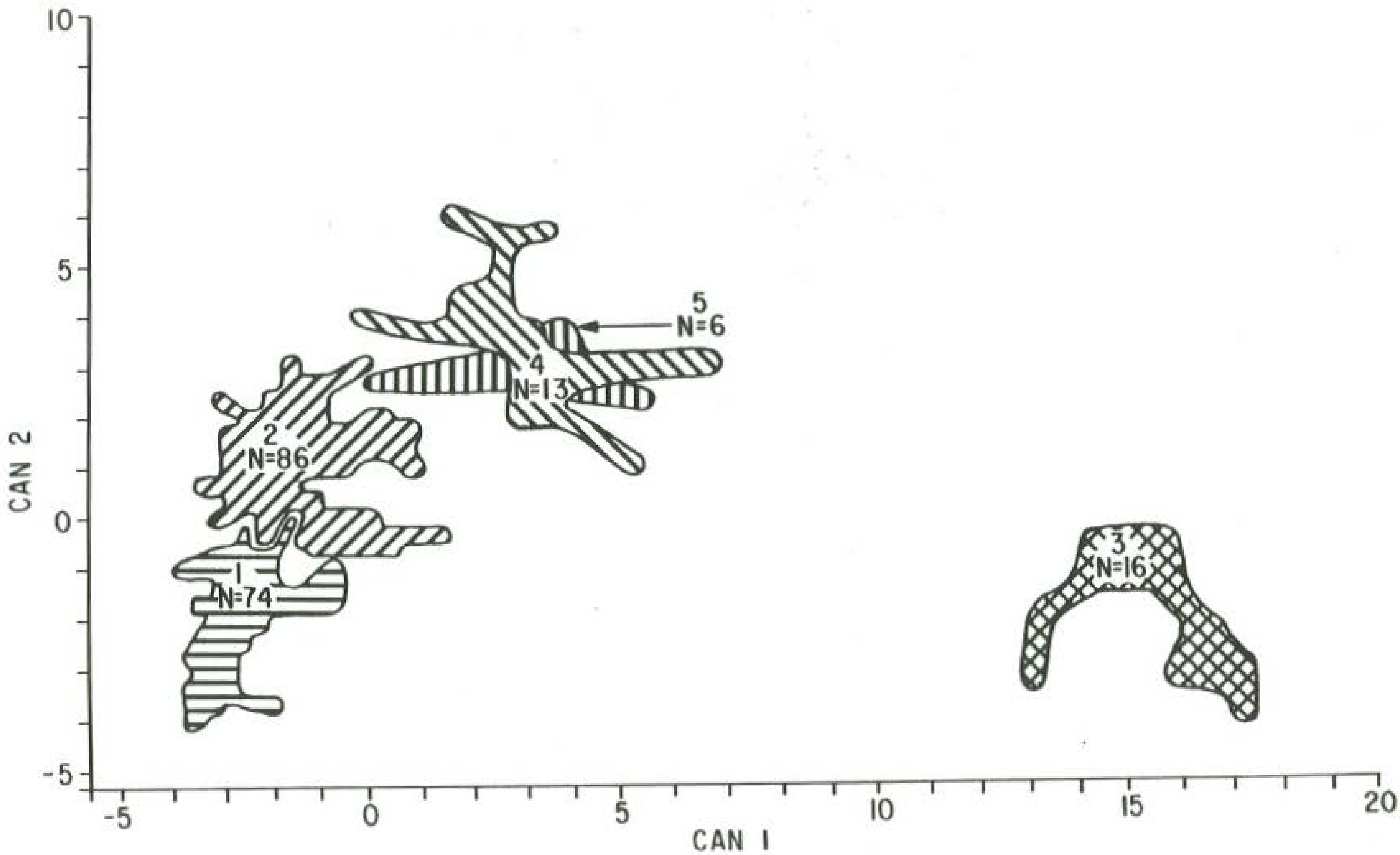

Figure 12. 195 Albemarle-Pamlico Sound nursery area stations grouped into similarity clusters according to the sixteen biotic variables.

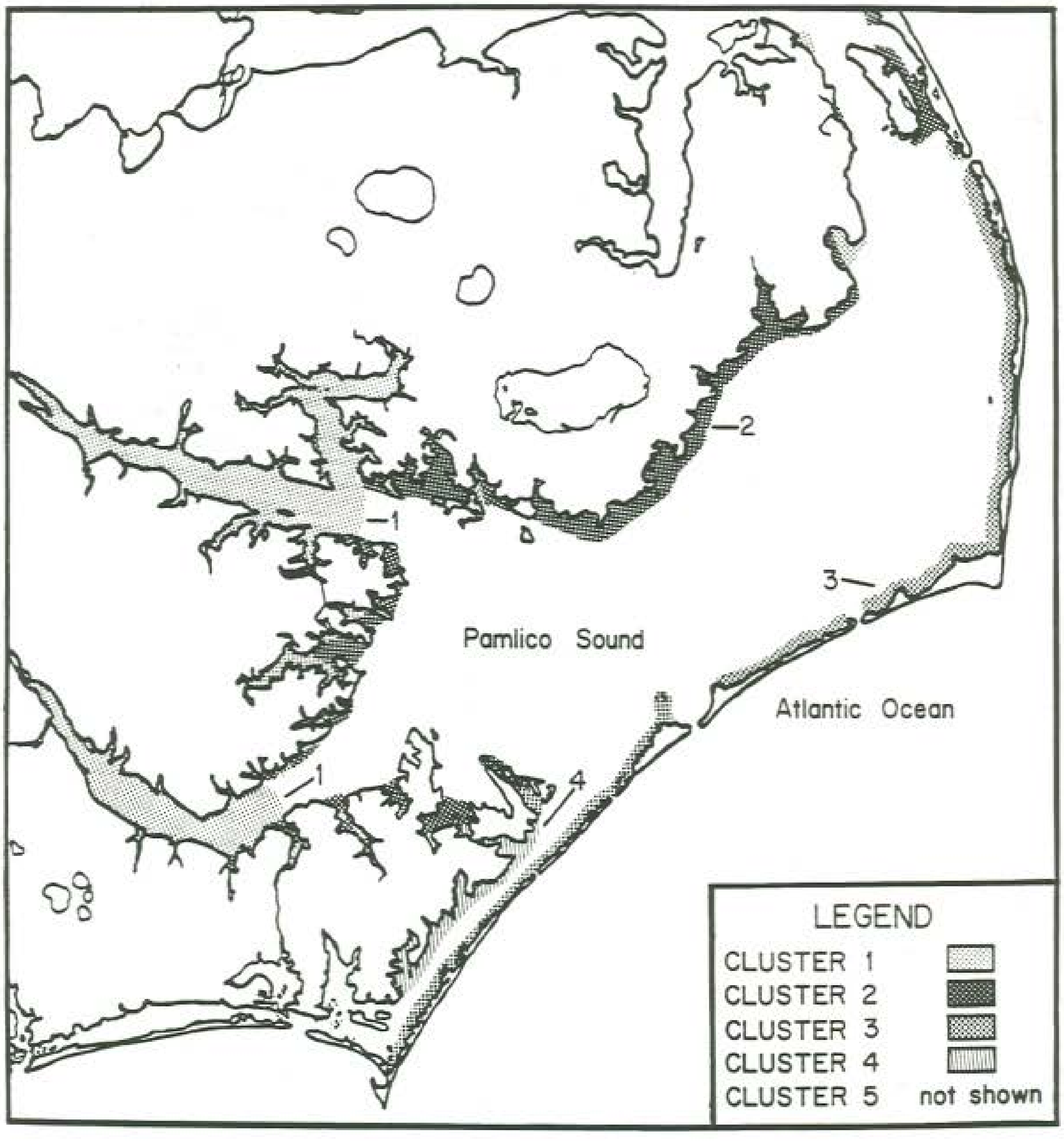

Figure 13. Map of areas defined by biotic clustering of Albemarle-Pamlico Sound nursery area stations.

Table 15 displays those correlation coefficients between cluster means which are significantly different from zero, testing at the 5% and 1% levels, and form the basis for identifying species groups. Of particular interest are the negative correlations between Atlantic croaker abundance and that of pink shrimp, gag, pigfish, gulf flounder, pinfish, and red drum. Such correlations suggest that where Atlantic croaker is abundant, these other species are sparse or absent. However, gulf flounder is positively correlated with these same species. Another positive correlation is seen between weakfish and silver perch. Black sea bass is significantly correlated with gag, pinfish, and pigfish. Pinfish and pigfish are positively correlated at the 1% level, as are red drum with gag and pinfish. Generally, species appeared to be independently distributed among clusters and thence, geographically.

A biotic discriminant and then an abiotic discriminant were applied to the biotic clustering (Tables 16 and 17) with results similar to those of the preceding section. The biotic discriminant function classification was nearly identical to the original clustering and made relatively sharp delineations into the cluster groups. In results not shown here, the anomalous cluster 7 retained its identity, but the other four anomalous stations in clusters 8, 9, 10, and 11 were placed in clusters 4 and 5, which is reasonable with respect to the geographic distribution. There was a decline in the sharpness of classification by the abiotic discriminant. This change is always expected when a predictive function derived from one set of data is applied to an independent set of variables not used in computing the prediction. The marked overlap between clusters 1 and 2 appeared here as was seen in the abiotic clusters. Again, the anomalous clusters 7, 10, and 11 were placed in clusters 2, 3, and 4, respectively, reflecting the intrinsic difficulty found with all similarity indices.

4.2.3 Abiotic-biotic Clustering

Pseudo-F and pseudo T^2 statistics and the cubic clustering criterion best identified nine clusters of the 183 stations utilized in the abiotic-biotic classification (or combinational) analysis. Five clusters were identified as meaningful station groupings based on abiotic variables, species composition, cluster numbers and geographic location. Cluster means for the six abiotic variables and 16 biotic variables are given in Table 18. The relationships of the clusters to each other are shown graphically in Figure 14. Eight stations of the set did not fall into one of those five clusters (Table 19).

Results from this abiotic-biotic classification were similar to those from the abiotic classification and biotic classification. Based on percent species composition and abiotic variables combined, stations in the same geographic areas formed core groups. Again, the species composition of the low salinity station group was dominated by Atlantic croaker, brown shrimp, blue crab, and southern flounder. Species composition of the classification that included highest salinity stations was dominated by pinfish, pigfish, and pink shrimp. Black sea bass, gag, and gulf flounder were most abundant in these areas. Bluefish, spotted seatrout and silver perch were most abundant in the bays and tributaries surrounding Pamlico Sound. The stations located on the mainland side of Core Sound again were classified together, having

Table 15. Significant interspecies correlation coefficients computed from the biotic clusters of Albemarle-Pamlico Sound stations.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Brown shrimp (1)	-					0.60*										
Pink shrimp (2)		-										-0.60*		0.82**	0.60*	
Blue crab (3)			-													
Black sea bass (4)				-	0.82**		0.62*	0.60*								
Gag (5)					-		0.83**	0.92**				-0.70*	0.75**		0.85**	
Bluefish (6)						-										
Pigfish (7)							-	0.79**				-0.71*	0.64*		0.75**	
Pinfish (8)								-				-0.69*	0.91**		0.87**	
Spotted seatrout (9)									-	0.65*	0.81**					
Weakfish (10)										-	0.85**					
Silver perch (11)											-					
Atlantic croaker (12)												-	-0.65*		-0.71*	
Red drum (13)													-		0.72*	
Summer flounder (14)														-		
Gulf flounder (15)															-	
Southern flounder (16)																-

* Significant at the 5% level.

** Significant at the 1% level.

Table 16. Classification by a biotic discriminant of Albemarle-Pamlico Sound station groups determined by biotic clustering.

From cluster	Number of stations and percent classified into clusters 1	2	3	4	5	Original totals
1	72 97	2 3				74 100
2		86 100				86 100
3			16 100			16 100
4				11 85	2 15	13 100
5					6 100	6 100
Total classified	72	88	16	11	8	195
Percent	37	45	8	6	4	100

Table 17. Classification by an abiotic discriminant of Albemarle-Pamlico Sound station groups determined by biotic clustering.

From cluster	Number of stations and percent classified into clusters 1	2	3	4	5	Original totals
1	44	23		1	3	71
	62	32		2	4	100
2	19	53		2	8	82
	23	65		2	10	100
3		1	6	1		8
		12.5	75	12.5		100
4		1	4	5	3	13
		8	31	38	23	100
5	1				5	6
	17				83	100
Total classified	64	78	10	9	19	180
Percent	35	43	6	5	11	100

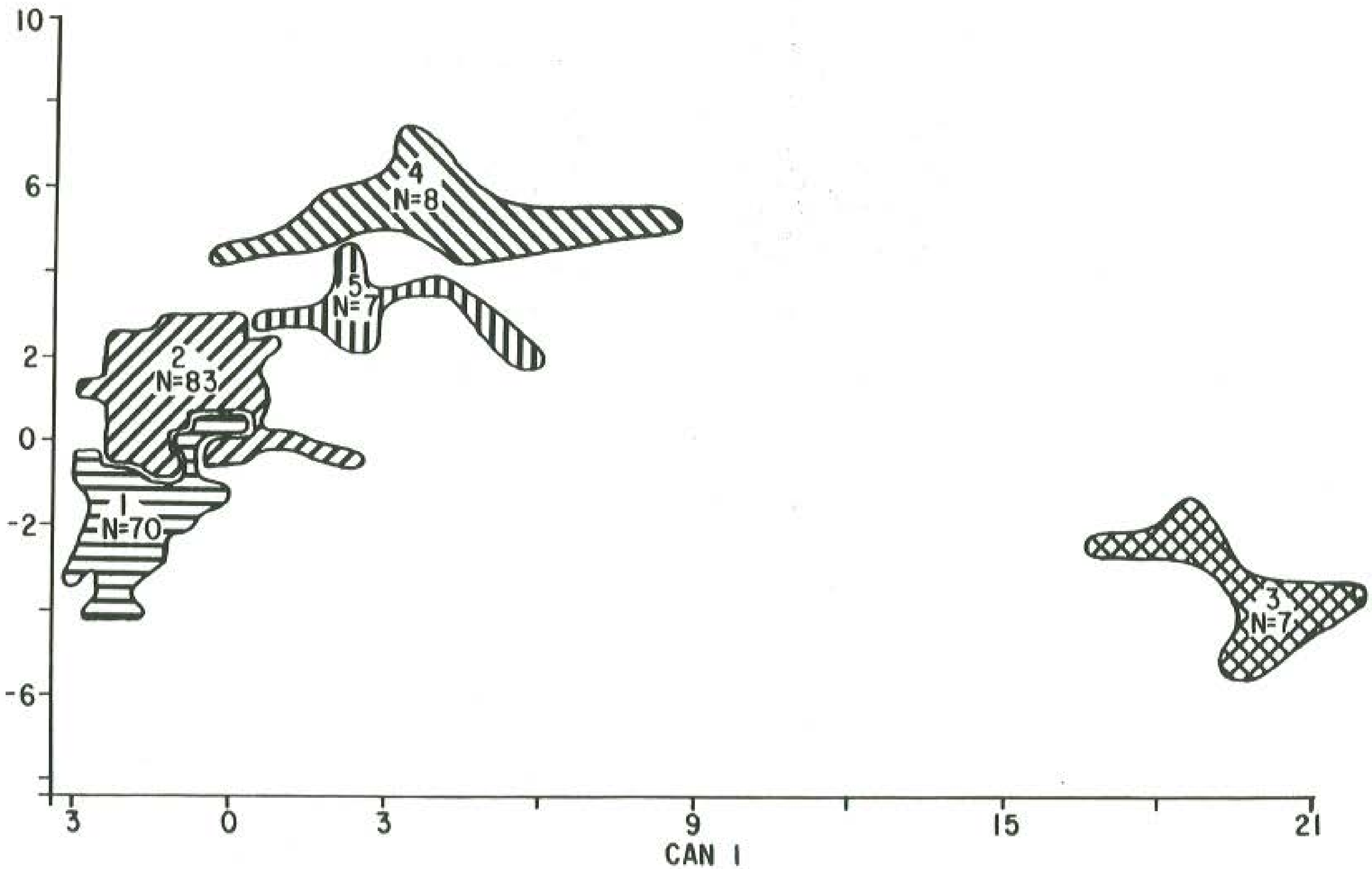

Figure 14. 175 Albemarle-Pamlico Sound nursery area stations grouped into similarity clusters according to the twenty-two abiotic-biotic variables.

Table 18. Variable means for major abiotic-biotic clusters of Albemarle-Pamlico Sound stations.

	Cluster/Number of stations				
	1/70	2/83	3/7	4/8	5/7
Salinity (ppt)					
April	7.2	10.2	23.2	19.9	10.1
May	7.4	11.0	25.2	23.6	11.3
June	9.1	12.1	25.9	24.2	11.7
Temperature (°C)					
April	17.9	17.4	15.5	17.4	15.0
May	22.9	22.9	22.2	22.2	19.6
June	26.7	26.4	26.3	26.9	24.8
Transformed species composition[1]					
Brown shrimp	7.51	22.95	2.52	34.3	20.00
Pink shrimp	0.98	0.89	10.33	13.12	1.88
Blue crab	6.35	15.55	15.28	20.09	40.11
Black sea bass	0.00	0.03	0.87	0.00	0.00
Gag	0.00	0.00	0.79	0.30	0.00
Bluefish	0.47	0.82	0.29	0.25	0.60
Pigfish	0.00	0.14	16.35	4.13	0.98
Pinfish	1.38	3.64	58.79	12.41	6.79
Spotted seatrout	0.01	0.28	0.14	0.00	0.00
Weakfish	0.68	2.80	0.30	0.23	4.86
Silver perch	1.03	3.53	1.38	2.78	1.18
Atlantic croaker	73.97	47.92	1.15	20.60	21.27
Red drum	0.06	0.16	0.15	0.42	0.35
Summer flounder	0.29	0.59	2.19	4.63	0.92
Gulf flounder	0.02	0.02	2.61	2.59	0.00
Southern flounder	5.02	11.34	1.12	15.35	10.97

1 The variable means are angles expressed in degrees. Species composition percentages can be obtained by finding the sine of the mean angle, squaring the result, and multiplying by 100.

Table 19. Variable means for anomalous abiotic-biotic clusters of Albemarle-Pamlico Sound stations.

	Cluster/Number of stations					
	6/2	7/2	8/1	9/1	10/1	11/1
Salinity (ppt)						
April	9.0	9.6	9.0	10.0	16.5	22.0
May	10.8	12.7	10.5	11.0	19.3	26.6
June	11.9	13.9	13.0	11.0	21.0	28.7
Temperature (°C)						
April	16.5	13.8	20.0	14.0	15.8	16.8
May	21.6	23.7	22.5	24.0	21.7	21.4
June	24.8	26.5	25.0	24.0	26.8	26.3
Transformed species composition[1]						
Brown shrimp	32.09	17.17	10.55	0.00	3.01	9.81
Pink shrimp	0.00	0.00	5.42	0.00	3.65	53.21
Blue crab	18.31	15.22	5.13	49.87	66.64	9.16
Black sea bass	0.00	0.00	0.00	0.00	0.80	0.00
Gag	0.00	0.00	0.00	0.00	1.81	0.00
Bluefish	0.00	1.01	0.00	22.50	0.00	0.00
Pigfish	0.00	0.00	0.00	0.00	12.60	2.05
Pinfish	7.80	35.82	66.24	0.00	12.29	5.88
Spotted seatrout	0.00	0.00	2.42	0.00	0.00	0.00
Weakfish	2.18	0.95	0.00	0.00	0.00	0.00
Silver perch	0.00	0.00	0.00	0.00	3.15	3.57
Atlantic croaker	9.36	26.21	12.38	17.63	0.00	19.79
Red drum	0.00	1.34	5.60	0.00	0.00	0.00
Summer flounder	0.00	0.00	0.00	0.00	3.93	12.05
Gulf flounder	0.00	0.00	0.00	0.00	0.00	0.00
Southern flounder	31.93	12.30	4.61	0.00	2.46	5.59

[1] The variable means are angles expressed in degrees. Species composition percentages can be obtained by finding the sine of the mean angle, squaring the result, and multiplying by 100.

high salinities and species compositions dominated by brown shrimp, pink shrimp, blue crab, pinfish, Atlantic croaker and southern flounder.

Table 20 shows results of discriminant function analysis with all 22 variables. The five major groups consisted of 175 (96%) of the 183 stations clustered. The linear discriminant classified 100% of these stations into the five major clusters, with only one station changing clusters (from cluster 2 to cluster 1). All other stations remained in their original cluster. The remaining eight stations (4%) were classified into their own cluster, or moved into one of the five major clusters.

Table 21 shows results of the discriminant function analysis with the 16 biotic variables. As with the results from the discriminant function analysis with all 22 variables, when using only the 16 biotic variables, all 175 stations (100%) were clustered in the five major groups. One station moved from cluster 2 to cluster 1, and two stations moved from cluster 2 to cluster 5. The remaining stations stayed in their original clusters. Again, the eight anomalous stations either fell into their own cluster or into one of the five major clusters.

The classification summary of abiotic discriminants to the abiotic-biotic clustering was not as successful in placing stations in the first two clusters in their respective clusters (Table 22). Only 63% remained in cluster one and only 56% remained in cluster two. The abiotic linear discriminant, unlike the first two discriminants, does not strongly support the original clustering using the average linkage method for the same reasons suggested for the abiotic discriminant applied to the biotic clustering.

4.2.4 Species Groups

From the results of the classification and discriminant analyses, the following species groups were determined (Table 23). Atlantic croaker, brown shrimp, blue crab and southern flounder very clearly formed species group I. Summer flounder, although present in low numbers, had its highest class mean in the same station group where brown shrimp and southern flounder were most abundant. Pinfish, pigfish and pink shrimp constituted the species group II. Black sea bass, gag, gulf flounder, and red drum, although present in low numbers, had their highest class means in this second species group. Spotted seatrout, weakfish and silver perch constituted species group III. All had their highest class means in the same station group. Weakfish also had a high class mean in the same station group as blue crab and bluefish.

4.3 DISCUSSION

4.3.1 Species Habitat Utilization

Studies by Weinstein (1985) support the hypothesis that distinct spatial partitioning of habitat occurs in estuarine waters. Based on results of the classification analysis, habitat utilization in the study area by each of the sixteen target species is summarized below. Although overlap of species utilization occurs, there are station groupings that represent waters

Table 20. Classification by abiotic-biotic discriminants of Albemarle-Pamlico Sound station groups determined by abiotic-biotic clustering.

From cluster	Number of stations and percent classified into clusters 1	2	3	4	5	Original totals
1	70 100					70 100
2	1 1	82 99				83 100
3			7 100			7 100
4				8 100		8 100
5					7 100	7 100
Total classified	71	82	8	7	7	175
Percent	40	47	5	4	4	100

Table 21. Classification by biotic discriminants of Albemarle-Pamlico Sound station groups determined by abiotic-biotic clustering.

From cluster	Number of stations and percent classified into clusters 1	2	3	4	5	Original totals
1	70 100					70 100
2	1 1	80 97			2 2	83 100
3			7 100			7 100
4				8 100		8 100
5					7 100	7 100
Total classified	71	80	8	7	9	175
Percent	40	46	5	4	5	100

Table 22. Classification by abiotic discriminants of Albemarle-Pamlico Sound station groups determined by abiotic-biotic clustering.

From cluster	Number of stations and percent classified into clusters 1	2	3	4	5	6	7	Original totals
1	44 63	16 23			2 3	3 4	5 7	70 100
2	13 16	46 56			7 8	10 12	7 8	83 100
3			6 86	1 14				7 100
4			1 12	7 88				8 100
5					5 71	2 29		7 100
Total classified	57	62	8	7	14	15	12	175
Percent	32	35	5	4	8	9	7	100

Table 23. Species groups determined from classification analysis of Albemarle-Pamlico Sound nursery area data.

Species group	More abundant	Less abundant	Absent
I	Atlantic croaker Brown shrimp Blue crab Southern flounder	Summer flounder Bluefish	Black sea bass Gag Spotted seatrout
II	Pinfish Pink shrimp Pigfish	Black sea bass Gag Gulf flounder Red drum	Weakfish
III	Spotted seatrout Weakfish Silver perch		Black sea bass Gag

functioning as primary nursery areas for different species and groups of species.

Atlantic croaker

Atlantic croaker was most abundant in the bays and tidal creeks bordering western Pamlico Sound. It was common in all other station groupings, although least abundant along the Outer Banks and Core Banks. Based on the class means for each of the five station groupings Atlantic croaker was the most ubiquitous of all sixteen species. When Atlantic croaker was dominant in the catch composition, so were brown shrimp, blue crab, and southern flounder. Weinstein (1985) also found Atlantic croaker to be much more abundant in lower salinity areas of the Cape Fear River estuary than near the mouth of the estuary.

Blue crab

Blue crab was present and very abundant in all five station groupings. It's lowest class mean was in the riverine stations. Even there however, it was the third most abundant species after Atlantic croaker and brown shrimp. Heck and Thoman (1984) found eelgrass beds in the Chesapeake Bay to support large numbers of juvenile blue crabs. Their explanation for the large difference in juvenile crab abundance in vegetated versus non-vegetated areas was protection from predators such as fishes and other crabs.

Brown shrimp

As with Atlantic croaker and blue crab, brown shrimp was present in all five station groupings. Brown shrimp was most abundant on the west side of Core Sound. They were also very abundant in the bays and estuaries surrounding western and southwestern Pamlico Sound. Brown shrimp was least abundant in the high salinity areas behind the Outer Banks.

Southern flounder

Although not as abundant as Atlantic croaker, blue crab and brown shrimp, southern flounder was present in all five station groupings and co-occurred with those three species. Southern flounder was most abundant in the estuaries surrounding Pamlico Sound and the western side of Core Sound.

Black sea bass

Black sea bass was not an abundant species at any of the five station groupings. It was not present in the riverine areas, along the western side of Core Sound, nor in many of the areas surrounding Pamlico Sound. Its relative abundance was highest along Core Banks and in many of the Outer Banks areas.

Gag

Gag was not abundant at any time in the five station groupings and was completely absent from the stations in Pamlico, Neuse, and Pungo rivers, and the vast majority of those stations surrounding Pamlico Sound. They were present in Core Sound and on the Outer Banks.

Red drum

Red drum was not very abundant in any of the five station groupings. They were found most often along Core Banks and the Outer Banks. As with juvenile black sea bass and gag, very small numbers were sampled in nursery areas of the Pamlico, Pungo, and Neuse rivers, and also surrounding Pamlico Sound.

Gulf flounder

Gulf flounder was most abundant along Core Banks and the Outer Banks, with very few present in the other parts of the study area.

Pinfish

Pinfish was another abundant species. However, it did not constitute a high percentage of the species composition when Atlantic croaker, brown shrimp, blue crab or southern flounder were present. Juvenile pinfish dominated the nursery areas of Core Sound and the Outer Banks, together with pink shrimp and pigfish. Few pinfish were found in the low salinity areas of Pamlico Sound, or the Pamlico, Pungo, and Neuse rivers.

Pink shrimp

Pink shrimp was most abundant in Core Sound and in many of the nursery areas of the Outer Banks. Pink shrimp was least abundant in the low salinity areas of the Pamlico, Pungo, and Neuse rivers and those areas influenced by Albemarle Sound.

Pigfish

Pigfish was most abundant where pinfish and pink shrimp were found; however, they constituted a much smaller percentage of the species composition than those species. The areas where pigfish were most abundant were the higher salinity areas behind Core Banks and the Outer Banks. Pigfish were least abundant in the rivers and those areas influenced by Albemarle Sound. Weinstein (1985), in studies of the Cape Fear River, also found pigfish to inhabit shallow, high salinity habitats. He found this species to be restricted to localities near the estuary mouth.

Spotted seatrout

Spotted seatrout had very low class means in three station groupings, and was absent from two. This species had its highest class mean in those bays and estuaries surrounding Pamlico Sound and the stations behind Core Banks and the Outer Banks. It was absent in the nursery areas of mainland Core Sound.

Silver perch

Silver perch was most abundant in the nursery areas surrounding Pamlico Sound. Silver perch, spotted seatrout, and weakfish all had their highest class means in this station grouping. Silver perch was less abundant in the nursery areas behind Core Banks and the Outer Banks.

Weakfish

Weakfish was most abundant in the bays and estuaries surrounding western Pamlico Sound. This species was most common in the same station grouping where blue crabs and bluefish had their highest class means, and also the station grouping where spotted seatrout and silver perch had their highest class mean. Weakfish was absent from those stations behind Core Banks and the Outer Banks.

Summer flounder

Summer flounder had its highest class means in those stations on the mainland side of Core Sound. Other species that also had their highest class means in this station group were southern flounder and brown shrimp. Summer flounder was least abundant in the lower salinity nursery areas influenced by Albemarle Sound and the Pamlico, Pungo, and Neuse rivers.

Bluefish

Although numbers were low, bluefish was most abundant in the bays and estuaries of western Pamlico Sound. Blue crab was most abundant in these same areas. Bluefish was less abundant in the Pamlico, Pungo, and Neuse rivers, Core Sound and the Outer Banks.

4.3.2 Core Group Characterizations

Station groupings resulting from the abiotic, biotic, and combinational classifications had similar geographic patterns. Although there were some exceptions, the following core groups can be characterized:

1. Low salinity areas
2. Areas influenced by Pamlico Sound
3. Transitional zones between groups 1 and 2, above
4. Outer Banks north of Cape Hatteras
5. Outer Banks south of Cape Hatteras
6. Core Banks
7. Mainland Core Sound

Low Salinity Areas

Thirty-one percent of the stations used in the analyses were categorized into this core group. They were located in the Pamlico, Pungo, and Neuse rivers, and also the southeastern portion of Albemarle Sound (including the Roanoke Island area).

The mean class salinities for April, May, and June were 5.6 ppt, 6.5 ppt, and 7.9 ppt, respectively; monthly mean class temperatures were 16.8°C, 22.9°C, and 26.8°C.

The dominant species was Atlantic croaker, which had its highest class mean in the low salinity areas. Other abundant species were brown shrimp, blue crab, and southern flounder (i.e., species group I). Juvenile black sea bass and gag were not present in these areas. All other species were present in very low numbers, and except for bluefish and silver perch, had their lowest class means here.

Qualitative sediment size was available for 75% of the stations in the low salinity areas. For those stations, 90% were noted as having mud bottoms, 3% had sandy-mud bottoms, 3% had sand bottoms, and 4% had shell bottoms. Only 42% of the stations in this core group had qualitative information of the presence or absence of vegetative matter. Of those 42%, 77% were noted as having some type of grass or algae, and/or detritus. We can assume that the grass in these areas was primarily widgeon grass (*Ruppia maritima*). For a few of these stations, the presence of bryozoans and tunicates was also noted. Twenty-three percent had information stating no grass was present. From the information available, bottom type for this station group was predominantly soft mud bottoms with grass, algae and/or detritus present. A conservative conclusion would be that less than 10% of the stations had sand or shell bottoms.

Based on available data, 78% of the stations in this core group had a depth of two meters or less. Of all stations used in the analysis, 82% had a depth of two meters or less.

Pamlico Sound Areas

Twenty-eight percent of the stations used in the analysis were categorized into this core group. They were located in the bays and tidal creeks surrounding Pamlico Sound.

The mean class salinities for this group for April, May and June were 10.9 ppt, 12.0 ppt, and 13.2 ppt, respectively. These salinities were approximately double those in the low salinity areas. Temperatures, however, were very similar. Mean class temperatures for the stations influenced by Pamlico Sound for April, May, and June were 17.3°C, 22.7°C, and 26.4°C, respectively.

The dominant species was Atlantic croaker. Other abundant species (of the sixteen target species) were brown shrimp, blue crab, and southern flounder. Relative to other core groups, there were low numbers of pink shrimp, pigfish, red drum, and summer flounder. Gulf flounder and black sea bass had their lowest class means in this area. Juvenile gag was absent. Even though not very abundant, spotted seatrout, weakfish, and silver perch had their highest class means in these areas. Species groups present in this core group were I and III (Table 23).

Qualitative sediment size was available for 88% of the stations in this core group. Of those, 79% had mud bottoms, 15% had sand bottoms, 3% were sandy-mud, and 3% had a mixture of mud and shell. Compared to the low salinity core station group, this core group had a few more stations (14) with a sand bottom and 12% fewer mud bottom stations. Information on the presence or absence of vegetative matter was available for 59% of the stations in this core group. Of those stations, 87% had some type of grass, detritus, and/or algae present. As with the stations in the low salinity areas, widgeon grass would be the dominant grass present. Bryozoans and tunicates were noted at a few stations.

Water depth was 2 m or less in 81% of the stations where depth was recorded. There was no difference between the low salinity core group and the Pamlico Sound core group in the distribution of depths, with 80% of the stations having less than or equal to two meters, 18% between 2.1 and 4.0 meters, and only 2% greater than four meters.

Transitional Zones

At the mouths of both the Pamlico and Neuse rivers and in the northwestern bays of Pamlico Sound, transitional zones existed in terms of salinity, temperature, as well as in species composition. Half of the stations had abiotic and biological characteristics of the low salinity core group, and the other half had characteristics more like those bays influenced by Pamlico Sound. Thirty percent of the stations used in analysis were characterized into this core group.

Outer Banks North of Cape Hatteras

Although there was a very small sample size for this core group (2%), it did exhibit distinct mean salinities ranging from 14.7 ppt (April) to 18.0 ppt (May) to 18.6 ppt (June). Temperatures for these months were 16.1°C, 22.1°C, and 26.4°C, respectively.

Species composition was very similar to the juvenile populations along the Outer Banks south of Cape Hatteras and Core Banks. Species group II was dominant. Pinfish was the most abundant species. There were also good numbers of pink shrimp, blue crab, and pigfish. Pink shrimp, black sea bass, gag, pigfish, pinfish, red drum, and gulf flounder had their highest class means here. Brown shrimp, bluefish, silver perch, Atlantic croaker, and southern flounder had their lowest class means here, and weakfish was absent.

All of the stations behind the Outer Banks (north and south of Cape Hatteras) were less than or equal to two meters in depth.

Sediment size and bottom type information showed stations having sandy bottoms and submerged aquatic vegetation dominated by eelgrass (*Zostera marina*) and shoal grass (*Halodule wrightii*), with widgeon grass (*Ruppia maritima*) also present. It is important to note that for this station group, quite a different bottom habitat exists than in the stations of the Pamlico and Neuse rivers, and on the western periphery of Pamlico Sound.

Outer Banks South of Cape Hatteras

Two percent of the stations utilized in the analyses were categorized into this core group. The species composition for this core group was the same as for those stations located north of Cape Hatteras (species group II), as was sediment size and bottom type. Salinity regimes, however, were similar to mainland Core Sound stations. Stations sampled behind Hatteras and Ocracoke islands had higher mean salinities ranging from 21.0 ppt (April) to 25.2 ppt (May) to 26.7 ppt (June). Temperatures for these same months were 17°C, 21.6°C, and 26.6°C, respectively.

As was true for the Outer Banks stations north of Cape Hatteras, these stations were less than or equal to two meters in depth.

Sediments were sandy and submerged aquatic vegetation was present.

Core Banks

Three percent of the stations used in the analyses were categorized into this core group. Those stations sampled behind Core Banks had the highest salinities of all station groups. Mean class salinities for April, May and June were 29.4 ppt, 30.2 ppt and 30.7 ppt, respectively. Mean monthly class temperatures were 16.6°C, 22.2°C, and 26.2°C.

Species composition was again the same (species group II) as described for those stations on the Outer Banks (north and south of Cape Hatteras).

All of the stations sampled in this core group had depths less than or equal to one meter.

Sediment size and bottom type information was the same as stations located behind the Outer Banks--sandy bottom and submerged aquatic vegetation.

Mainland Core Sound

Four percent of the stations used in analyses were categorized into this group. Those stations in the bays and tidal creeks of mainland Core Sound had distinct abiotic and biotic characteristics. Salinities were ranked second highest in the study area. Mean class salinities for April, May and June were 21.0 ppt, 25.2 ppt and 26.7 ppt, respectively. Temperatures for these months were 17.0°C, 21.6°C, and 26.6°C.

Species composition was a combination of Outer Banks and Pamlico Sound. Representatives of all three species groups (Table 23) were present in mainland Core Sound. Brown shrimp was the dominant species and had it highest class mean in this area. Summer flounder and southern flounder also had their highest class means in this area. Pink shrimp, blue crab, and pinfish had their second highest class means in this area. Atlantic croaker was also abundant. No black sea bass or spotted seatrout were caught in these areas. Gag, bluefish, weakfish, pigfish, silver perch, red drum, and gulf flounder were present in low numbers.

Bottom type for this core group was a combination of mud and sand, with 100% of those stations with data available having grass present. Widgeon grass, eelgrass, and shoal grass all occur in this area.

Station depths were somewhat greater on the mainland side of Core Sound than behind Core Banks, ranging from 0.8 to 2.0 meters.

The only previous classification study in the Pamlico Sound estuary was conducted by Ross and Epperly (1985). Their study included 51 stations and involved a number of abiotic variables not recorded during the present study of 307 stations. Their target species and clustering methodology differed from those of the present study. Therefore, it was not feasible to compare the two studies on any basis other than geographic grouping of the stations. The two studies agree on a group at the Albemarle-Pamlico peninsula, and a low-salinity group in the Neuse and Pamlico rivers. No Outer Banks stations were included in the earlier study, nor was Core Sound represented by more than one or two stations. It can be concluded, therefore, that where a reasonable basis exists for comparison between the two studies, there is substantial agreement.

5.0 DESIGNATED NURSERY AREAS VERSUS NON-DESIGNATED AREAS

Of the stations used in all three cluster analyses (abiotic, biotic, and combinational), 14% were located in designated secondary nursery areas, 34% in designated primary nursery areas, and 52% were located in undesignated waters (Table 24). The determination of primary or secondary nursery areas has been developed by DMF over a period of years (See Introduction). For those stations located in undesignated areas, no information was available as to whether or not these unclassified areas had been considered, rejected, or not considered at all for nursery area designation. The clusters formed from the abiotic-biotic variables were separated into primary (PNA), secondary (SNA), and unclassified (UNCL) nursery areas, as shown in Table 25. Cluster 1 was predominately unclassified stations, clusters 2 and 4 were mainly designated nursery areas, and clusters 3 and 5 were mostly unclassified areas. The three types of stations (PNA, SNA, UNCL) were classified by employing discriminant function analysis using abiotic, biotic, and combined variables. The abiotic discriminant function was the least effective in delineating nursery areas (Table 26), while the function using the combined variables was most effective (Table 27), but was not much better than the biotic variables alone (Table 28). Of the unclassified sites, 23% would be regarded as potential nursery areas, and of the designated nursery areas, 15% would not have been so classified by the same criterion. Since the clustering has delineated geographic areas, we conclude that the discriminant function identifies

Table 24. Number and percent of stations in the three cluster analyses that were located in designated primary nursery areas (PNA), designated secondary nursery areas (SNA), and unclassified waters (UNCL) in the Albemarle-Pamlico Sound.

	Abiotic cluster N = 307			Biotic cluster N = 204			Combination cluster N = 183		
	PNA	SNA	UNCL	PNA	SNA	UNCL	PNA	SNA	UNCL
Number	96	46	165	71	28	105	69	26	88
Percent	31%	15%	54%	35%	14%	51%	38%	14%	48%

Table 25. Number of primary and secondary nursery areas, and unclassified areas from the Albemarle-Pamlico Sound found in each cluster formed by abiotic-biotic variables.

Abiotic-biotic cluster designation	Number of stations and percent of externally classified groupings: PNA	SNA	UNCL	Totals percent
1	17 24	6 9	47 67	70 100
2	44 53	15 18	24 29	83 100
3	0 -	0 -	7 100	7 100
4	4 50	3 38	1 12	8 100
5	2 29	0 -	5 71	7 100
6	0 -	1 50	1 50	2 100
7	2 100	0 -	0 -	2 100
8	0 -	0 -	1 100	1 100
9	0 -	0 -	1 100	1 100
10	0 -	0 -	1 100	1 100
11	0 -	1 100	0 -	1 100
Totals Percent	69 38	26 14	88 48	183 100

Table 26. Externally designated areas in the Albemarle-Pamlico Sound classified by a discriminant function of abiotic variables.

Designated areas	Number of stations and percent classified by DF: PNA	SNA	UNCL	Totals percent
PNA	40	13	16	69
	58	19	23	38
SNA	8	15	3	26
	31	58	11	14
UNCL	28	18	42	88
	32	20	48	48
Totals	76	46	62	183
Percent	41	25	34	100

Table 27. Externally designated areas in the Albemarle-Pamlico Sound classified by a discriminant function of abiotic-biotic variables.

Designated areas	Number of stations and percent classified by DF: PNA	SNA	UNCL	Totals percent
PNA	56	5	8	69
	81	7	12	38
SNA	3	17	6	26
	12	65	23	14
UNCL	14	6	68	88
	16	7	77	48
Totals	73	28	83	183
Percent	40	15	45	100

Table 28. Externally designated areas in the Albemarle-Pamlico Sound classified by a discriminant function of biotic variables.

Designated areas	Number of stations and percent classified by DF			Totals percent
	PNA	SNA	UNCL	
PNA	52 75	9 13	8 12	69 38
SNA	2 8	16 61	8 31	26 14
UNCL	11 12	9 10	68 78	88 48
Totals Percent	65 35	34 19	85 46	183 100

similar habitats with respect to the variables included in the analyses. However, the general conclusion is that the discriminant function is a feasible tool for classifying nursery areas, and when supplemented with additional variables and/or biological considerations, may be a workable, objective method of classification.

6.0 HABITAT SUITABILITY INDEX REVIEW

Habitat suitability indices (HSI) are models which define variables related to habitat characteristics meeting the needs of particular species. They are intended for use in impact assessment and habitat management. The index of habitat suitability ranges from 0, which defines an unsuitable habitat for a particular species, to 1, which defines optimal habitat. They should be viewed as a probable species-habitat relationship and not as a statement of proven cause and effect relationships. Although HSIs are very helpful for a wide variety of planning applications where habitat information is an important consideration in the decision process, they do have their limitations. The best use of most HSI models is for comparison of habitat potential of a single area at different points in time or of different areas at a single point in time (Buckley 1984). Specific habitat requirements (variables) that may be included in a model are temperature variation, salinity, turbidity, pH, dissolved oxygen minimum, wetland type, shoreline configuration, depth, substrate type, percent organic matter in sediment, and abundance and size of food.

The existing database used for this project had virtually no data on turbidity, pH, dissolved oxygen, sediment percent organic matter, or food. The information on substrate type was incomplete and inconsistent for the large number of stations analyzed. Therefore, no new HSI models were developed for species present in North Carolina's estuarine nursery areas as part of this project. However, the U.S. Fish and Wildlife Service (USFWS) has developed HSI models for several estuarine species. Following is a brief summary of the USFWS models developed for early life stages of Atlantic croaker, red drum, spotted seatrout, southern and gulf flounders, spot, and also brown, white, and pink shrimp.

Diaz and Onuf (1985) developed the HSI model for juvenile Atlantic croaker from a review and synthesis of existing information. Those optimum habitat variable values (suitability index [SI] = 1.0) developed are shown in Table 29. The geographic areas covered by their model are the southeast Atlantic coast and Gulf of Mexico coast. The model is designed to evaluate spring and summer conditions and is intended only for the estuarine habitat. No minimum spatial requirements for the Atlantic croaker were identified by Diaz and Onuf (1985). Accessibility of an area to larval recruits is an important determinant of the level of area utilization. In some areas, the salinity variable is a correlate of accessibility. For other areas, however, the accessibility factor cannot be incorporated into the HSI model.

Enge and Mulholland (1985) developed the HSI model for juvenile southern and gulf flounders of the northern and eastern Gulf of Mexico from Florida to

Table 29. Optimal habitat variable values (suitability index = 1.0) for estuarine species adapted from U.S. Fish and Wildlife Service habitat suitability index (HSI). These values are based on the assumption that a particular habitat variable is independent of other variables that contribute to habitat suitability.

Juvenile Atlantic croaker of the South Atlantic and Gulf of Mexico (Diaz and Onuf 1985)	Juvenile southern and gulf flounders of the Gulf of Mexico (Enge and Mulholland 1985)	Larval and juvenile red drum of the Gulf of Mexico (Buckley 1984)	Egg, larval, and juvenile spotted seatrout of the Atlantic Coast and Gulf of Mexico (Kostecki 1984)
Mean turbidity (Mar-Sep) 20 - 30 FTU or mg/l Minimum DO concentration (Jul-Sep) 4.9 - 8 mg/l Mean salinity 0 - 15 ppt (Mar-May) 6 - 26 ppt (Jun-Sep) Depth Shallow areas closely associated with marsh Dominant substrate type >75% mud	Average minimum DO 10-15 cm above bottom (May-Aug) 4-6 mg/l Average annual salinity 10-15 cm above bottom 20 - 35 ppt (gulf flounder) 5 - 20 ppt (southern flounder) Average water temperature 10-15 cm above bottom (May-Aug) 20° - 35°C Substrate composition Southern flounder >66% mud, remainder silt or sand Gulf flounder <34% soft sediment remainder sand or shell	Mean salinity during larval development period 25 - 30 ppt Mean water temperature during larval development period 25° - 30°C Mean depth-estuarine open water area at low tide 1.5 - 2.5 m Substrate composition mud Percentage of area covered by submerged vegetation 50 - 75% Percentage of open water edge fringed with persistent emergent vegetation 100%	Mean monthly salinity (Dec-Sep) 19 - 38 ppt Mean monthly water temperature (Dec-Sep) 20° - 32°C Percentage of area with submerged and/or emergent vegetation, shell reefs, or oyster beds >50%

Table 29. (Continued).

Juvenile spot of the Atlantic Coast and Gulf of Mexico (Stickney and Cuenco 1982)	Juvenile brown and white shrimp of the northern Gulf of Mexico (vegetated areas only) (Turner and Brody 1983)	Larval and juvenile red drum of the Gulf of Mexico (Buckley 1984)	Juvenile pink shrimp of the Gulf of Mexico (Mulholland 1984)
Average minimum summer DO 5 - 6 mg/l	Mean spring salinity-brown shrimp 10 - 20 ppt	Mean annual salinity 15 - 35 ppt	
Average summer salinity 14 - 31 ppt	Mean summer salinity - white shrimp 1 - 15 ppt	Mean annual water temperature 24° - 35°C	
Average summer water temperature 18-30°C	Mean water temperature (spring for brown shrimp and summer for white shrimp) 20° - 30°C	Substrate class firm bottom with some organic material - sandy silt, silty sand	
Average water depth at mean high water 0 - 3 m	Substrate composition Peaty silts, organic muds with decaying vegetation and organic material	Percentage of open water/seagrass zone covered with seagrasses 75-100%	
Dominant sediment type mud	Percentage of estuary covered by marsh and seagrass 100%	Percentage of emergent wetland zone covered with herbaceous emergent vegetation or mangroves 100%	

Texas from a review and synthesis of existing information. Caution should be used in adapting this information to North Carolina's estuarine systems. The model is valid year-round and only applicable to estuarine habitat. Optimum habitat variable values (SI = 1.0) developed are shown in Table 29. Enge and Mulholland (1985) assumed food to be a nonlimiting life requisite given suitable water quality and cover. No minimum spatial requirements were reported. Juvenile southern and gulf flounders do require estuarine areas accessible from offshore spawning sites. Enge and Mulholland (1985) cautioned that habitat suitability may define the upper limit, but not the exact level of species density.

Buckley (1984) developed two HSI models for larval and juvenile red drum from a review and synthesis of existing information. Habitat variables were derived from research on Gulf of Mexico red drum populations. One HSI model was designed for use in estuaries with naturally vegetated substrates and the other for use in estuaries that cannot support bottom vegetation because of natural factors such as high turbidity. Caution should be used when applying the model to Atlantic coast habitats. The model is applicable to estuarine subtidal habitats, not marine habitat use. Optimal habitat variable values (SI = 1.0) for larval and juvenile red drum are shown in Table 29.

Kostecki (1984) developed an HSI model for spotted seatrout. It is a generalized model applicable year-round in estuarine habitats of the Atlantic and Gulf coasts. Because egg, larval, and juvenile life stages are most sensitive to environmental variation and their survival is important in contributing to population size, the model considers habitat suitability for these stages. Optimal habitat variable values (SI = 1.0) developed are shown in Table 29. Kostecki (1984) cautioned that tolerance of spotted seatrout to changes in temperature and salinity depends on the rate of change. This should be taken into account when calculating average values where variability is extreme.

Stickney and Cuenco (1982) developed an HSI model from existing data for juvenile spot in Gulf and Atlantic coast estuaries. The model deals with the estuarine phase of the spot life cycle lasting from immigration of postlarvae in winter to emigration of pre-spawning adults in fall. Optimal habitat variable values (SI = 1.0) are given in Table 29. The authors noted that optimal spot habitat is found in a river-marsh estuary where waters are turbid.

Turner and Brody (1983) developed an HSI model for brown and white shrimp in the northern Gulf of Mexico from existing data. Only postlarval and juvenile life stages in estuarine habitats are included in the model. The model is to be applied only to areas that are vegetated and not to open bay bottom (unvegetated) areas. Turner and Brody (1983) cautioned that large fluctuations exist in the water quality factors included in the model. Therefore, longterm existing data sets should be used. Habitat should be evaluated between January and May for brown shrimp and between May and October for white shrimp. Optimal habitat variable values (SI = 1.0) are given in Table 29.

Mulholland (1984) developed an HSI model for postlarval and juvenile pink shrimp in estuarine habitat of the Gulf of Mexico from existing information. The model can be applied throughout the year, but is not designed for use in open bay bottom (unvegetated) areas. Optimal habitat variable values (SI = 1.0) are given in Table 29. Mulholland (1984) noted that the percentage of estuarine area covered with vegetation is the most important variable in the pink shrimp HSI model. Whereas pink shrimp occur over a wide range of temperatures and salinities, little is known on the combined effects of these abiotic variables on shrimp survival.

7.0 INLAND WATER NURSERY AREA DESIGNATION

Prior to the initiation of this project, communication between DMF and the North Carolina Wildlife Resources Commission (WRC) had already been established concerning designation and protection of Inland Waters that function as primary nursery areas. In February 1989, a meeting was held with representatives from both agencies. The process by which DMF designates its Coastal Fishing Waters as nursery areas was described to WRC staff. It was agreed that a report would be prepared by DMF documenting the importance of those inland waters sampled by DMF as nursery areas.

A report was submitted to the WRC in October 1989 nominating specific Inland Waters for primary nursery area designation. Those identified water bodies met DMF's existing criteria for primary nursery area designation. Information on each nominated waterbody included the name of the creek or tributary, descriptive boundaries, a map, and species composition and relative abundance of the economically important species. A total of 10,386 acres of Inland Waters was nominated for primary nursery area designation. The WRC formally approved the designations, and they became effective July 1, 1990. The DMF plans to propose additional new Inland Waters in the future for consideration by the WRC.

8.0 RECOMMENDATIONS FOR CRITICAL HABITAT CRITERIA

Based on the core group characterizations determined from classification and discriminant function analysis, a first conclusion is that primary nursery areas do exist for species groups not traditionally considered by DMF and the MFC in their designation process. Geographic areas where primary nursery area designations are obviously absent are behind Core Banks and the Outer Banks. In these high salinity environments, pinfish was determined to be the dominant species. Juvenile pink shrimp, black sea bass, gag, pigfish, red drum, and gulf flounder had their highest class means in these areas, as well.

Waterbodies traditionally designated as nursery areas by the MFC have species compositions dominated by spot, Atlantic croaker, southern flounder, blue crab, brown shrimp, and Atlantic menhaden. As evident from nursery area maps and the cluster analyses, these habitats are predominantly in the upstream sections or tidal creeks of the bays surrounding western Pamlico Sound, and also the uppermost portions of the Neuse and Pamlico river estuaries. Further categorization of these traditional nursery areas may be unnecessary. Evident from the analyses, the Pamlico Sound core group had salinities three times higher than the riverine core group. Species which were present in very low numbers (spotted seatrout, weakfish and silver perch) in the riverine systems had their highest class means in the Pamlico Sound core group. So, differences in abiotic and biotic variables do exist in these "traditional" nursery area environments. Also, there are habitats in these areas that qualify for nursery area designation, but are not as yet protected.

In its development of critical habitat criteria, DMF and the MFC will need to look at more of the available data than were analyzed for this report. Obvious omissions in this project's data set was information on clam, bay scallop, and oyster abundance, and quantitative sediment and bottom composition information. The identification of critical habitat for anadromous species was also not addressed. The best critical habitat criteria could be developed by combining the understanding of the spatial-temporal distribution of the sixteen target species in the Pamlico and Core sounds estuarine complex and the associated salinity regimes, together with better information on habitat characteristics and bivalve and anadromous finfish habitat requirements.

Based on analytical results, the areas of Core Sound and Pamlico Sound adjacent to Core Banks and the Outer Banks exhibiting the specified abiotic and biotic characteristics are critical habitats and should be considered by the MFC and DMF for primary nursery area designation. These polyhaline habitats dominated by seagrasses and sand sediments are critical habitat for economically important species. Depths in most cases are 2 m or less.

1. Core Banks

Mean salinities (ppt)	29.4 (April) 30.2 (May) 30.7 (June)
Bottom composition	Predominantly sand sediments and submerged aquatic vegetation
Species composition	Dominant juvenile species (excluding spot): pinfish, pigfish, pink shrimp, blue crab Other important juvenile species: black sea bass, gag, Atlantic croaker, red drum, summer flounder, gulf flounder, and spotted seatrout

2. Outer Banks

Mean salinities (ppt) south of Cape Hatteras	21.0 (April) 25.2 (May) 26.7 (June)

north of Cape Hatteras	14.7 (April) 18.0 (May) 18.6 (June)
Bottom composition	Predominantly sand sediments and submerged aquatic vegetation
Species composition	Dominant juvenile species (excluding spot): pinfish, pink shrimp, blue crab, pigfish Other important juvenile species: black sea bass, gag, spotted sea trout, red drum, summer flounder and gulf flounder

Seagrass habitats have been shown by numerous studies to be critical nursery areas. Thayer et al. (1984) documented that in the Newport River estuary of North Carolina 1979-1980, the summer biomass of fish fauna found in grass bed habitats included juvenile pinfish, pigfish and silver perch. They also stated that the primary life history stage of nekton present in grass beds were juveniles which use the meadows as a refuge and for food resources. They sampled fish species with a gill net, fyke net, and seine from eel grass habitat in the Newport River estuarine complex. Silver perch constituted 21.8% of the catch, pinfish 9.9% and pigfish 2.8%. Adams (1976), using a different gear (drop net), found pinfish to dominate the seagrass community. Very large catches of adult spot, Atlantic croaker, bluefish, weakfish, red drum, speckled trout, and pigfish are produced by gill nets and long hauls on the grass beds behind the Outer Banks (Jeff Ross, NC DMF, personal communication). Other species of economic importance found in eel grass (throughout most of their temperate range) in the spring and early summer by Kenworthy et al. (1988) were larval and juvenile gag, bluefish, mullet, spot, Atlantic croaker, and herrings (*Alosa or Clupea sp.*) In the Chesapeake Bay, Weinstein (1985) found seagrass meadows to contain more diverse fish communities than surrounding marshes and tidal creeks. Diversity was three times greater in the structurally complex seagrass habitat. Orth and Heck (1980) found that abundance and composition of fishes using seagrass habitats in the lower Chesapeake Bay were more correlated with eelgrass density than with water temperature. McMichael and Peters (1989) found seagrass beds to be the primary habitat for juvenile spotted seatrout in Tampa Bay, Florida. Seventy-eight percent of the juveniles were collected over seagrass beds, with the remainder collected in quiet, unvegetated backwaters. Zimmerman and Minello (1984) compared finfish and crustacean densities between adjacent vegetated and non-vegetated habitats in a Gulf of Mexico salt marsh. Of the eleven most abundant species, pinfish, spotted seatrout, and blue crab were found in vegetation. Brown shrimp were also significantly more abundant in vegetation during all but the winter months. Spot were collected primarily in non-vegetated habitats. Atlantic croaker and southern flounder were collected in both habitats. Zimmerman and Minello (1984) also found in laboratory studies that the presence of vegetation reduced predation on post-larval brown shrimp (7-19 mm) by juvenile pinfish and red drum between 37 mm and 59 mm in length.

At present, usually only spot, Atlantic croaker, Atlantic menhaden, southern flounder, brown shrimp, and blue crab are used in CPUE comparative analyses by DMF for primary nursery area designation. Nursery area designation analyses should not incorporate Atlantic menhaden as one of the target species due to high variability in catches. These same species are used for all areas in the Albemarle-Pamlico estuarine system. This report's classification analyses characterized the Pamlico and Neuse rivers as a unique core group separate from the areas surrounding western Pamlico Sound. The following differences could be addressed between the two core groups in future nursery area designations:

1. Mean April, May, and June salinities differed by 5 ppt each month between the two areas,

2. Brown shrimp was three times more abundant in the Pamlico Sound areas,

3. Juvenile blue crab abundance was 2.5 times greater in the sound stations,

4. Juvenile weakfish and silver perch, although present in low numbers in both areas, were more abundant in the sound stations than anywhere else in the study area,

5. Atlantic croaker was almost twice as abundant in the riverine habitats than in the sound stations, and

6. Southern flounder was twice as abundant in the sound habitats than in the riverine stations.

Similarly, primary nursery area designation in the mainland Core Sound area can be made more accurate by recognizing the following differences in species composition and salinity regimes:

1. April, May, and June salinities averaged 17.6 ppt higher in mainland Core Sound than in the Pamlico and Neuse River estuaries, and 12.3 ppt higher than in the Albemarle-Pamlico Peninsula,

2. Juvenile gag, gulf flounder, and red drum were present in these areas, although not in large numbers, while virtually absent from the riverine and sound stations,

3. Both summer flounder and southern flounder were more abundant in the mainland Core Sound stations than anywhere else in the study area, and

4. Dominant species that could be used in comparative analyses between designated primary nursery areas and proposed nursery areas for mainland Core Sound in order of greatest abundance are, 1) brown shrimp, 2) blue crab, 3) Atlantic croaker, 4) southern flounder, 5) pinfish, 6) pink shrimp.

Another recommendation for critical habitat criteria development in the Albemarle-Pamlico estuarine system is that bottom composition, sediment size, and standardized depth information should be taken by DMF for all stations. These data would then be available for use in comparative analyses.

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A P P E N D I X A

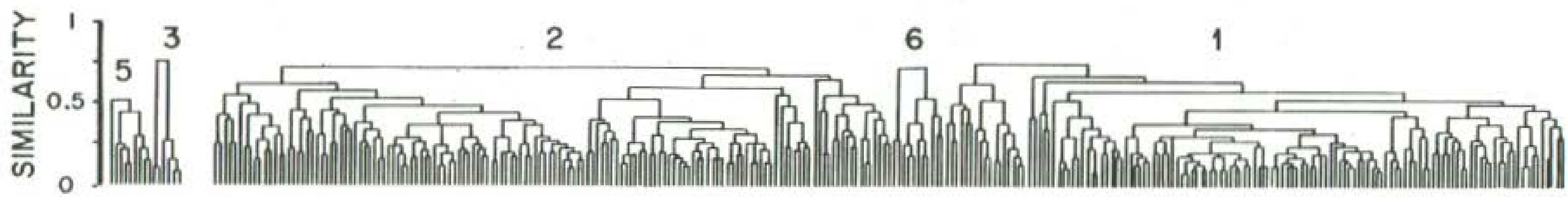
Program 120 stations pulled with 10.5 ft. otter trawl (GEAR = 556) from 1970 through 1988 in the A/P study area (Currituck Sound to Back Sound, 0008000000 < LOCATION < 0700000000). Note: Many of these stations were also pulled with other gears (i.e. GEAR = 556, 20 ft lightly chained otter trawl, GEAR = 558, 20 ft. heavily chained otter trawl, GEAR = 300, seine, GEAR = 311, seine). Total number of 10.5 ft otter trawl stations in the study area is 470.

AB1	B20	CC17	E10	G14	H3	L3	OI10	PUR11	RB32	SPB3
AB2	B21	CC19	E1	G15	H4	L4	OI13	PUR12	RB33	SPB4
AB8	B22	CC6	E11	G16	H5	L5	OI12	PUR14	RB34	SPB6
	B30	CC7	E12	G19	H6		OI3	PUR30	RB35	SPB8
A10	B31	CC8	E13	G20		M10	OI5	PUR3	RB36	
A1	B32	CC9	E14	G2	JB1	M1	OI7	PUR32	RB37	SQB10
A11	B33		E15	G21	JB11	M11	OI8	PUR34	RB38	SQB1
A12	B39	CN10	E16	G22	JB2	M12	OI9	PUR39	RB39	SQB11
A13	B40	CN1	E17	G3	JB4	M13	OI2	PUR40	RB4	SQB13
A14	B41	CN11	E2	G4	JB6	M14		PUR41	RB7	SQB15
A15	B42	CN12	E3		JB7	M15	ORI3	PUR42		SQB16
A16	B43	CN13		HAT1	JB8	M16		PUR43	RI10	SQB17
A17	B44	CN14	FC1	HAT2		M17	PAR10	PUR44	RI1	SQB19
A18	B45	CN2	FC2	HAT4	J10	M18	PAR11	PUR45	RI11	SQB20
A19	B46	CN3	FC3	HAT6	J1	M19	PAR13	PUR47	RI2	SQB2
A20	B49	CN4	FC5A	HAT7	J11	M20	PAR14	PUR5	RI3	SQB21
A2	B50	CN5	FC5	HAT8	J12	M2	PAR16	PUR7	RI4	SQB22
A3	B51	CN6	FC9		J13	M3	PAR20	PUR9	RI5	SQB3
A4		CN7		HI11	J20	M4	PAR2		RI6B	
A50	CB10	CN8	F10	HI12S	J2	M5	PAR23	P10	RI6	S54
A5	CB1		F1	HI14	J21	M6	PAR24	P1	RI7	
A51	CB12	CR22	F11	HI15A	J30	M7	PAR27	P11	RI8	WB1
A52	CB13	CR23	F12	HI15	J3	M8	PAR30	P12		WB2
A53	CB14		F13	HI16B	J31	M9	PAR3	P2	RJ11	WB3
A54	CB16	CS10	F14	HI16			PAR31	P3		WB4A
A55	CB17	CS1	F15	HI17B	KHB2	NHC2	PAR32	P4	RS1	WB4
A56	CB18	CS11	F20	HI17	KHB3		PAR4	P5	RS2	WB7
A57	CB19	CS12	F2	HI18		NR10	PAR50	P6	RS4	WB9
A58	CB20	CS13	F21	HI19	K1	NR11	PAR51	P7		
A59	CB21	CS14	F22	HI2	K2	NR12	PAR53	P8	SB1	51
A60	CB22	CS2	F23	HI21	K3	NR17	PAR54	P9	SB15	52
A6	CB23	CS3	F24	HI24	K4	NR18	PAR55		SB16	53
A7	CB24	CS4	F25	HI25		NR15	PAR56	RB1	SB17	54
A8	CB26	CS5	F26	HI26	LN1	NR20	PAR57	RB11	SB18	62
A9	CB27		F30	HI27		NR2	PAR58	RB12	SB19	64
	CB28	DOC3	F3N	HI28	LSR1	NR5	PAR59	RB14	SB20	72
BB4	CB3	D10	F3	HI29	LSR11	NR7	PAR7	RB18	SB2	73
	CB5	D1	F4	HI30	LSR13		PAR8	RB19	SB21	74
BI1A	CB6	D20S	F5	HI3	LSR15	N1	PAR9	RB20	SB22	81
BI1	CB7	D2	F6	HI31	LSR2	N2		RB2	SB23	83
BI3	CB8	D3		HI33	LSR3	N3	PCB1	RB21	SB3	84
B10	CB9	D4	G10	HI4S	LSR4	N4		RB22	SB5	91
B11		D5	G1	HI4	LSR5		PI1	RB30	SB8	92
B12	CC0	D6	G11	HI5S	LSR6	OC1	PI2	RB3	SB9	93
B13	CC10	D7	G12			OC2	PI4	RB31		94
B14	CC11	D8	G13	HI	L1	OC3	PI6		SPB1	
B19	CC14			H2	L2	OC5	PI7		SPB2	
							PI9			

Program 120 stations pulled with 20.0 ft. otter trawl, both heavily and lightly chained (GEARS = 556,558) from 1970 through 1988 in the A/P study area (Currituck to Back Sound, 0008000000 < LOCATION < 0700000000). Note: Many of the stations were also pulled with other gears (i.e. GEAR = 556, 10.5 ft otter trawl and GEARS = 300, 311, seines). Total number of 20.0 ft otter trawl stations in the study area is 234.

AB2	CN14	HI19	M15	ORI1	BR23	302
	CN3	HI2	M16		RB28	303
AL1	CN6	HI24	M17	PAR10	RB8	305
AL2	CN8	HI25	M18	PAR13		314
AL3		HI27	M19	PAR14	RI10B	315
AL4	CR20	HI3	M20	PAR17	RI1	316
	CR21A	HI31	M2	PAR2	RI11	318
A12	CR21	HI4	M21	PAR28	RI12B	320
A13	CR22A	HI5S	M22	PAR33	RI2A	321
A52	CR22		M23	PAR34	RI2	51
		H5	M3	PAR35	RI3	53
BB3	CS2		M4	PAR48	RI5	72
BB4		JB12	M5	PAR49	RI6	81
	D1	JB13	M6	PAR52		
BI1	D7	JB14	M7	PAR6	RS2	
BI2		JB2	M8		RS3	
BI3	E12	JB5	M9	PA1	RS4A	
		JB7		PA2	RS4	
B12	FC2		NO1	PA3		
B33		J11	NO2	PA4	SB2	
B42	F14	J12	NO3	PA5		
B46	F27		NO4	PA6	SPB2	
		KHB1	NO5	PA7	SPB7	
CB10	G13	KHB2	NO6		SPB8	
CB14	G20	KHB3A	NO7	PI1		
CB16	G21	KHB3B	NO8	PI2	SQB12	
CB17	G3	KHB3		PI4	SQB15	
CB18	G4		NR14	PI6	SQB2	
CB20		LSR12	NR16	PI7	SQB8	
CB21	HAT1	LSR14	NR19	PI9		
CB23	HAT2	LSR2	NR4		S35	
CB24	HAT3	LSR4	NR5	PUR12	S37	
CB28	HAT5		NR6	PUR2	S39	
CB6	HAT7	MP1	NR7	PUR22	S40	
CB8				PUR24	S43	
	HI12S	M10	OC4	PUR29	S45	
CC10	HI13A	M1		PUR33	S46	
CC19	HI13B	M11	OI11	PUR35	S52	
CC7	HI13	M12	OI12	PUR36		
	HI15A	M13	OI2	PUR37	WB11	
CN1	HI16B	M14	OI3	PUR38	WB2	
	HI17B		OI8	PUR4		
	HI17			PUR6	161	
	HI18				162	
				RB13	163	
				RB14	300	
				RB2	301	

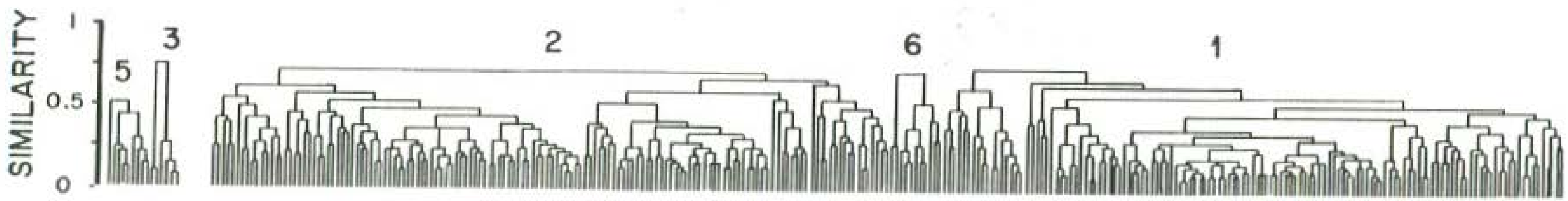
APPENDIX B



CLUSTER I - STATIONS

J20	A19	CN11	RB21	B43	SQB1	G12	E12	JB4	P8
J13	A20	CN12	RB22	CN3	RB20	G16	M10	OC2	LSR2
J3	A17	D4	RB18	CN6	SQB3	PAR59	M8	M20	WB7
WB4	A18	SB9	RB19	CS13	F3D	E2	M6	JB7	PUR14
J21	H2	D2	CN8	CS2	G11	CN14	M7	JB2	FC5A
J31	M4	D3	SB15	JB1	AB1	F3N	RI10	OC3	FC9
LSR11	SQB2	D6	OC1	RB3	E3	F1	SQB11	J2	FC5
SQB21	CS5	D7	WB1	D5	G3	G19	SQB13	CS3	WB4A
B50	D10	AB2	SB5	D8	RB1	A58	F6	FC3	B31
B51	B49	P1	DØ3C	LSR1	G14	B40	SQB10	FC1	PUR34
RS2	G20	SB2	B10	LSR3	SPB1	RB11	SQB15	WB3	PUR47
SQB16	CS14	SPB3	B30	LSR5	B42	E15	P5	FC2	J1
A60	M3	RB2	B20	SB3	G13	CN1	SPB8	P7	M19

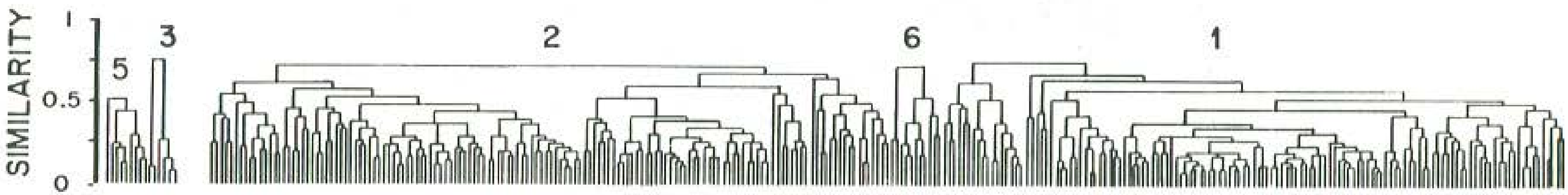
Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic cluster. Abiotic cluster 1 stations are listed. Station order is from top to bottom of columns, beginning with far left column (J20, J13, J3, WB4, etc.)



CLUSTER 2 - STATIONS

M11	E1	H115	B21	B14	F24	K1	PAR53	A11	M14	R11
M12	H5	B11	F2	B41	F25	K3	PAR58	A14	F10	PUR45
M13	B19	G22	E10	B44	RB14	PAR2	PAR51	A5	A7	KHB2
G2	B39	M1	E16	E14	RS4	PAR3	PAR54	NR15	A8	PUR43
G4	B11	F13	PAR27	B45	SPB6	PAR4	PAR9	NR17	A53	PUR44
K4	B12	F11	E11	D20S	CN5	NR2	PAR11	NR18	A56	PAR55
F26	RB4	F4	F12	PAR23	G21	NR5	PAR30	NR7	A51	PAR56
SQB19	SPB4	A57	F14	PAR24	SB1	A50	PAR7	A4	A54	PAR57
F23	PUR38	F5	G10	PAR31	PUR3	PUR9	PAR8	F20	RS1	CR22
H1	PUR41	NR20	G15	PAR20	PUR5	PUR11	A15	F21	A13	AB8
F22	PUR42	B32	G1	PAR13	PUR7	PUR12	A1	PAR32	RB12	CR23
K2	R11	F3	JB6	PAR16	A12	BB4	H6	NR10	SB16	PUR30
H3	R16	B22	PUR39	JB11	A2	PAR10	A10	NR11	PUR40	

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic cluster. Abiotic cluster 2 stations are listed. Station order is from top to bottom of columns, beginning with far left column (M11, M12, M13, etc.).



CLUSTER 3 - STATIONS

OI10	CB13
OI9	CB17
CC17	CB19

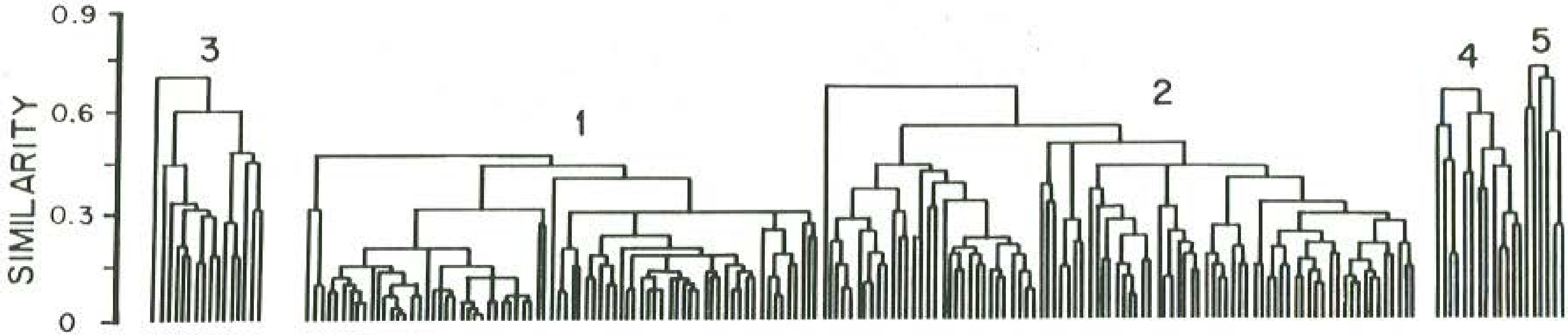
CLUSTER 5 - STATIONS

CC14	CC19	HAT8
CC10	CC7	CC0
CC6	CC8	CC11

CLUSTER 6 - STATIONS

M17	HI15A	WB9
M18	HAT4	HI17B
J10	HAT1	OR13
CC9	RB34	

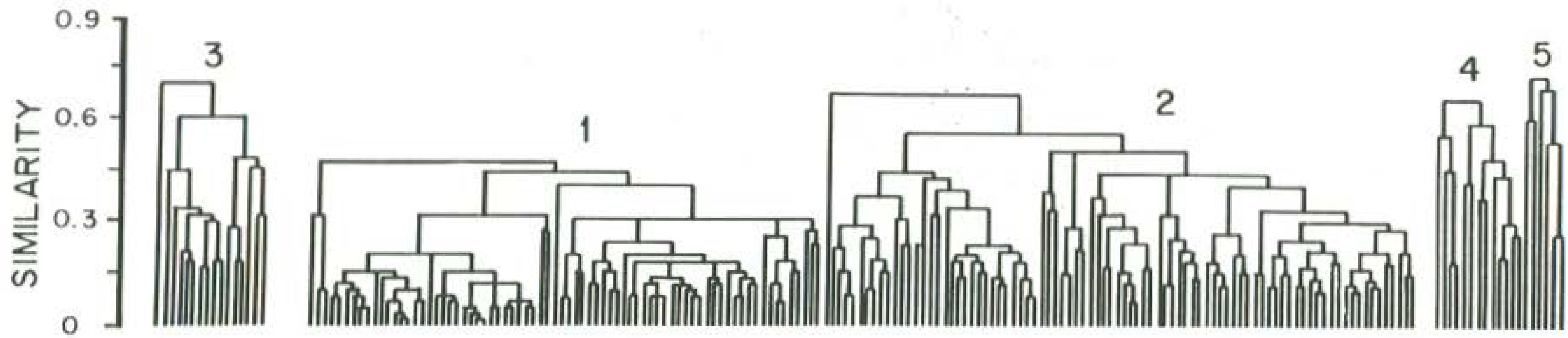
Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic cluster. Abiotic clusters 3, 5, and 6 are listed. For each cluster, station order is from top to bottom of columns, beginning with far left column (cluster 6 - M17, M18, J10, CC9, HI15A, etc.).



CLUSTER 1 - STATIONS

SPB1	PAR7	F21	PAR3	PAR10	F20	NR11	PUR7	DØ3C	F22
P1	PUR11	P7	P6	A50	G10	F12	PAR16	B42	G12
P5	G22	SPB6	G13	A8	PAR9	F3D	A53	F1	
PAR13	H3	M3	PUR9	B11	PAR32	PUR3	PAR27	CS5	
PAR8	L1	A13	PAR4	CN3	P11	CS13	F13	SB9	
NR7	K1	NR2	PUR12	PUR5	P8	A2	CR22	CN1	
SQB15	RB14	PAR2	E14	CS2	E10	NR10	PAR31	G20	
K3	CN8	PAR11	NR5	D5	PAR30	G15	CN14	JB7	

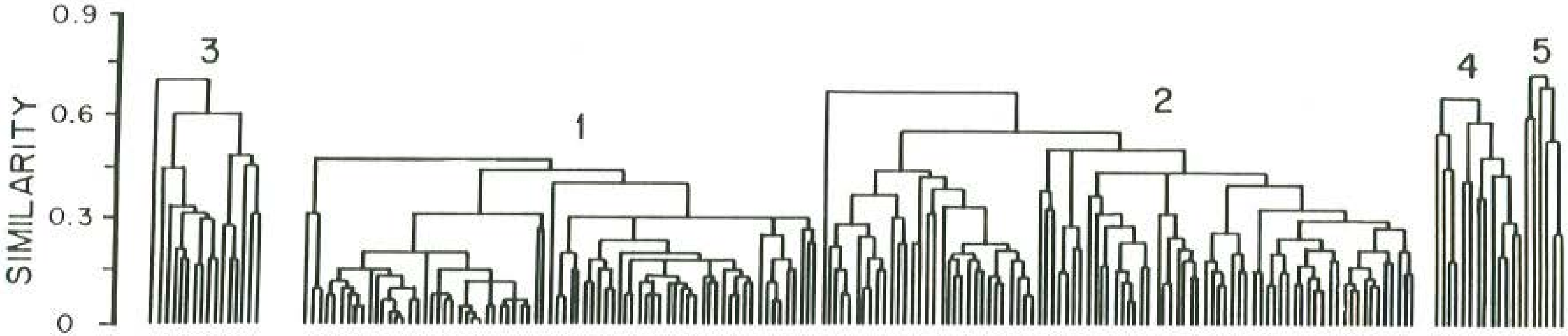
Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in biotic cluster. Biotic cluster 1 stations are listed. Station order is from top to bottom of columns, beginning with far left column (SPB1, P1, P5, PAR13, etc.).



CLUSTER 2 - STATIONS

F6	G21	A9	SB2	PAR20	B31	WB7	J2	FC3	WB3	F3N
FC5A	LSR13	AB2	F14	SB3	SB5	BB4	B20	JB4	D8	PUR34
FC9	OC3	E12	RB2	A59	SQB1	RI6	LSR1	B30	R11	SB1
PCB1	RB20	F3	JB2	G11	B40	CR23	E2	CN6	G3	OC1
SPB4	RB22	F5	FC1	G1	E3	RB18	D4	FC5	E15	LSR11
OC2	H5	RB4	CN5	G14	SQB3	RI10	H2	RB1	LSR5	SPB8
FC2	M4	F2	F4	SQB16	B43	WB4A	JB1	A58	A12	
SPB3	A16	LSR2	G16	G19	RB3	B10	LSR3	WB1	AB1	

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in biotic cluster. Biotic cluster 2 stations are listed. Station order is from top to bottom of columns, beginning with far left column (F6, FC5A, FC9, etc.).



CLUSTER 3 - STATIONS

CB18	CB13	CB19	HI19
CCØ	OI3	HAT1	CB26
PI7	CB17	PI1	PI6
HAT4	HAT8	CB28	RB19

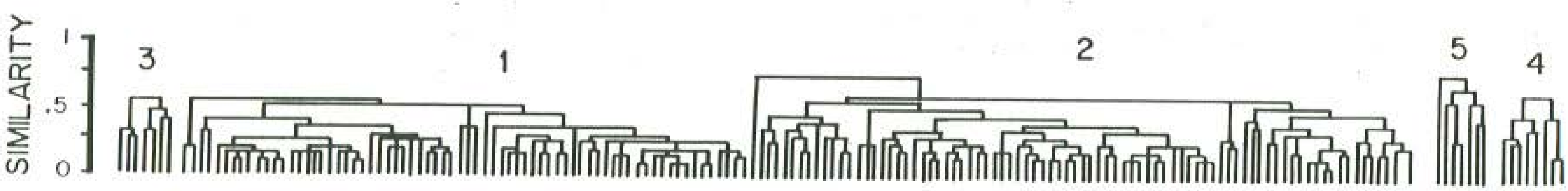
CLUSTER 4 - STATIONS

WB4	RB21	CC8	J10
CC10	SQB13	CC9	
CC6	SQB11	93	
CC7	SQB2	CC11	

CLUSTER 5 - STATIONS

J13	J20
KHB2	RI11
SQB10	RS2

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in biotic cluster. Biotic clusters 3, 4, and 5 are listed. For each cluster, station order is from top to bottom of columns, beginning with far left column (Cluster 5 - J13, KHB2, SQB10, J20, RI11, RS2).



CLUSTER 1 - STATIONS

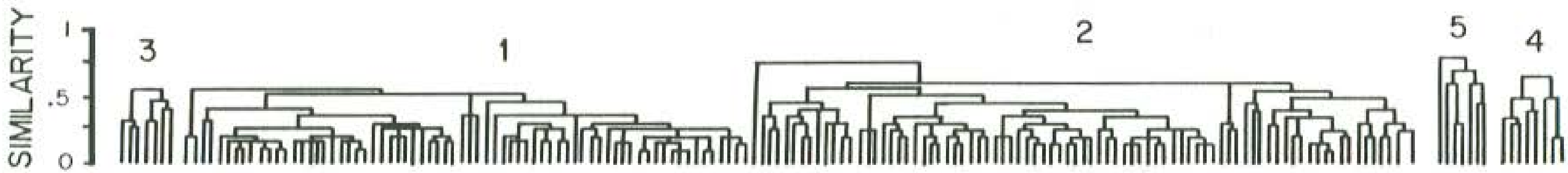
P1	PAR11	NR7	A13	CN8	F1	P8	NR10	A2
P5	PAR2	PAR13	M3	SQB15	CS5	PAR30	NR11	PUR7
A50	PAR3	PUR11	E14	M4	SB9	F20	G15	F13
A8	NR5	K1	SPB6	H5	G12	G10	E10	DØ3C
NR2	PAR4	F21	H3	JB7	CN3	CR22	PUR3	CN14
PUR9	PAR32	K3	G22	B11	PUR5	A53	F12	PAR31
PAR10	PAR8	PAR7	G13	F22	CS2	PAR16	F3D	
PUR12	PAR9	P7	RB14	CN1	D5	PAR27	CS13	

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic-biotic cluster. Abiotic-biotic cluster 1 stations are listed. Station order is from top to bottom of columns, beginning with far left column (P1, P5, A50, A8, etc.).

CLUSTER 2 - STATIONS

F6	AB2	B42	F2	LSR3	WB3	LSR5	ABI	D8	SQB3	RIIO
OC3	SPB4	LSR2	CN5	J2	FC3	FC5	F3N	SQBI6	B43	CR23
RB20	FC5A	EI2	F4	BIO	JB4	A58	GI	GI9	RB3	RII
RB22	FC2	G20	RB4	B20	LSRII	RBI	A59	B3I	WB7	
OC2	FC9	JB2	F3	LSRI	OCI	PUR34	GII	SB5	RBI8	
SPBI	H2	SB2	F5	B30	SPB8	GI4	GI6	SQBI	WB4A	
G2I	D4	FI4	FCI	CN6	G3	SBI	PAR20	B40	BB4	
SPB3	E2	RB2	JBI	WBI	EI5	AI2	SB3	E3	RI6	

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic-biotic cluster. Abiotic-biotic cluster 2 stations are listed. Station order is from top to bottom of columns, beginning with far left column (F6, OC3, RB20, RB22, OC2, etc.).



CLUSTER 3 - STATIONS

CB17	HAT1	HAT8
CB13	HAT4	
CB19	CCO	

CLUSTER 4 - STATIONS

CC11	CC8	CC6
C9	93	CC7
J10	CC10	

CLUSTER 5 - STATIONS

KHB2	RS2	SQB2
J20	J13	
RI11	SQB11	

Dendrogram indicating similarities among Albemarle-Pamlico Sound nursery area stations present in abiotic-biotic cluster. Abiotic-biotic clusters 3, 4, and 5 are listed. Station order is from top to bottom of columns, beginning with far left column (Cluster 5 - KHB2, J20, RI11, RS2, J13, SQB11, SQB2).