NOAA Technical Report NMFS 144

March 1999

Distribution of Atlantic Menhaden, *Brevoortia tyrannus*, Purse-seine Sets and Catches from Southern New England to North Carolina, 1985–96

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Distribution of Atlantic Menhaden, *Brevoortia tyrannus*, Purse-seine Sets and Catches from Southern New England to North Carolina, 1985–96

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ABSTRACT

Sets and catches of Atlantic menhaden, *Brevoortia tyrannus*, made in 1985–96 by purse-seine vessels from Virginia and North Carolina were studied by digitizing and analyzing Captain's Daily Fishing Reports (CDFR's), daily logs of fishing activities completed by captains of menhaden vessels. 33,674 CDFR's were processed, representing 125,858 purse-seine sets. On average, the fleet made 10,488 sets annually. Virginia vessels made at least one purse-seine set on 67%–83% of available fishing days between May and December. In most years, five was the median number of sets attempted each fishing day. Mean set duration ranged from 34 to 43 minutes, and median catch per set ranged from 15 to 30 metric tons (t). Spotter aircraft assisted in over 83% of sets overall. Average annual catch in Chesapeake Bay (149,500 t) surpassed all other fishing areas, and accounted for 52% of the fleet's catch. Annual catch from North Carolina waters (49,100 t) ranked a distant second.

Fishing activity in ocean waters clustered off the Mid-Atlantic states in June–September, and off North Carolina in November–January. Delaware Bay and the New Jersey coast were important alternate fishing grounds during summer. Across all ocean fishing areas, most sets and catch occurred within 3 mi. of shore, but in Chesapeake Bay about half of all fishing activity occurred farther offshore. In Virginia, areas adjacent to fish factories tended to be heavily fished. Recent regulatory initiatives in various coastal states threaten the Atlantic menhaden fleet's access to traditional nearshore fishing grounds.

Introduction

Atlantic menhaden, *Brevoortia tyrannus*, form large, dense, near-surface schools which are the targets of a large industrial purse-seine fishery for reduction from North Carolina to the Gulf of Maine (Smith, 1991). The chief products of the industry are fish meal, fish oil, and fish solubles. The fishery is prosecuted mostly by large (up to 200 ft) ocean-going purse-seine vessels, a majority of which are based in Virginia and North Carolina.

During most fishing years, initial catches are made in May as spring migratory schools move north in nearshore ocean waters along the North Carolina and Virginia coasts. By early summer, Atlantic menhaden stratify along the Eastern Seaboard by size and age, with the oldest and largest fish (up to age 7 and 500 g) migrating as far north as southern Maine. During summer, Atlantic menhaden reside in all major estuarine systems and in nearshore ocean waters along the U.S. east coast (Ahrenholz, 1991). Most catches in summer occur within the Virginia portion of Chesapeake Bay. The regulatory code of Virginia allows reduction purse-seine vessels to fish in Chesapeake Bay proper, but prohibits these vessels from small tributaries and major rivers above designated lines, mostly near river mouths. Catches north of Virginia in summer occur in ocean waters, Delaware Bay (until 1992, when fishing was prohibited), and Long Island Sound. During fall, large menhaden schools migrate south past the Virginia and North Carolina capes, and are intensely pursued by vessels from these two states.

Between 1950 and 1988, up to 23 shoreside factories from northern Florida to Maine processed Atlantic menhaden (Smith, 1991). Since 1989, U.S. shoreside reduction facilities for Atlantic menhaden have been located exclusively in Beaufort, North Carolina (a single plant; Fig. 1) and Reedville, Virginia (two plants; Fig. 2). Of

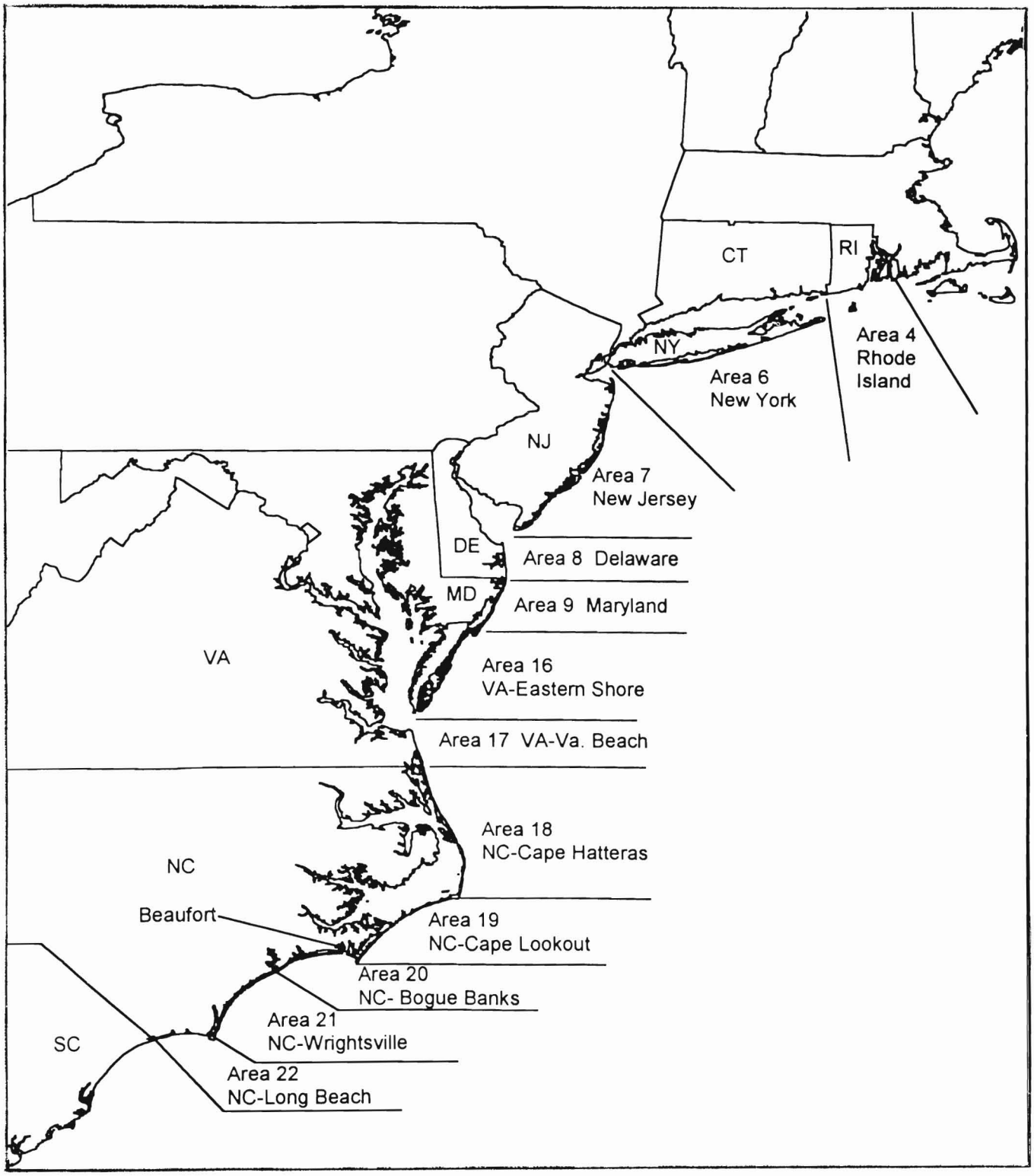

Figure 1
Captain's Daily Fishing Report (CDFR) fishing areas for Atlantic menhaden, Rhode Island to North Carolina.

the extant facilities, the two Virginia factories support the largest fleet of purse seiners, up to 20 vessels combined (9–10 vessels per factory), compared to 2–6 vessels supported by the North Carolina factory. Consequently, landings at Reedville account for up to 80% of the annual menhaden landings for reduction along the Atlantic Coast. From 1988 to 1993, several Russian factory ships processed Atlantic menhaden caught in the Gulf of Maine by U.S. vessels during summer. In addition, from 1987 to 1993 two Canadian factories in New

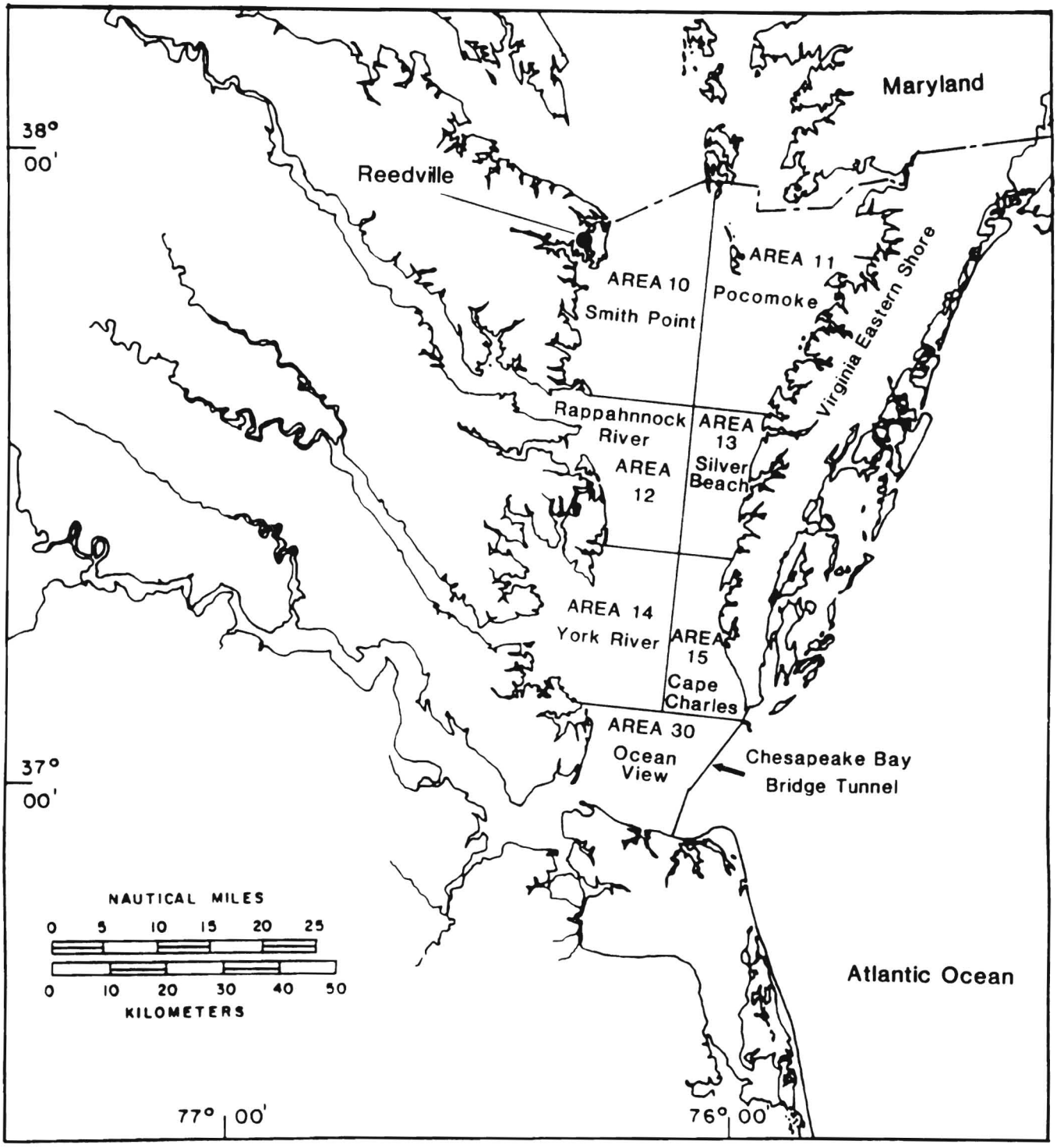

Figure 2
Captain's Daily Fishing Report (CDFR) fishing areas for Atlantic menhaden in Chesapeake Bay, Virginia.

Brunswick and Nova Scotia processed Atlantic menhaden caught in southern Maine.

Modern purse-seine vessels are capable of long-range, multiple-day fishing trips mainly because they are equipped with large fish holds and refrigerated seawater systems. Fishing is conducted Monday through Friday, and rarely on Saturday. Generally, vessels from North Carolina make trips of 1–3 days, and fish within the state's territorial waters; they seldom venture farther north than Chesapeake Bay, and rarely south to Georgia. On the other hand, if fish become scarce in Chesapeake Bay during summer, Virginia vessels regularly fish off Delaware and New Jersey, and occasionally travel to Long Island Sound and Rhode Island. During fall, Virginia vessels range south to Cape Hatteras and Cape Lookout, North Carolina.

Since the mid-1950's, the Beaufort Laboratory of the National Marine Fisheries Service (formerly the Bureau of Commercial Fisheries, prior to 1971) has monitored landings, fishing effort, and size and age composition of the catch in the Atlantic menhaden fishery (Smith, 1991). During the 1950's and 1960's, and ancillary to biological sampling, menhaden vessel captains were asked to complete logbooks (June and Reintjes, 1959) designed to assess daily fishing activities and patterns. Annual summaries of logbook data were reported by June and Reintjes (1959, 1960) and June (1961). More synoptic logbook summaries were published by Roithmayr (1963) and Nicholson (1971).

In the late 1970's, menhaden companies and vessel captains were asked by the Atlantic Menhaden Advisory Committee (AMAC) of the Atlantic States Marine Fisheries Commission to participate in a new logbook project called Captain's Daily Fishing Reports (CDFR's). The project evolved as a joint industry, state, and federal effort, with many of the original formats and guidelines developed by Standard Products of Virginia, Inc.[1] CDFR's are deck logs of daily menhaden fishing activities (Fig. 3). For each fishing and non-fishing day, captains (although the task is often accomplished by the vessel pilot) are asked to specify dates and times of departure and return; time and location of each purse-seine set (or reason no sets were made, if this is the case); and, for each set, the estimated catch, distance and direction to shore, and weather conditions.

The Virginia and North Carolina fleets have been continuous participants in the program since its inception, while vessels landing at various now-defunct plants along the coast (in Maine, Massachusetts, New Jersey, North Carolina, and Florida) contributed through the early to mid-1980's. Vessels active in the menhaden fishery in the Gulf of Maine through the early 1990's did not participate in the CDFR Program.

Through 1991, CDFR's existed primarily as paper files, although limited attempts were made to digitize the data. Beginning in 1992, menhaden program personnel began entering CDFR data into database files on personal computers.

In this paper, I report on summaries of CDFR data for the Atlantic menhaden purse-seine fishery for 1985–96. Included is information on the latitudinal and temporal distribution of purse-seine sets and catches from southern New England to North Carolina, and the distribution of purse-seine sets by distance from shore.

Materials and Methods

Vessel captains completed CDFR forms (Fig. 3) on a daily basis, and menhaden company personnel mailed batches of CDFR's to the Beaufort Laboratory on a weekly basis. Set-specific data were manually coded on CDFR forms by a captain after each individual purse-seine set. Set start and set finish times were given as military time. The captain's estimate of the catch was in thousands of "standard fish" (1,000 standard fish = 670 lb; see Smith, 1991). If a set was assisted by an airplane spotter pilot, the company's two-digit spotter code was used. Unassisted sets were coded as "0" or "self," indicating a "self-set".

In a manual distributed to menhaden vessels, each state's coastline along the eastern seaboard was highlighted and coded with a unique one- or two-digit number (Fig. 1). The North Carolina coast, Virginia's ocean shoreline, and the Virginia portion of Chesapeake Bay were further divided into five, two, and seven areas, respectively (Fig. 1, 2); each was named for a prominent geographic feature. Within each area, specific fishing sites, usually adjacent to well-known geographic points, were coded with three-digit numbers. For example, Antipoison Creek off the mouth of the Rappahannock River (Area 10) in Virginia was coded as "10-310". Captains were asked to identify new fishing areas not listed in the CDFR manual, and these areas were later assigned new codes.

For each purse-seine set, distance (in miles) and direction to the nearest shoreline were recorded, as well as weather conditions at the time of the set (cloud cover, air temperature, and wind direction and speed).

At the laboratory, each CDFR form was stamped with a unique eight-digit collection number. Annual CDFR data sets were key-entered into relational databases and edited for errors. Later, databases were merged and analyzed using SAS (SAS Institute, Inc., 1995).

Initially, I examined general catch trends by subdividing the study area into five geo-temporal regions: 1)

[1] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

NET No. 5-96

CAPTAIN'S DAILY FISHING REPORT

96100790

NAME OF VESSEL (1)	PLANT (2)	DATE OF SETS (3)	(4)
John O. Dehl	Reedville	6-14-96	

LEFT DOCK / ANCHORAGE

DATE: 6-14-96

TIME: 4:30 ☒AM ☐PM

IF DID NOT LEAVE DOCK (CHECK ONE) (6)

☐ WEATHER UNFIT FOR FISHING ☐ UNLOADING
☐ LACKING SUFFICIENT CREW ☐ RADIO
☐ MECHANICAL ☐ OTHER_____
☐ NET ☐ HOLIDAY

IF NO SETS WERE MADE (CHECK ONE) (7)

☐ ROUGH SEAS ☐ OTHER_____
☐ FOGGY
☐ NO FISH SHOWING
☐ NO PLANES
☐ CHANGING LOCATION

(8) SET NO.	(9) TIME START	(9) TIME END	(10) FISH (000)	(11) PLANE NO.	(12) LOCATION		(13) MILES AND DIRECTION TO SHORE		(14) WEATHER CONDITIONS AND REMARKS	(15) SEA WATER TEMP
1	0655	0735	100	39	12-250		7	NW	4-70-5-4	
2	0820	0900	20	39	12-210		3	W	4-72-5-5	
3	0950	1030	35	47	13-160		4.5	SE	4-76-5-4	
4	1110	1155	120	39	14-030		4.5	W	4-78-3-2	
5	1215	1305	50	39	12-110		6	SE	4-79-9-3	
6	1315	1355	75	39	13-160		4	SE	4-79-9-5	
7	1405	1440	40	27	13-160		3.5	SE	4-80-9-5	
8	1450	1525	40	37	13-160		5	SE	4-81-9-5	
9										
10										
11										
12										

(16) REMARKS & COMMENTS (17)

519

DATE TIME RETURN TO DOCK: 6/14/96 1800

CAPTAIN'S SIGNATURE (18)

This form is required by State Law

Figure 3
The Captain's Daily Fishing Report form for reporting daily Atlantic menhaden fishing activities.

Mid-Atlantic, from Rhode Island to Delaware; 2) Maryland and Virginia ocean waters; 3) Chesapeake Bay, Virginia, waters inside the Chesapeake Bay Bridge Tunnel; 4) North Carolina summer, from April through October; and 5) North Carolina fall, from November through January. For more refined analyses, I summarized number of sets and catches by month and by distance from shore using the area definitions in the CDFR manual (Fig. 1, 2). Ocean areas (Rhode Island through Maryland; Eastern Shore and Virginia Beach, Virginia; and North Carolina) and Delaware Bay were examined separately from areas within Chesapeake Bay.

Menhaden captains are particularly adept at estimating the size of individual purse-seine catches. For example, in 1995, vessel-specific ratios of annual catch (as recorded from daily catch records routinely supplied to the NMFS by menhaden companies) to CDFR estimates of catch ranged from 0.90 to 1.03 for the 20-vessel fleet. Nevertheless, captains' catch estimates for individual sets were adjusted slightly using vessel-specific correction factors. Daily records of vessel landings provided by menhaden companies were summed over the fishing year. Total annual landings for a vessel were divided by the respective captain's estimate of annual catches in CDFR's. Individual catch estimates in CDFR's were multiplied by the appropriate correction factor, then by 0.3039 to convert to metric tons (Smith, 1991).

The CDFR data set is comprehensive, as most vessels from Virginia and North Carolina completed CDFR's on a daily basis during the fishing season (approximately May to mid-December for Virginia vessels, and May to mid-January for North Carolina vessels), although

there were a few exceptions. Virginia captains maintained CDFR's even if no sets were made, and indicated the reason for no fishing activity (weather unfit for fishing, mechanical problems). North Carolina captains only completed CDFR's for days that they caught fish. Several small vessels (less than about 100 ft in length) in both states kept incomplete CDFR's. They generally fished in estuarine waters close to a factory, and did not account for a major portion of the annual landings. For these reasons, I excluded these small vessels from my analyses. On the other hand, during 1990 and 1991 three large ocean-going vessels had incomplete or missing CDFR's. I assumed that the vessels in question fished similarly to the rest of the fleet. Based on the percentage of the catch by these vessels relative to the fleet's total annual landings, I adjusted total number of sets and catches upward to account for the missing CDFR data.

Results

CDFR's Processed

A total of 33,674 CDFR's were processed, representing 125,858 purse-seine sets. During 1985–96, between 12 and 22 purse-seine vessels annually participated in the CDFR program (Table 1). On average, the fleet completed 2,806 CDFR's per year, representing 10,488 purse-seine sets. 1986 was an anomalous year, with only 12 vessels participating, because one company in Virginia did not fish for economic reasons. The following year, the company fished four vessels; by 1988, the firm was sold, and the new owners fished up to eight vessels.

Fishing versus Non-fishing Days

The annual percentage of days fished (where at least one set was completed) by the Virginia fleet was relatively consistent, ranging from 67% to 83% (Table 2). Over the 12-yr period, the three most-often-cited reasons for remaining in port on days when Virginia vessels did not leave the dock were "weather unfit for fishing" (54%), "waiting to unload" (20%), and "mechanical problems" (4%). On days when vessels went to sea but failed to make a set, the three most-often-cited reasons for no sets were "no fish showing" (41%), "rough seas" (34%), and "changing location" (10%).

Distribution of Sets and Catch

Over the entire study period, the median number of purse-seine sets per day was five, except for 1991 when it was four (Table 1). Median catch per set ranged annually from 15 to 30 t. Mean set time was 34–43 min, and the proportion of annual sets assisted by spotter aircraft was 83%–93%.

In all regions, the distributions of set (catch) size were highly skewed towards larger size intervals; a majority of catches were 30 t or less (Fig. 4). Median catch per set in ocean regions was comparable for all regions during summer. Median catch was 24 t in the Mid-Atlantic region, 23 t in the Maryland–Virginia ocean region, and 26 t in the North Carolina summer region. Median catch was lowest in Chesapeake Bay, at 18 t. The North Carolina fall region had the highest median catch of all regions, at 38 t.

Table 1
Summary statistics for Atlantic menhaden CDFR data set, 1985–96.

Year	CDFR's processed	Vessels	Sets	% Spotter pilot-assisted	Median sets/day	Catch size (t)		Mean set time (min)
						Median	25th–75th percentiles	
1985	2,636	20	11,075	87.6	5	18	11–30	39
1986	1,619	12	5,703	88.3	5	30	15–53	43
1987	2,128	16	9,312	85.6	5	23	12–41	39
1988	2,362	22	9,761	93.4	5	20	11–30	37
1989	3,335	21	11,135	89.5	5	18	11–30	37
1990	3,382	21	12,197	86.5	5	18	9–30	38
1991	3,739	22	13,379	83.1	4	15	8–30	35
1992	3,522	22	11,740	89.9	5	15	8–30	35
1993	2,565	22	9,694	89.2	5	23	12–38	38
1994	2,909	20	10,917	91.4	5	15	9–30	34
1995	2,866	20	11,234	90.0	5	22	11–38	37
1996	2,611	20	9,711	86.7	5	23	11–38	38
Totals	33,674		125,858					
Mean	2,806		10,488					

Annual catches of Atlantic menhaden in Chesapeake Bay surpassed catches in other areas along the eastern seaboard (Fig. 5; Table 3). Over the study period, estimated total annual catch in Chesapeake Bay averaged 149,500 t (Table 3). The catch from North Carolina ranked a distant second, averaging 49,100 t, followed by Virginia ocean waters (Eastern Shore and Virginia Beach areas combined, 44,900 t), New Jersey (20,600 t), Delaware Bay (8-yr average through 1992 only, 13,000 t), Rhode Island to New York (4,400 t), Delaware ocean waters (4,300 t), Maryland ocean waters (3,200 t), and lastly South Carolina and Georgia ocean waters (200 t).

In general, the distribution of the mean number of purse-seine sets by ocean area and month tended to mirror the distribution of mean catches by area and month (Fig. 6, 7; Append. Table 1, 2). Excluding Chesapeake Bay, most effort and catch in ocean areas were concentrated between Virginia Beach and New Jersey from May through August. Peak catches for this period were from Delaware Bay in June and from New Jersey in

Table 2

Fishing and non-fishing days for Virginia vessels in the Atlantic menhaden purse-seine reduction fleet, 1985–96.

Year	CDFR's completed	Fishing days *n* (%)	Non-fishing days: Did not leave dock *n* (%)	Non-fishing days: Did not set at sea *n* (%)	Non-fishing days: Total days not fished *n* (%)
1985	2,540	1,889 (74)	398 (16)	253 (10)	651 (26)
1986	1,289	877 (68)	330 (26)	82 (6)	412 (32)
1987	1,967	1,625 (83)	178 (9)	164 (8)	342 (17)
1988	2,213	1,738 (79)	185 (8)	290 (13)	475 (21)
1989	3,044	2,047 (67)	526 (17)	471 (16)	997 (33)
1990	3,122	2,295 (74)	364 (12)	463 (14)	827 (26)
1991	3,612	2,612 (72)	433 (12)	567 (16)	1,000 (28)
1992	3,406	2,289 (67)	514 (15)	603 (18)	1,117 (33)
1993	2,425	1,841 (76)	293 (12)	291 (12)	584 (24)
1994	2,826	1,983 (70)	422 (15)	421 (15)	843 (30)
1995	2,783	2,008 (72)	390 (14)	385 (14)	775 (28)
1996	2,564	1,894 (74)	306 (12)	364 (14)	670 (26)

Table 3

Annual and mean catch (in thousands of metric tons) of Atlantic menhaden by fishing area, 1985–96, as estimated from CDFR data.

Area	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	12-yr mean
New York–Rhode Island	33.0		3.0	4.0	0.4		1.5	0.8	0.1	0.3	6.3	2.9	4.4
New Jersey	26.9	1.2	12.2	10.8	24.2	12.8	10.8	32.4	22.6	12.5	52.1	29.1	20.6
Delaware	3.0	1.2	0.2	0.6	0.9	15.2	0.7	5.2	5.5	4.9	8.2	5.7	4.3
Delaware Bay	9.5	7.4	3.4	9.0	14.5	21.8	20.4	17.6					13.0[1]
Maryland	0.1	1.6	1.2		0.6	5.3	1.5	2.8	0.1	7.9	9.6	7.5	3.2
Chesapeake Bay	127.2	141.4	177.4	155.9	156.0	149.5	161.8	135.7	168.5	125.9	147.4	147.8	149.5
Virginia (ocean)	52.4	36.4	58.5	25.6	41.3	52.7	55.7	21.8	60.7	41.2	49.8	43.1	44.9
North Carolina	28.2	27.9	34.3	52.8	35.2	75.6	67.4	46.8	37.3	65.6	62.2	55.3	49.1
South Carolina–Georgia	0.4			2.2					0.1				0.2
Total	280.7	217.1	290.2	260.9	273.1	332.9	319.8	263.1	294.9	258.3	335.6	291.4	289.2

[1] 8-yr mean for Delaware Bay.

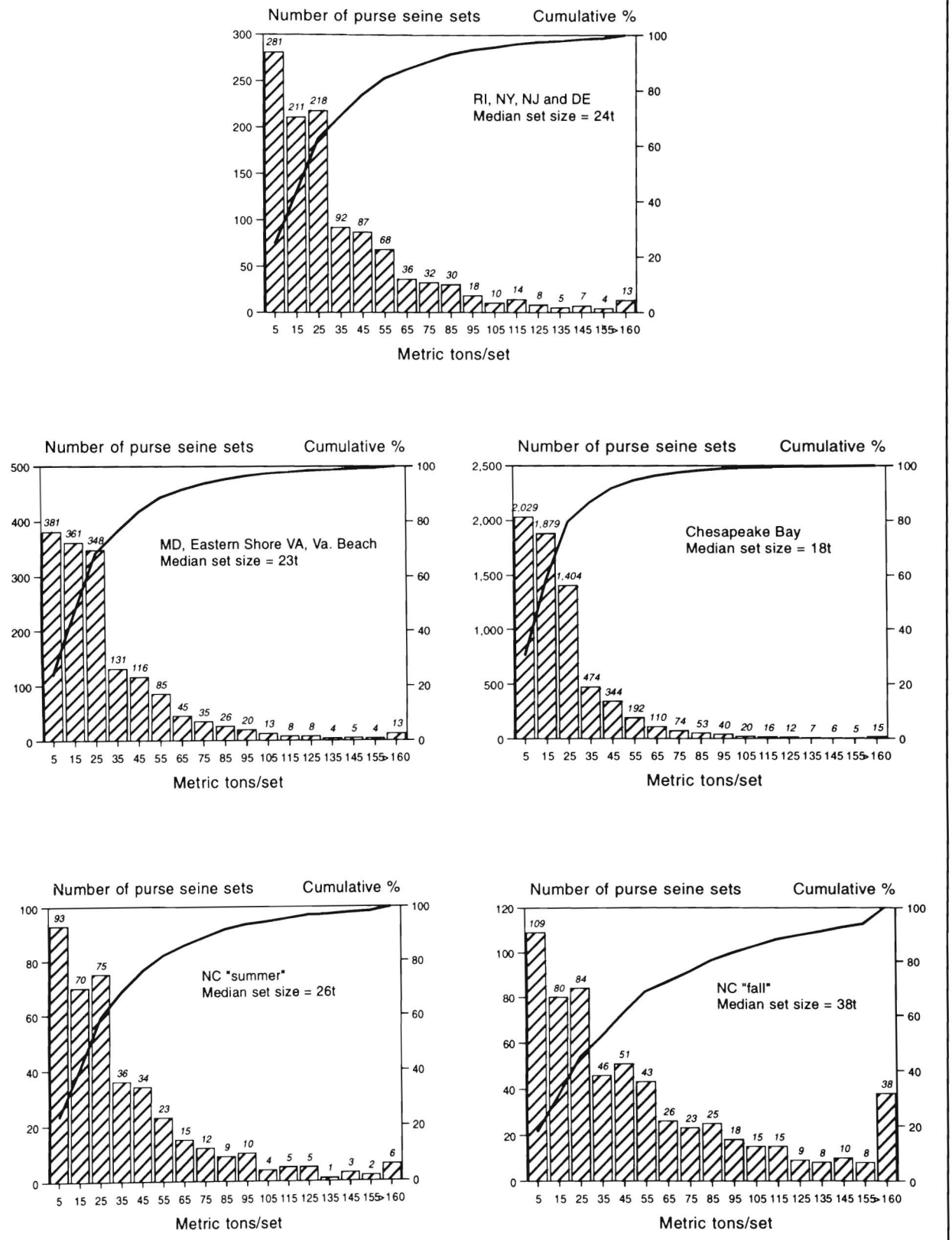

Figure 4

Frequency distributions of Atlantic menhaden catch per set in five geotemporal regions, 1985–96. Number of sets in each size interval is a mean for the 12-year period. Note different *y*-axis scales.

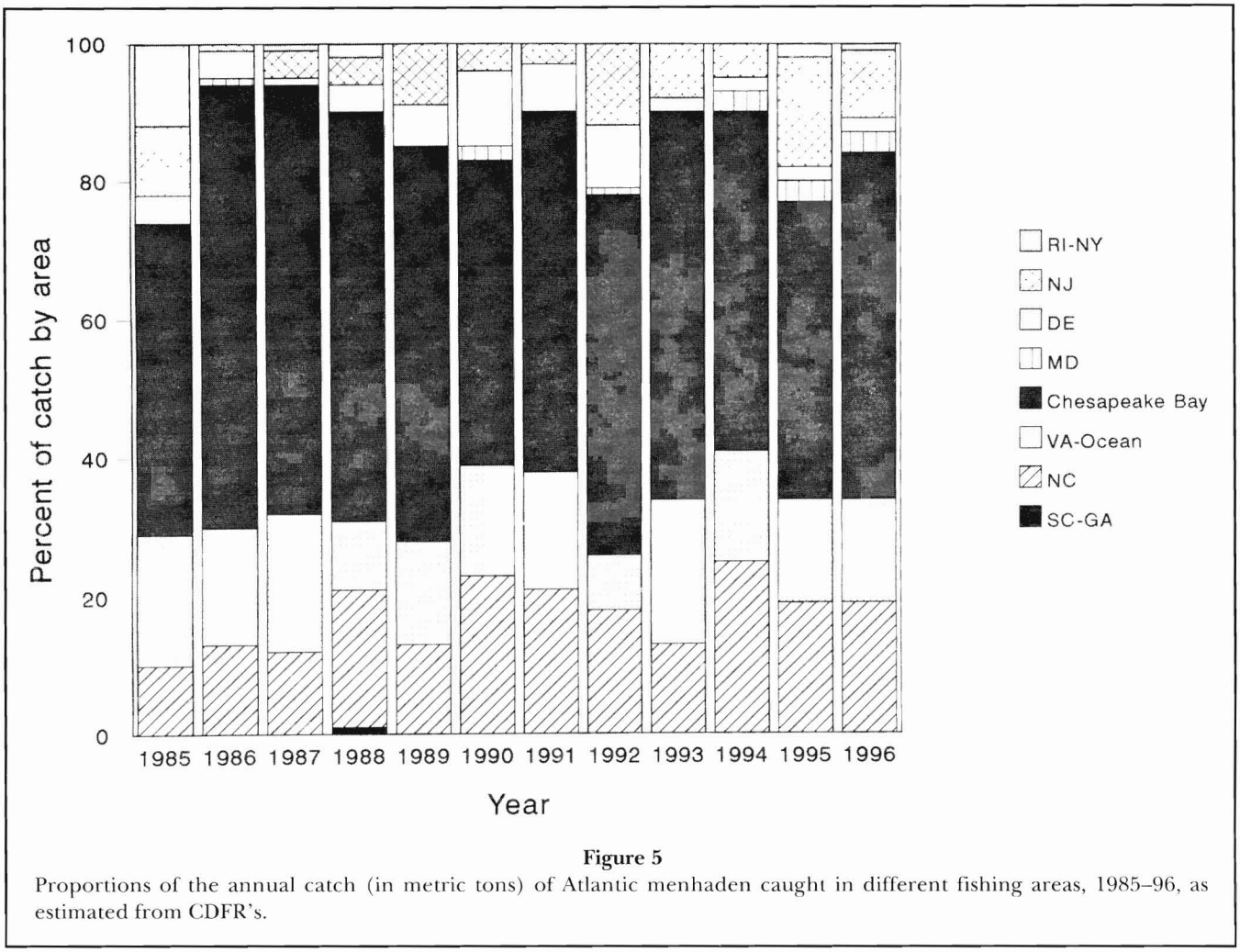

Figure 5
Proportions of the annual catch (in metric tons) of Atlantic menhaden caught in different fishing areas, 1985–96, as estimated from CDFR's.

July. During September and October, most effort and catches shifted south to Virginia's Eastern Shore and Virginia Beach areas. By November, virtually all fishing activity occurred between Virginia Beach and the Bogue Banks area off North Carolina. During January through March, most activity was in the Cape Lookout and Bogue Banks areas of North Carolina.

Within Chesapeake Bay, peak fishing effort and catches occurred in most areas during August (Fig. 8, 9; Append. Table 3, 4). Across all months, the Smith Point, Rappahannock River, and York River areas ranked one through three in importance, respectively, in terms of number of sets and catch.

Rhode Island to New York—Occasionally, as catches in Chesapeake Bay declined or became sporadic during summer, vessels from Virginia, and rarely North Carolina, ranged farther north in search of fish. Vessels fished in Rhode Island waters (Narragansett Bay) only during 1985, 1988, 1991, and 1995; this was the farthest north that the Virginia fleet traveled. On average, the fleet made 106 sets in the Rhode Island to New York area (1% of coastwide sets), and harvested 4,400 t (2% of the coastwide catch; Fig. 6, 7; Append. Table 1, 2). Fishing activity during 1985 was atypical for this area in that 33,000 t of Atlantic menhaden were harvested (the second highest harvest, 6,300 t, occurred in 1995). If the 1985 catch is excluded, average harvest from this area for 1986–96 declined to 1,800 t.

New Jersey—In 1989, the state of New Jersey enacted regulations to prohibit menhaden vessels from fishing within 1.2 mi. of the New Jersey ocean shoreline; previously, the restricted area had been within 0.6 mi. of shore. Menhaden fishing along the New Jersey coast occurred almost exclusively from June through September, with the greatest activity in July. On average, the fleet made 512 sets off the New Jersey coast (5% of the coastwide sets), and harvested 20,600 t of Atlantic menhaden (7% of the coastwide catch; Fig. 6, 7; Ap-

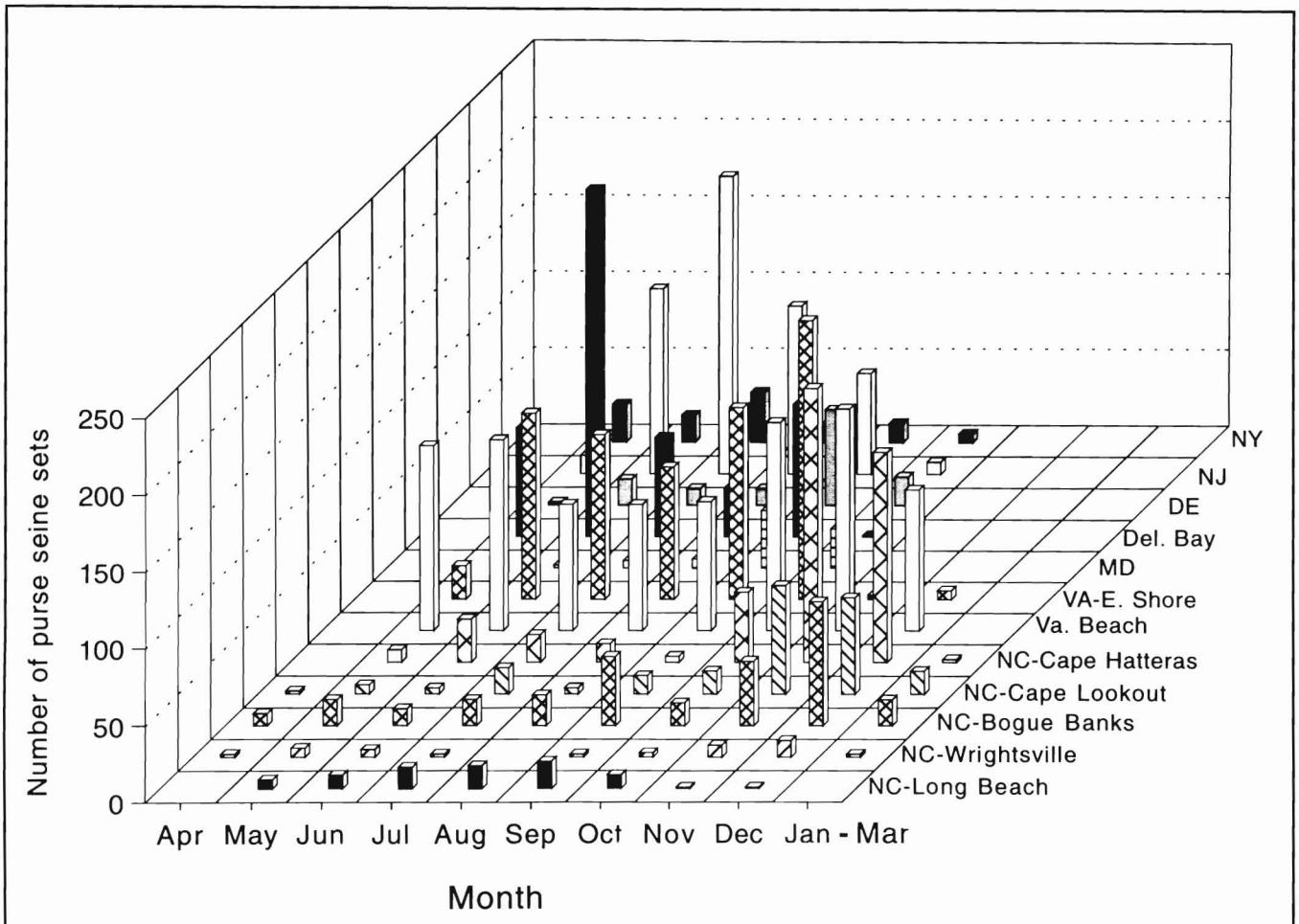

Figure 6
Mean number of purse-seine sets for Atlantic menhaden in ocean areas (including Delaware Bay) by month, 1985–96.

pend. Table 1, 2). Prior to 1992, when purse-seine fishing for reduction was permitted in Delaware Bay, the catch along the New Jersey coast averaged 14,100 t per yr (1985–91; Table 3). After Delaware Bay was closed to the menhaden fleet in July 1992, fishing activity increased off the New Jersey coast and annual average catch in New Jersey waters doubled to 29,700 t for 1992–96.

Delaware and Delaware Bay—Fishing in Delaware waters commenced in May and continued through September, with only minor activity in October. Fishing effort and catches by month were bimodal; peak activity occurred in June with a minor peak in September. Prior to 1992, purse seining for reduction was permitted in an ellipse-shaped area within lower Delaware Bay, more than 3 mi. from Delaware's shoreline. In July 1992, Delaware enacted regulations prohibiting menhaden reduction vessels from fishing in Delaware Bay. Thus, vessels were limited to fishing beyond 3 mi. from the state's ocean shore. Within Delaware Bay, during 1985–92 the fleet averaged 483 sets per yr (5% of coastwide sets) and harvested 13,000 t of fish (5% of the coastwide catch; Fig. 6, 7; Append. Table 1, 2). Off the Delaware coast, the fleet on average made 123 sets (1% of coastwide sets) and harvested 4,300 t of Atlantic menhaden (2% of the coastwide catch).

Maryland—Maryland prohibits purse-seine fishing within its portion of Chesapeake Bay and state territorial waters. Hence, menhaden fishing off Maryland's coast occurred in ocean waters beyond 3 mi. from shore. Relative to coastwide activity, fishing activity off Maryland was minimal. On average, the fleet made 77 sets (1% of coastwide sets) off the Maryland coast and harvested 3,200 t (3% of the coastwide catch; Fig. 6, 7; Append. Table 1, 2). Peak fishing activity occurred in September and October.

Virginia and Chesapeake Bay—Annual fishing activity in Virginia waters (Chesapeake Bay and ocean areas

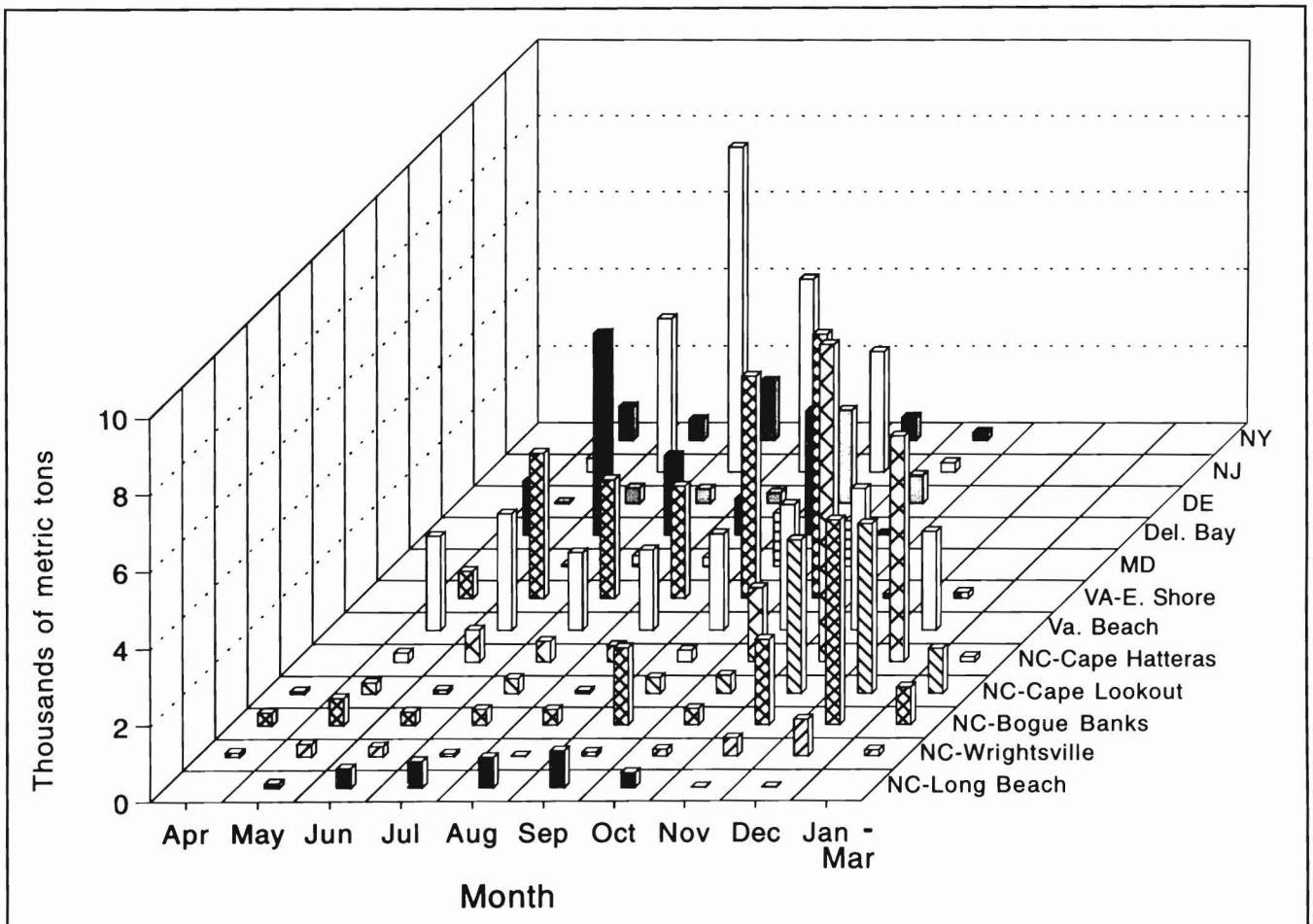

Figure 7
Mean catch of Atlantic menhaden from ocean areas (including Delaware Bay) by month, 1985–96.

combined) predominated over all other areas. On average, the fleet made 8,230 sets in Virginia waters (78% of coastwide sets), and harvested 194,400 t of Atlantic menhaden (67% of the coastwide catch). In Virginia's ocean areas (Eastern Shore and Virginia Beach), the fleet averaged 1,530 sets per yr (15% of coastwide sets) and harvested 44,900 t (16% of the coastwide catch; Fig. 6, 7; Append. Table 1, 2). Peak catches occurred in October along Virginia's Eastern Shore and in November off Virginia Beach.

Within Chesapeake Bay the fleet averaged 6,700 sets annually (63% of coastwide sets) and caught 149,500 t of Atlantic menhaden (52% of the coastwide catch; Fig. 8, 9; Append. Table 3, 4). Peak fishing activity occurred in August, when on average the fleet made 1,513 sets (23% of sets in Chesapeake Bay) and caught 36,100 t of Atlantic menhaden (24% of the catch in Chesapeake Bay). During June, July, and September, monthly variation in number of sets was slight, ranging from 1,016 sets in July to 1,091 sets in September (15%–16% of the total sets in Chesapeake Bay), as was the variation in catch, which ranged from 23,200 t in September to 24,800 t in July (16%–17% of the catch in Chesapeake Bay).

By area within Chesapeake Bay, the Smith Point area (adjacent to the fish factories) led all areas in number of sets with 1,843 (28% of the total sets in Chesapeake Bay), and in catch with 40,900 t (27% of the catch in Chesapeake Bay). The Smith Point area and the adjacent Rappahannock River area combined accounted for 3,490 sets (52% of the total sets in Chesapeake Bay) and 75,300 t (51% of the catch in Chesapeake Bay).

North Carolina—Through 1993, a few small (less than 90 feet long) purse-seine vessels fished for menhaden in the estuarine waters of North Carolina's sounds near Beaufort. CDFR data from several of these vessels were judged complete, and were included in the analyses; however, these vessels rarely ventured into ocean waters, and total annual catch for an individual vessel was usually less than 4,000 t. Thus, their contribution to

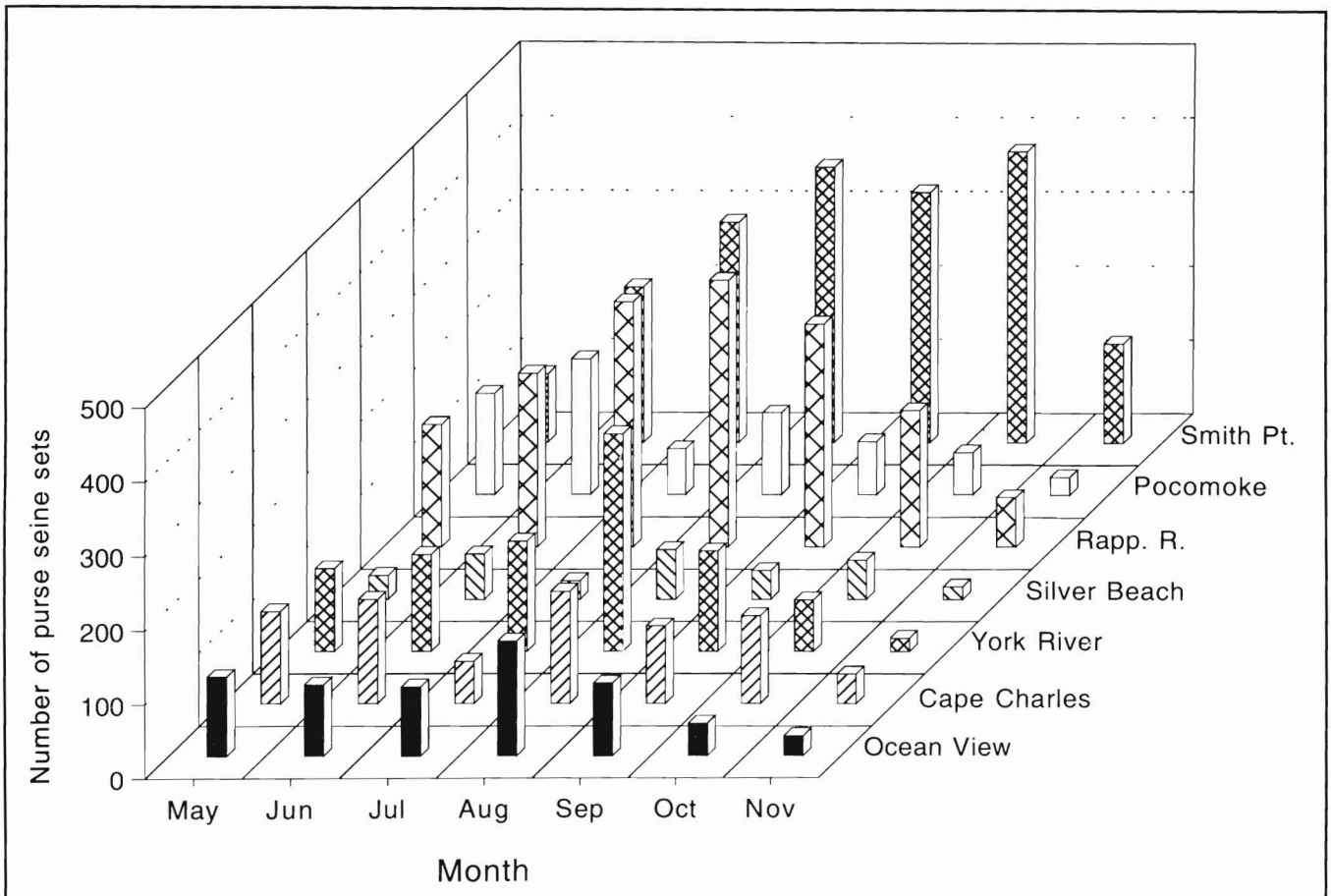

Figure 8
Mean number of purse-seine sets for Atlantic menhaden in Chesapeake Bay areas by month, 1985–96.

overall North Carolina fleet effort and catch was minor. Beginning in 1994, North Carolina purse seining for Atlantic menhaden for reduction was exclusively in nearshore ocean waters.

Fishing activity in all areas along the North Carolina coast on average amounted to 1,032 sets (10% of coastwide sets), yet the catch averaged 49,100 t (17% of the coastwide catch; Fig. 6, 7; Append. Table 1, 2). Although menhaden fishing off North Carolina occurred during all months, a majority of the activity occurred during November and December as fish migrated south along the state's coastline. Peak fishing activity occurred in the Cape Hatteras area during these months. By January–March, fishing was mostly restricted to the Cape Lookout and Bogue Banks areas.

South Carolina and Georgia—Menhaden fishing activity south of North Carolina was minimal for several reasons. First, a small factory in Fernandina Beach, Florida, closed in 1987. Its single vessel had fished off northern Florida and southern Georgia, but rarely landed more than 4,000 t annually. Second, in 1985 South Carolina prohibited purse-seine fishing for menhaden within its territorial waters. Third, although Georgia permits purse seining in its ocean waters, the distance and time (up to 24 h one-way) required for vessels to reach the Georgia fishing grounds from North Carolina was excessive. Despite refrigerated fish holds, carrier vessels often had difficulty delivering a quality product to dockside in mid-summer. Moreover, catches off Georgia generally consisted of age-1 and age-2 Atlantic menhaden less than 200 mm in fork length (FL = distance from the tip of the snout to the central rays of the fork in the tail); these are less desirable for the industry because of their low oil yield. Nevertheless, North Carolina vessels made trips to Georgia waters in summer 1985, 1988, and 1993. Peak catch occurred in 1988, when 2,200 t of menhaden were harvested.

Distribution by Distance from Shore—An analysis of fishing activity for Atlantic menhaden by distance from shore underscored the nearshore and estuarine nature

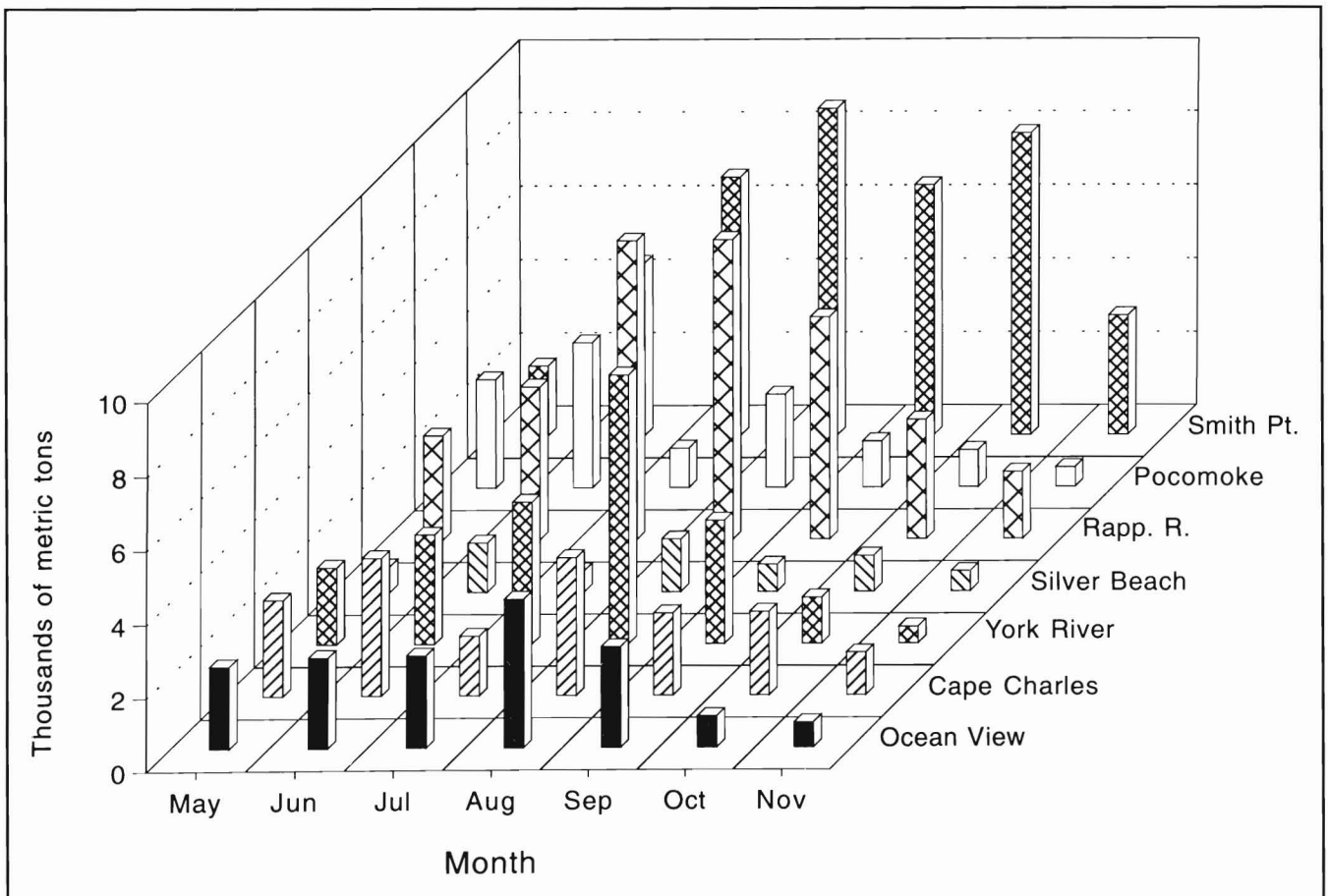

Figure 9
Mean catch of Atlantic menhaden from Chesapeake Bay areas by month, 1985–96.

of the fishery. Along the shores of New Jersey, Virginia, and North Carolina, where menhaden fishing is permitted in nearshore ocean waters, a majority of the sets and catches occurred within 3 mi. of ocean beaches (Fig. 10, 11; Append. Table 5, 6). For example, along the New Jersey coast, the fishery annually made on average 482 sets and caught 16,300 t of fish (representing 81% of sets and 80% of catch off New Jersey) within 3 mi. of the state's shoreline. Similarly, in Virginia's Eastern Shore area, vessels made 506 sets and caught 17,500 t within 3 mi. of shore (representing 78% of sets and 75% of catch from this area); in the Virginia Beach area, vessels made 717 sets and caught 17,800 t within 3 mi. of shore (representing 83% of sets and 83% of catch from this area). Along the North Carolina coast, sets and catches were even more concentrated inshore. This was most pronounced off the Bogue Banks area, where menhaden vessels on average made 176 sets and caught 7,400 t annually (62% of sets and 57% of catch for this area) within 0.5 mi. of shore. Moreover, a total of 223 sets were made and 9,500 t of fish caught (78% of sets and 74% of catch for this area) within 1 mi. of the shore.

Across all fishing areas within Chesapeake Bay, most menhaden fishing activity occurred more than 1 mi. from shore (Fig. 12, 13, Append. Table 7, 8). On average, only 64 sets, accounting for 1,500 t of fish, came from within 0.5 mi. of shore (1% of sets and 1% of catch from the Bay), while only 547 sets, accounting for 12,100 t of menhaden, came from within 1 mi. of shore (8% of sets and 8% of catch from the Bay). The next two farthest strata from the shore, 1.1–2.0 mi. and 2.1–3.0 mi., were nearly equivalent in fishing activity, each accounting for about one-quarter of sets within the Bay, and one-fifth to one-quarter of the catch. Clearly, almost one-half of all fishing activity in the Bay occurred beyond 3 mi. from the shoreline; on average, 3,125 sets occurred in this stratum, accounting for 69,700 t of menhaden (47% of sets and 47% of catch from the Bay).

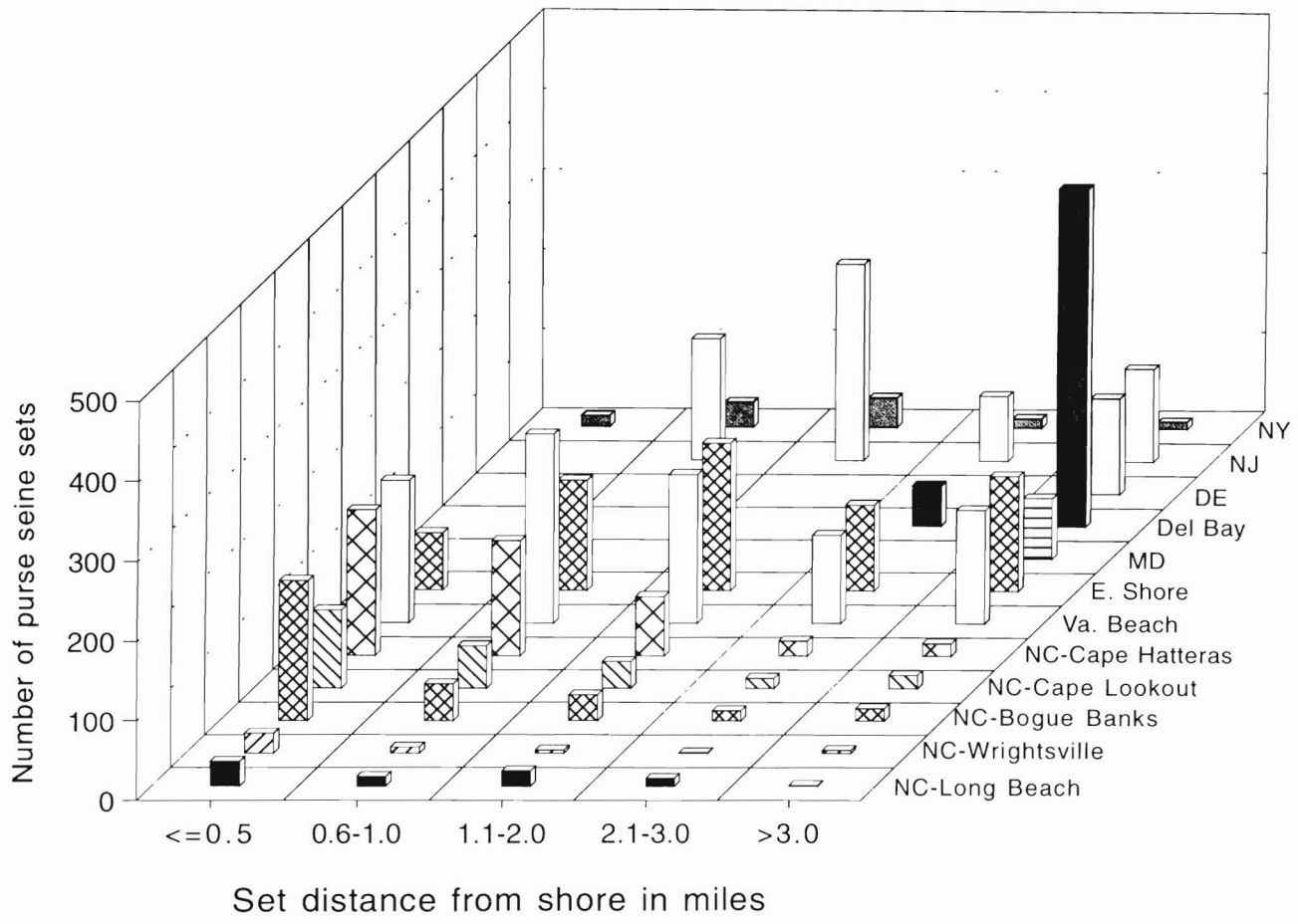

Figure 10
Mean number of purse-seine sets for Atlantic menhaden in ocean areas (including Delaware Bay) by distance from shore, 1985–96.

Discussion

Digitization and summary of CDFR data have yielded greater insights into the fishing activities of the Atlantic menhaden purse-seine fleet, especially in terms of catch and effort (sets) by state and by distance from shore. Prior to this study, with few exceptions, older and slower vessels of the 1950's and 1960's had limited range and, in general, fished in the vicinity of their home port (Nicholson, 1971). Accordingly, catches and landings were roughly equivalent, and were summed by arbitrary coastal area (June and Reintjes, 1959), e.g. North Atlantic, Middle Atlantic, Chesapeake Bay, and South Atlantic areas. Exceptions included vessels from New Jersey (Middle Atlantic area) that fished in Long Island Sound (North Atlantic area), and vessels from New York that fished off New Jersey (Nicholson, 1971). Through the late 1970's and 1980's, the premise that catch and landings within each coastal area were roughly equivalent became invalid as newer and larger purse-seine vessels from Virginia and North Carolina ranged farther from their home ports (north to Rhode Island and south to Georgia). Unlike earlier logbook programs, CDFR's provided a complete daily history of vessel activity, including the means to estimate menhaden catch by state and by distance from shore.

Studies of previous Atlantic menhaden logbook projects had several shortcomings in comparison with the present study. Roithmayr's (1963) report examined the number and distribution of purse-seine sets, but did not provide areal catch information. Nicholson's (1971) study included estimates of mean catch by geographic area (e.g. Middle Atlantic, etc.; see above) and by set, but his catch data were obtained from daily records of vessel landings (i.e. combined dock unloadings of multiple sets), not from set-specific infor-

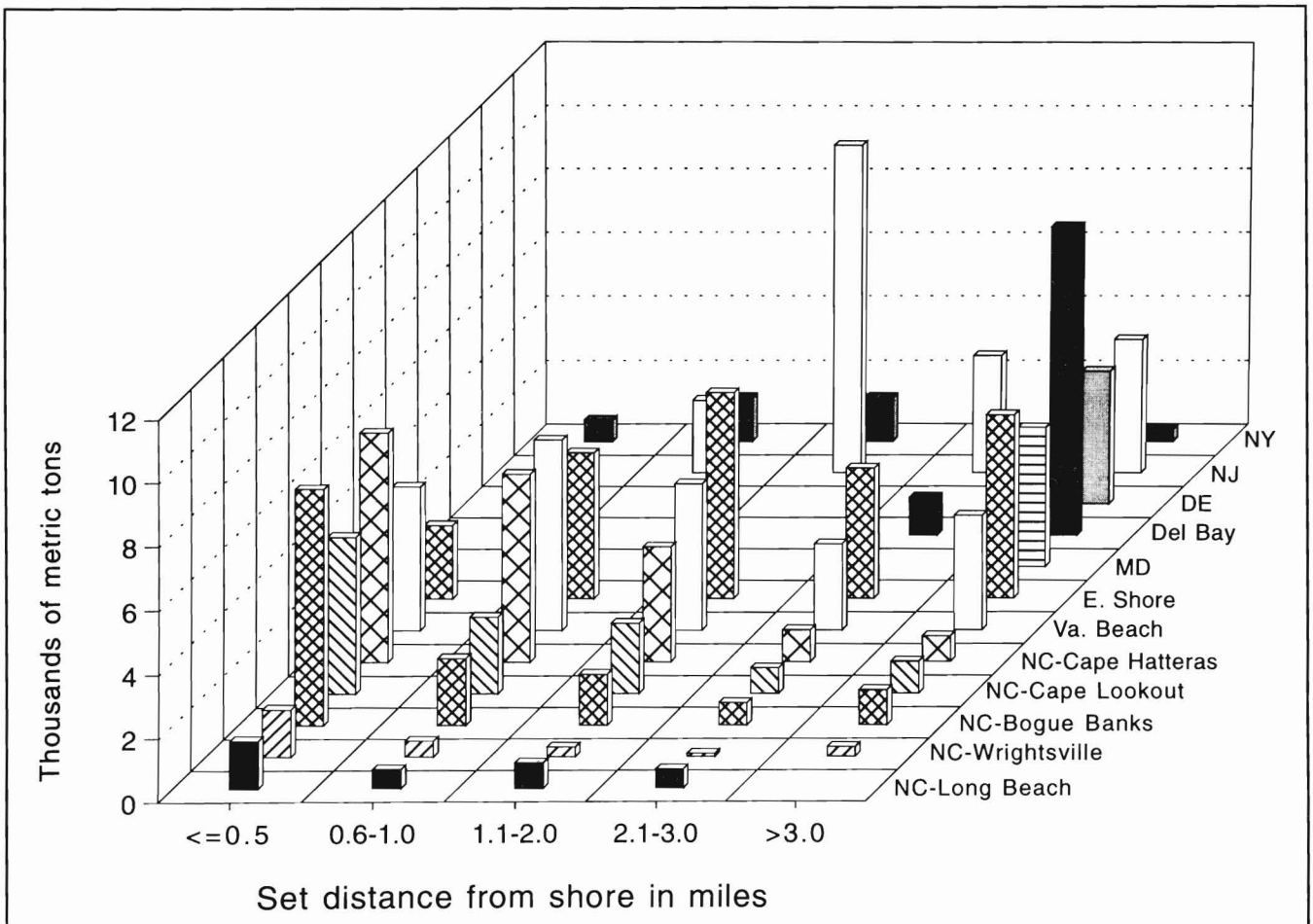

Figure 11
Mean catch of Atlantic menhaden from ocean areas (including Delaware Bay) by distance from shore, 1985–96.

mation. Again, vessels during the 1950's and 1960's tended to fish near their home port. Nevertheless, some comparisons with earlier reports are possible.

Fishing effort, in terms of number of sets, in the Chesapeake Bay area has remained relatively stable since the late 1950's. Roithmayr (1963) estimated that between 1955 and 1959, the menhaden fishery averaged 8,342 sets annually in the Chesapeake Bay area (which roughly included this study's Eastern Shore and Virginia Beach areas in Virginia), while Nicholson's (1971) annual estimates for the Chesapeake Bay area during 1956–66 averaged 9,102 sets. To compare CDFR data with these earlier studies, I combined the Eastern Shore and Virginia Beach areas with Chesapeake Bay and determined that in these areas, the fishery averaged 8,230 sets per year in 1985–96.

Elsewhere along the Atlantic Coast, menhaden fishing activity has declined since the 1950's and 1960's. Roithmayr (1963) estimated that 5,818 sets occurred annually in 1955–59 in the South Atlantic area (*sensu* June and Reintjes, 1959; roughly Cape Hatteras to northern Florida), while Nicholson (1971) estimated that 4,641 sets were made each year in 1955–66 in the same area. Contemporary CDFR data indicated that sets in North Carolina waters averaged 1,032 annually in 1985–96. This decline in fishing activity in the South Atlantic area was primarily due to plant closures. As recently as 1983, five reduction plants operated in North Carolina and Florida (four and one, respectively). However, by 1987 all but the facility at Beaufort, North Carolina, had closed (Smith, 1991).

The decrease in number of sets was even more striking in the Middle Atlantic area (*sensu* June and Reintjes, 1959; roughly New Jersey to Maryland). My estimate of 1,195 sets made annually during 1985–96 in waters from New Jersey to Maryland showed a tenfold decline in effort for the area, compared to Roithmayr's (1963) estimate of 14,265 annual sets during 1955–59 and

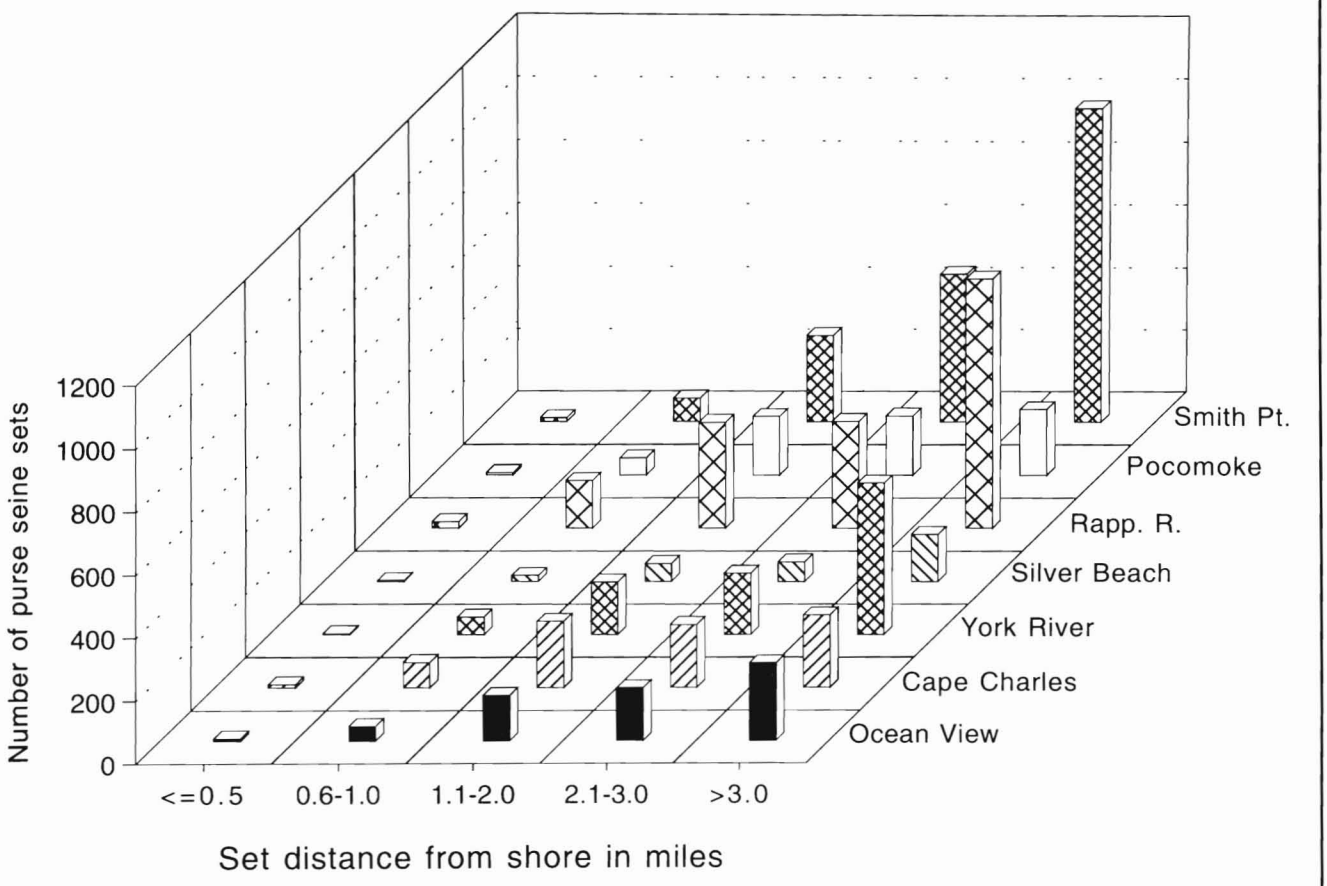

Figure 12
Mean number of purse-seine sets for Atlantic menhaden in Chesapeake Bay areas by distance from shore, 1985–96.

Nicholson's (1971) of 10,569 sets during 1955–66. The decline in effort in the Middle Atlantic area was mostly attributable to plant closures; the area's last fish factory at Port Monmouth, New Jersey, closed in late 1981 (Smith, 1991). Since 1982, all sets for reduction in the Middle Atlantic have been made by vessels from Virginia or, rarely, North Carolina.

Nicholson (1971) documented numerous technological improvements in the menhaden fishery through the 1960's which improved fishing efficiency, one of which was the spotter aircraft. That spotter airplane pilots annually assisted with 83%–93% of purse-seine sets during the present study attests to the importance of aircraft in locating menhaden schools.

The number of purse-seine sets completed per day during 1985–96 was higher than during the 1950's and 1960's, although the reasons are not as readily apparent as in the examples documented by Nicholson (1971). Nicholson (1971) estimated that between 1955 and 1966, the mean number of sets per day for the Atlantic menhaden fleet ranged from 1.97 to 4.56, depending upon year and location. Although not directly comparable, CDFR information revealed that during 1985–96 the median number of sets per day was five except during 1991, when it was four.

On the other hand, median catches per set by area as calculated from CDFR's (24 t in the Middle Atlantic, 18 t in Chesapeake Bay, and 38 t during fall off North Carolina) were comparable to mean catch-per-set values estimated by Nicholson (1971). Perhaps larger and faster carrier vessels and purse boats account for the greater number of sets per day in the modern menhaden fleet (average time for set completion was 34–43 min; Table 1). Also, intra-vessel competition for fish schools is apparently less in the modern fishery (with about 20 vessels) than it was in the 1950's and 1960's, when up to 100 vessels operated during summer from the Middle Atlantic coast to northeast Florida (Smith et al., 1987).

The large size of the menhaden schools that migrate along the North Carolina coast in fall (June and Reintjes, 1959; Nicholson, 1971) no doubt accounts for the North

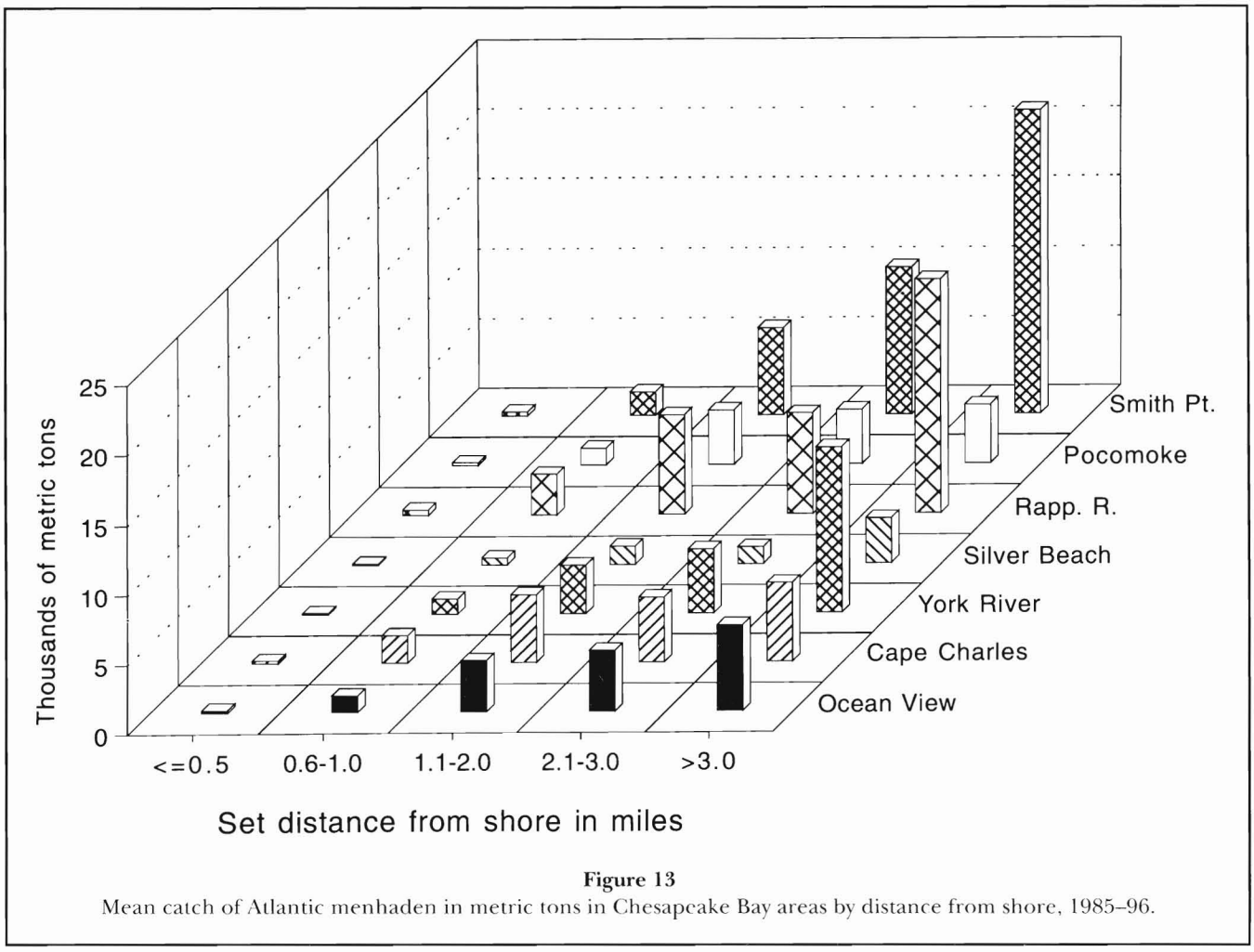

Figure 13
Mean catch of Atlantic menhaden in metric tons in Chesapeake Bay areas by distance from shore, 1985–96.

Carolina fall region having the highest median catch (38 t) of all regions. On the other hand, it is not surprising that Chesapeake Bay had the lowest median catch (18 t), given that vessel competition within the Bay (among 18–20 vessels) is intense, and that the number of purse-seine sets within the Bay is an order of magnitude greater than in other regions. Nicholson (1972) concluded that fishing intensity above a certain level in Chesapeake Bay tended to decrease menhaden availability. Although set-specific catch data were unavailable to him at the time, he speculated that intense fishing pressure affected the mechanism by which small menhaden schools coalesced into larger ones. CDFR information from 1986 (Table 1) may confirm his suspicions, as only ten vessels fished in Chesapeake Bay that year (one plant was inactive) and median catch per set for the fleet increased to 30 t.

In terms of catch, Chesapeake Bay is the center of the modern Atlantic menhaden fishery, as revealed by CDFR data summaries. Over the study period, catch within Chesapeake Bay averaged 149,500 t, which accounted for 52% of the catch by the Virginia and North Carolina fleets. If catches from Virginia's Eastern Shore and Virginia Beach areas are added to catch in Chesapeake Bay, catch in Virginia waters amounted to 194,400 t annually, or 67% of the total catch by vessels from Virginia and North Carolina. Other areas along the coast were seasonally important to the fishery. Catches off North Carolina annually amounted to 49,100 t (17% of the catch), with the bulk of the catch during November and December as migratory fish moved south past the North Carolina capes. Despite the travel time of almost 24 h one-way from Reedville, Virginia, to the Middle Atlantic area, Delaware Bay (through July 1992) and the New Jersey coast were important alternate fishing grounds for the Virginia fleet (and, rarely, North Carolina vessels) from June to September. Vessels generally visited these areas when fish became scarce in Chesapeake Bay, and/or when intra-vessel competition for fish intensified within Chesapeake Bay. Extra travel time and expense were offset by the greater fish-oil yields from the larger and older fish usually found in

the Middle Atlantic. Closure of Delaware Bay to purse-seine fishing in 1992 reduced historical fishing grounds available to the menhaden fishery, and probably served to increase fishing activity off the New Jersey coast.

Information attained from CDFR's confirmed the coastal nature of the Atlantic menhaden fishery, although historical comparisons of sets by distance from shore are unavailable. Along the New Jersey coast (where since 1989 fishing has been prohibited less than 1.2 mi. from shore), 50% of the catch came from within 2.0 mi. of the ocean beaches. Along Virginia's Eastern Shore and Virginia Beach areas, 75% and 83% of the catch, respectively, were harvested within 3 mi. of the coast. Off North Carolina, where until recently few restrictions on distance from shore existed, 70% of the catch on average came from within 1 mi. of the shoreline. Recent regulatory measures established in North Carolina to prohibit purse seining within 1.5 mi. of some densely populated beaches in Dare County (northern Outer Banks) in summer, and within 0.5 mi. of these beaches in fall, have reduced the fleet's access to nearshore waters.

More stringent regulatory actions are pending or have recently been enacted in New Jersey, New York, Connecticut, and Rhode Island. As conflicts between user groups arise, state regulatory agencies have often responded by closing nearshore areas to menhaden purse seining. In general, these measures have not been based on sound biological evidence (AMAC[2]), and they jeopardize the menhaden industry's ability to seasonally utilize traditional nearshore fishing grounds.

Counter to the nearshore nature of the menhaden fishery along ocean beaches, catches in the main stem of Chesapeake Bay occurred farther from shore, as 47% of the catch within the Bay (69,700 t on average) was harvested more than 3 mi. from shore. The CDFR data suggest that menhaden are more abundant in the deeper portions of Chesapeake Bay, farther from the shoreline, although vessels may actively avoid shallow nearshore areas and potential gear conflicts with the myriad of blue-crab pots that saturate shallow areas of the Bay.

An additional phenomenon in Chesapeake Bay was the fact that a majority of the fishing activity was in areas adjacent to the Reedville fish factories. Reasons for this are probably threefold. First, if fish were scarce or reluctant to "show" in near-surface waters, captains were more likely to wait for schools to appear near their home port, rather than to travel to more distant fishing grounds. Second, captains often choose to "top-off" the fish hold with a set near the factory upon return from more distant fishing grounds. Third, and perhaps more important, Maryland has historically prohibited purse seining for menhaden within its state waters. Thus, the Maryland portion of Chesapeake Bay is an enormous refuge for menhaden schools. If fish schools along the border line move slightly south into Virginia waters, they become available to the Virginia fleet in an area adjacent to the port of Reedville.

[2] Atlantic Menhaden Advisory Committee (AMAC). 1992. Fishery management plan for Atlantic menhaden, 1992 revision. Atlantic States Marine Fisheries Commission Fishery Management Report 22, 159 p. Available from ASMFC, 1444 Eye Street, N.W., 6th floor, Washington, D.C. 20005.

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Appendix Table 1

Mean number of purse-seine sets for Atlantic menhaden in ocean areas (including Delaware Bay) by month, 1985–96.

Area	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan–Mar	Mean sets/ fishing yr	% of coastwide sets[1]
New York–Rhode Island		25	18	33	11	13	6				106	1.0
New Jersey		12	121	195	110	66	8				512	4.9
Delaware		2	17	11	11	63	19				123	1.2
Delaware Bay		71	227	65	32	87	1				483	4.6
Maryland			2	5	6	38	26				77	0.7
Virginia												
Eastern Shore		22	122	108	87	126	183	3	6		657	6.2
Virginia Beach		121	125	83	83	85	137	146	93		873	8.3
North Carolina												
Cape Hatteras		8	28	18	12	4	46	180	138	2	436	4.1
Cape Lookout	2	6	4	17	4	12	15	71	63	15	209	2.0
Bogue Banks	8	17	11	17	20	45	15	42	81	17	273	2.6
Wrightsville	2	6	5	2		2	3	8	11	2	41	0.4
Long Beach		6	9	14	15	18	9	1	1		73	0.7

[1] Includes sets in Chesapeake Bay.

Appendix Table 2

Mean catch of Atlantic menhaden in thousands of metric tons from ocean areas (including Delaware Bay) by month, 1985–96.

Area	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan–Mar	Mean catch/ fishing yr[1]
New York–Rhode Island		0.9	0.6	1.6	0.5	0.6	0.2				4.4
New Jersey		0.4	4.0	8.5	5.0	3.2	0.2				21.3
Delaware		<0.1	0.4	0.4	0.3	2.4	0.7				4.3
Delaware Bay		1.4	5.3	2.1	0.9	3.2	<0.1				12.9
Maryland			0.1	0.3	0.2	1.4	1.2				3.2
Virginia											
Eastern Shore		0.7	3.8	3.1	2.9	5.8	6.9	0.1	0.2		23.5
Virginia Beach		2.5	3.0	2.0	2.1	2.5	3.3	3.7	2.6		21.6
North Carolina											
Cape Hatteras		0.2	0.8	0.5	0.4	0.3	1.9	8.3	5.9	0.1	18.6
Cape Lookout	0.1	0.3	0.1	0.4	0.1	0.4	0.5	4.0	4.4	1.2	11.4
Bogue Banks	0.3	0.7	0.4	0.4	0.4	2.0	0.4	2.2	5.3	1.0	13.2
Wrightsville	0.1	0.3	0.3	0.1	<0.1	0.1	0.2	0.5	1.0	0.2	2.7
Long Beach		0.1	0.5	0.7	0.8	1.0	0.4	<0.1	<0.1		3.5

[1] Values differ slightly from 12-yr means in Table 3 due to rounding.

Appendix Table 3
Mean number of purse-seine sets for Atlantic menhaden in Chesapeake Bay areas by month, 1985–96.

Area	May	Jun	Jul	Aug	Sep	Oct	Nov	Mean sets/ fishing yr	% of Chesapeake Bay sets	% of coast-wide sets[1]
Smith Point	93	211	298	373	339	394	135	1,843	27.5	17.5
Pocomoke	137	184	62	111	72	57	24	647	9.7	6.1
Rappahannock River	165	235	332	361	302	185	67	1,647	24.6	15.6
Silver Beach	32	61	25	67	39	53	17	294	4.4	2.8
York River	112	131	149	294	136	70	18	910	13.6	8.6
Cape Charles	125	141	57	152	105	119	40	739	11.0	7.0
Ocean View	107	96	93	155	98	44	27	620	9.3	5.9

[1] Includes ocean areas.

Appendix Table 4
Mean catch of Atlantic menhaden in thousands of metric tons from Chesapeake Bay areas by month, 1985–96.

Area	May	Jun	Jul	Aug	Sep	Oct	Nov	Mean catch/ fishing yr	% of Chesapeake Bay catch	% of coast-wide catch[1]
Smith Point	1.9	4.7	7.0	8.9	6.8	8.2	3.3	40.9	27.4	14.1
Pocomoke	3.0	4.0	1.1	2.5	1.3	1.0	0.5	13.3	8.9	4.6
Rappahannock River	2.8	4.2	8.1	8.2	6.1	3.2	1.8	34.4	23.1	11.9
Silver Beach	0.7	1.3	0.6	1.4	0.7	1.0	0.5	6.3	4.2	2.2
York River	2.1	3.0	3.9	7.3	3.3	1.3	0.5	21.3	14.3	7.3
Cape Charles	2.6	3.8	1.6	3.8	2.3	2.3	1.2	17.5	11.7	6.0
Ocean View	2.2	2.5	2.5	4.0	2.7	0.9	0.7	15.6	10.4	5.6

[1] Includes ocean areas.

Appendix Table 5
Mean number of purse-seine sets for Atlantic menhaden in ocean areas (including Delaware Bay) by distance from shore, 1985–96.

Area	≤0.5 mi	0.6–1.0 mi	1.1–2.0 mi	2.1–3.0 mi	>3.0 mi
New York–Rhode Island	14	32	38	12	9
New Jersey[1]		153	247	82	117
Delaware					121
Delaware Bay				51	426
Maryland					77
Virginia					
Eastern Shore	72	139	186	109	146
Virginia Beach	179	238	188	112	144
North Carolina					
Cape Hatteras	183	145	75	19	16
Cape Lookout	98	54	34	13	17
Bogue Banks	176	47	33	13	16
Wrightsville	25	8	4	1	4
Long Beach	31	12	19	10	1

[1] New Jersey permitted purse seining beyond 0.6 mi. from the coast until 1989, thereafter beyond 1.2 mi.

Appendix Table 6

Mean catch of Atlantic menhaden in thousands of metric tons from ocean areas (including Delaware Bay) by distance from shore, 1985–96.

Area	≤0.5 mi	0.6–1.0 mi	1.1–2.0 mi	2.1–3.0 mi	>3.0 mi
New York–Rhode Island	0.7	1.4	1.4	0.4	0.4
New Jersey[1]		2.3	10.3	3.7	4.2
Delaware					4.2
Delaware Bay				1.2	9.7
Maryland					4.4
Virginia					
Eastern Shore	2.3	4.6	6.5	4.1	5.8
Virginia Beach	4.5	6.0	4.6	2.7	3.6
North Carolina					
Cape Hatteras	7.2	5.9	3.6	1.0	0.8
Cape Lookout	4.9	2.4	2.2	0.8	1.0
Bogue Banks	7.4	2.1	1.6	0.7	1.1
Wrightsville	1.5	0.5	0.3	0.1	0.3
Long Beach	1.5	0.6	0.8	0.6	

[1] New Jersey permitted purse seining beyond 0.6 mi. from the coast until 1989, thereafter beyond 1.2 mi.

Appendix Table 7

Mean number of purse-seine sets for Atlantic menhaden in Chesapeake Bay areas by distance from shore, 1985–96.

Area	≤0.5 mi	0.6–1.0 mi	1.1–2.0 mi	2.1–3.0 mi	>3.0 mi
Smith Point	12	74	277	475	1,003
Pocomoke	7	54	186	188	209
Rappahannock River	21	152	336	340	799
Silver Beach	3	19	57	63	150
York River	3	56	168	193	484
Cape Charles	10	81	212	201	232
Ocean View	8	47	145	169	248

Appendix Table 8

Mean catch of Atlantic menhaden in thousands of metric tons from Chesapeake Bay areas by distance from shore, 1985–96.

Area	≤0.5 mi	0.6–1.0 mi	1.1–2.0 mi	2.1–3.0 mi	>3.0 mi
Smith Point	0.3	1.7	6.3	10.6	21.8
Pocomoke	0.2	1.2	3.9	3.9	4.2
Rappahannock River	0.4	2.9	7.1	7.2	16.8
Silver Beach	0.1	0.5	1.3	1.2	3.2
York River	0.1	1.1	3.5	4.6	11.8
Cape Charles	0.2	2.0	4.9	4.7	5.7
Ocean View	0.2	1.2	3.7	4.4	6.2