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Movements and Population Structure of Atlantic Menhaden Indicated by Tag Returns

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ABSTRACT: Over 968,000 adult Atlantic menhaden, *Brevoortia tyrannus*, were tagged from 1967 to 1969 and over 85,000 juvenile menhaden were tagged from 1969 to 1973. Recoveries of these tagged fish through 1975 provide direct evidence that Atlantic menhaden consist of a single population that over-winters in offshore waters off the southeastern coast of the United States, moves northward in spring and stratifies along the coast by age and size during summer, and moves southward in late autumn.

Introduction

Over 968,000 adult Atlantic menhaden, *Brevoortia tyrannus*, were marked with internal ferromagnetic tags from 1967 to 1969 and over 84,000 juveniles were marked from 1969 to 1973. One of the objectives of tagging was to test hypotheses pertaining to movements and population structure based on changes in age and size distributions, back-calculated lengths, meristics, differences in age and size composition of catches, and fishing effort. In this paper I analyse the returns of Atlantic menhaden, tagged at five locations along the Atlantic Coast from Florida to New York and recovered through the 1975 fishing season, to determine if they support or refute current hypotheses.

Atlantic menhaden range from coastal waters of northern Florida to the Gulf of Maine and occur mainly within 15 miles of the coast and in the larger bays and sounds. They are a dense schooling, filter-feeding fish subjected to an intense purse seine fishery from about May to December. The catches are steam-pressure cooked and reduced to oil, meal and solubles at plants located from Florida to New England. The oil is used in a variety of products from cosmetics to oleomargarine, and the meal and solubles are ingredients of cattle and poultry feed.

From about May to October, Atlantic menhaden age-1 or older are stratified by age and size along the coast. The youngest and smallest fish are found in the more southern areas while the oldest and largest are found in the more northern areas. Menhaden less than a year old (juveniles) occur in estuaries along the entire Atlantic coast.

The coastwise movements of Atlantic menhaden have been inferred from indirect evidence and are generally well understood. On the basis of a reduction in the number of purse seine sets in waters north of Cape Cod in September, Roithmayer (1963) concluded that menhaden in New England waters begin a southward movement in late August or early September. June and Reintjes (1959) noted the disappearance of menhaden schools in October from waters north of Chesapeake Bay and the appearance of large schools of older, migrating fish off the coast of North Carolina in November and concluded that most Atlantic menhaden move to south of Cape Hatteras by January. Nicholson (1971), after examining latitudinal differences in length frequency distributions of individual age groups throughout the fishing season, described a north-south cyclic movement: Fish winter south of Cape Hatteras and begin a rapid northward movement in late winter and early spring, the largest and oldest

fish proceeding farthest north; by June the population is stratified by age and size along the coast; fish south of Cape Hatteras show little movement in any direction the rest of the summer, but fish north of there appear to move slowly northward throughout the summer, the larger fish of each age group making the most northern penetration; a general southward movement begins in late summer, culminating in the movement of all fish to the area south of Cape Hatteras by mid-winter. A study of back calculated length frequencies at the time of first annulus formation (Nicholson 1972) supported the concept of a north-south cyclic movement, and also indicated that a great deal of mixing of fish from all areas occurred before the fish moved northward in spring.

The question of whether Atlantic menhaden constitute a single population or two or more subpopulations has been raised in past years. Sutherland (1963) found significant differences in the mean number of vertebrae between juvenile menhaden from north and south of Long Island and speculated that two subpopulations might exist. June and Nicholson (1964) speculated that a subpopulation also might exist south of Cape Hatteras, the older fish moving from Florida to North Carolina waters in spring and returning to Florida waters in autumn. June (1965) found differences in the mean number of vertebrae of menhaden spawning north of Long Island in spring and south of Long Island in winter and concluded that the differences supported the concept of two subpopulations. Nicholson (1972), however, re-examined June's data and concluded that the differences could have resulted from differences in water temperature at the time of larval development, and that in view of the extensive evidence of menhaden movement along the coast, the concept of two subpopulations was untenable.

One of the objectives of tagging was to provide direct evidence that would either support or refute the indirect evidence pertaining to movement and population structure. A preliminary analysis of tag returns through 1969 (Dryfoos, Cheek, and Kroger 1973) supported the concept of a single population and a north-south cyclic movement.

Methods of Tagging

Details of tagging methods have been presented by Pristas and Willis (1973). Most fish were obtained from commercial purse seines. Sometimes they were held in special floating pens until they were tagged by crews from small boats, other times they were held in special tanks and tagged by crews aboard the carrier vessels. Numbered stainless steel tags were inserted into the body cavity with tagging guns.

The number of tags lost from either shedding or fish mortality was unknown, but appeared to be highly variable and in some areas large. Limited laboratory experiments suggested that losses were greatest among fish less than 120 mm fork length (Kroger and Dryfoos 1972). Analysis of recoveries confirmed that losses varied with fish size and were highly variable and unmeasurable (Nicholson and Lewis)¹.

Methods of Recovering Tags

Tags were recovered on magnets placed at strategic locations in reduction plants (Parker 1973). Primary magnets were placed in the system conveying cooked and dried fish scrap to storage areas. Secondary magnets were placed in the system conveying fish scrap to grinders where it was ground into meal. Tags were usually recovered on primary magnets within 2 days after entering a plant, but could be recovered on secondary magnets weeks to months after entering a plant, depending on the length of time the scrap was stored before being ground.

All tags that entered a plant were not recovered, some were recovered several seasons after they entered a plant, and some were recovered at a different plant. About 1% of test tags placed in catches to test the recovery efficiency of plant magnets were recovered 1, 2, or even 3 years after they had been introduced (Nicholson and Lewis)¹. Some of these had been retained for varying periods in plant machinery, while others had remained in scrap storage areas. Occasionally, tags that had been introduced at one plant were re-

¹ Nicholson, W. R. and R. M. Lewis. Difficulties in analyzing Atlantic menhaden tag returns (Unpublished manuscript).

covered at another, primarily because scrap from one plant was moved to another to be ground.

Tagging and Recovery Areas

Since nearly all of the fish tagged were obtained from commercial purse seines, the time of year fish were tagged depended on the time reduction plants operated in each area (Fig. 1). Two plants at Fernandina Beach, Fla., and one plant at Southport, N.C., operated from about April to October; two plants at Beaufort, N.C., operated from May to January, and five others opened from late October to mid-December; two to four plants operated at Reedville or Cape Charles, Va., from the last week in May until late November; one plant operated at Wildwood, N.J., from early June until October through the

1969 season; one plant operated at Port Monmouth, N.J., from early June until October; one plant operated at Amagansett, N.Y., from mid-June until October during the 1966, 1968, and 1969 seasons. No plants in the New England area processed menhaden from 1967 to 1969.

There were five tagging areas: Florida-Georgia, North Carolina, Chesapeake Bay, New Jersey, and New York (Fig. 1). Within each area most fish were tagged in a rather restricted radius of the reduction plants. In North Carolina most fish were tagged near Beaufort although some were tagged near Southport. In the Chesapeake Bay area most fish were tagged inside the bay in Virginia waters. In the New Jersey area all fish were tagged near Port Monmouth except for a relatively small number tagged near Wildwood. In the New York area most of the tagging was done in the eastern part of Long Island Sound. The specific location within each area was not identified for any group of fish.

Only the plant at which a tag was recovered could be identified, not the specific location at which a tagged fish was caught. Vessels from Chesapeake Bay plants sometimes fished along the New Jersey coast in summer and along the North Carolina coast in November. Port Monmouth vessels sometimes fished in New York waters, and Amagansett vessels sometimes fished in New Jersey waters. But since vessels usually fished within a restricted distance of a plant, most recovered tags came from fish caught within a relatively small prescribed area.

Analysis

For each of the five tagging areas, the number of tags recovered at each port are listed for the year in which tags were applied and for each succeeding year (Tables 1 to 10). Since New England plants were checked for tags for the first time in 1971, some of the tags credited to those ports for 1971 could have been recovered in 1970.

ADULT TAGGING

Florida-Georgia Area

Only age-1 and -2 fish, age-1 being the more abundant, are found in this area and

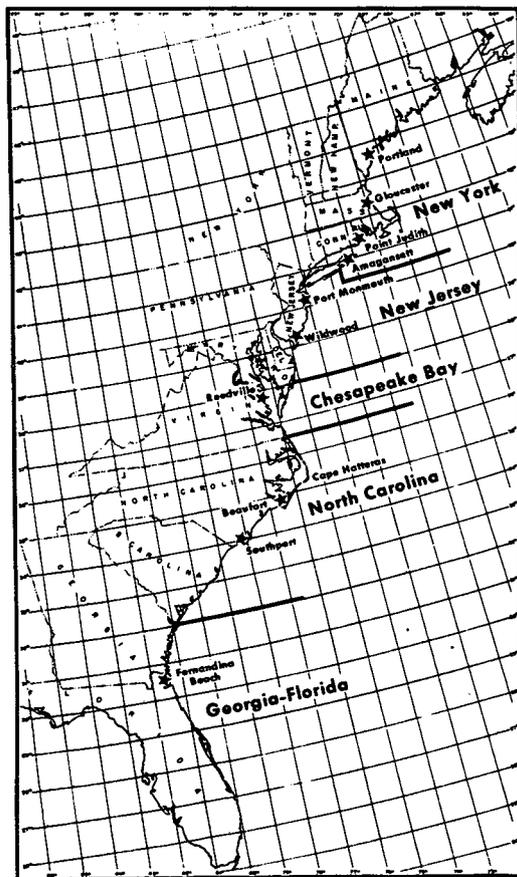


Fig. 1. Map of the Atlantic coast of United States showing locations of reduction plants and tagging areas.

fish of both ages tend to be smaller than those of the same age from areas farther north (Nicholson 1975). Fishing usually begins in April and may continue to late October or November. Two plants operated in 1967 and 1968 and one plant thereafter.

During the year of tagging, tags recovered at Florida plants far outnumbered those recovered at other locations (Table 1). The number decreased with increasing latitude, and only one, which could have been caught by a vessel from a Chesapeake Bay plant fishing in North Carolina waters, was recovered at a plant north of North Carolina.

In the year following tagging, relatively few tags were recovered at Florida plants while large numbers were recovered farther north at Southport, Beaufort, and Chesapeake Bay plants and small numbers at Wildwood and Port Monmouth.

In the second and succeeding years after tagging, relatively large numbers were recovered at plants in Chesapeake Bay, Wildwood, and Port Monmouth while relatively small numbers were taken at plants in Point Judith, R.I., and Gloucester, Mass., and in the North Carolina fall fishery. The small numbers taken at North Carolina and Florida plants during the summer were probably holdovers from previous years.

North Carolina Area

As in the Florida-Georgia area, the catch during the summer fishing season from May

to October is composed of age-1 and -2 fish. From early November until the fishery ends in late December or early January, fish of all ages are caught, including young of the year (juveniles) that are sometimes taken in large numbers near the end of the season. During the summer season two plants operated at Beaufort and one plant operated at Southport. Most of the fishing in the Beaufort area occurred in inside waters, while all of the fishing by Southport boats, which ranged as far south as Charleston, S.C., was in ocean waters. Fishing at Southport ended by late October. During the fall season (Nov.-Jan.) nearly all fishing was in ocean waters from about Cape Hatteras to New River Inlet. From 30 to 60 vessels operated from 5 plants.

During the year of tagging no recoveries were from south of the tagging area; 96% were from the N.C. area, mostly at Beaufort, and the remainder were from north of the area, mostly at Reedville, Va. (Table 2). Of the 4% recovered north of the tagging area, 3.3% were from fish tagged March-June, and 0.3% were from fish tagged July-September. None were from fish tagged after September. Fish tagged early in the season tended to move farther north than those tagged later in the season; tags were recovered at plants as far north as Amagansett, N.Y. for fish tagged March to June, but only as far north as Reedville, Va. for fish tagged July to September.

In the year following tagging, only 21% of the recoveries were from the North Carolina

TABLE 1. Number of tags recovered from 95,832 Atlantic menhaden tagged in 1967, 118,819 in 1968, and 108,150 in 1969, April-October, Florida-Georgia area, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered						
	0	1	2	3	4	5	6
Portland, ME	0	0	0	0	0	0	0
Gloucester, MA	0	0	0	0	0	0	0
Pt. Judith, RI	0	0	2	4	2	0	0
Amagansett, NY	0	0	0	^a	^a	^a	^a
Port Monmouth, NJ	0	83	83	104	34	4	1
Wildwood, NJ	0	68	12	^b	^b	^b	^b
Reedville, VA	1	2,237	706	172	15	1	0
Beaufort, NC							
Fall fishery	35	504	79	15	2	1	0
Summer fishery	111	1,530	7	0	0	0	0
Southport, NC	1,159	2,294	2	3	0	0	0
Fernandina Bch., FL	11,051	338	0	0	0	0	0

^a Plant did not operate in 1967 or after 1969.

^b Plant did not operate after 1969.

TABLE 2. Number of tags recovered from 151,348 adult Atlantic menhaden tagged in 1967, 109,120 in 1968, and 27,776 in 1969. March–December, North Carolina area, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered						
	0	1	2	3	4	5	6
Portland, ME	0	0	0	0	0	0	0
Gloucester, MA	0	0	0	10	2	0	0
Pt. Judith, RI	0	0	0	7	1	7	1
Amagansett, NY	1	135	81	^a	^a	^a	^a
Port Monmouth, NJ	18	480	189	115	86	26	6
Wildwood, NJ	17	320	64	^b	^b	^b	^b
Reedville, VA	1,346	3,820	677	200	75	17	6
Beaufort, NC							
Fall Fishery	10,693	1,665	353	32	17	6	0
Beaufort, NC							
Summer Fishery	21,069	959	6	0	0	0	0
Southport, NC	1,469	726	16	1	0	0	0
Fernandina Bch., FL	0	66	2	1	0	0	0

^a Plant did not operate in 1967 or after 1969.

^b Plant did not operate after 1969.

area during the summer fishery and 20% from the fall fishery, while 58% were from north of the tagging area, 47% at Chesapeake Bay plants, and 11% at New Jersey and New York plants. About 1% were recovered at plants south of the tagging area.

In the second and succeeding years after tagging, over 78% of the recoveries were from plants north of the tagging area as far north as Gloucester, Ma., and over 20% were from the N.C. fall fishery. The relatively few recovered during summer at plants in N.C. and Florida probably were from fish caught in previous years.

Chesapeake Bay Area

Although some age-3 and -4 fish are landed at Chesapeake Bay plants, particularly from pound net catches in April and May before the purse seine season begins, age-1 and -2 fish constitute the bulk of the catch. The age-1 and -2 fish are larger, on the average, than fish of the same age landed at Florida or North Carolina plants, but smaller than those landed at New Jersey plants. In some years large numbers of juveniles, or age-0, are landed in late summer or early fall. The purse seine fishery begins the last Monday in May and, for the years covered in this paper, generally ended by middle or late November.

During the year of tagging no returns were from south of Chesapeake Bay during summer; over 74% were from Chesapeake Bay plants, 1% were from plants north of the

tagging area as far north as N.Y., and over 24% were from the North Carolina fall fishery (Table 3). Of the 1% recovered at plants north of the Bay, 0.77% were from fish tagged April–June and 0.36% were from fish tagged July–September. None were from fish tagged after September.

In the year following tagging, 62% were recovered at Chesapeake Bay plants, 18% at plants north of the tagging area, and 20% in the N.C. fall fishery. None were recovered south of the tagging area during summer.

In the second and succeeding years following tagging, 40% of the recoveries were from plants north of the tagging area as far north as Portland, Maine, 50% were from Chesapeake Bay plants, and 10% were from the N.C. fall fishery. The percentage from north of the Bay probably would have been greater had not most plants either closed or reduced fishing after 1969. No tags were recovered in summer south of the Bay.

New Jersey Area

Most fish landed at New Jersey plants are age-2 and -3. Those older than age-3 are landed frequently at Port Monmouth but rarely at Wildwood. Age-2 fish tend to be larger than those landed at Chesapeake Bay plants. Fishing effort at Port Monmouth declined after 1965 and was particularly low in 1970–71. Effort at Wildwood became low and intermittent after 1965 and ceased entirely after the 1969 season. Most fish were tagged

near Port Monmouth, although some were tagged near Wildwood.

During the year of tagging, no tags were recovered from plants south of the area during summer except for six at Chesapeake Bay plants in 1968 (Table 4). These could have been caught by Chesapeake Bay vessels fishing in New Jersey waters. Nearly 73% were recovered at plants in New Jersey, 2% at the Amagansett, N.Y. plant, which operated only in 1968, and 25% during the N.C. fall fishery.

In the year following tagging, 66% of the recoveries were from plants in the New Jersey and New York areas, 19% were from Chesapeake Bay plants, and 15% were from the North Carolina fall fishery.

In the second and succeeding years following tagging, 54% were from Port Monmouth, the only plant operating in the New Jersey-New York region after 1969, 13% from Amagansett, and 5% from Wildwood. Over 8% were recovered during the N.C. fall fishery, nearly 19% at Chesapeake Bay plants during the summer fishery, and 1% at New England plants.

New York Area

Fish landed at plants in the New York and New England area are mostly age-3 or older. By the time fish were first tagged in 1967, the catch was less than 5% of what it had been

TABLE 3. Number of tags recovered from 100,128 Atlantic menhaden tagged in 1967, 132,596 in 1968, and 75,581 in 1969, April-October, Chesapeake Bay area, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered						
	0	1	2	3	4	5	6
Portland, ME	0	0	0	0	0	1	0
Gloucester, MA	0	0	6	1	9	0	4
Pt. Judith, RI	0	0	53	26	31	18	0
Amagansett, NY	4	428	215	^a	^a	^a	^a
Port Monmouth, NJ	263	2,370	1,096	644	299	70	11
Wildwood, NJ	227	615	154	^b	^b	^b	^b
Reedville, VA	30,350	11,854	2,270	784	203	63	23
Beaufort, NC							
Summer Fishery	0	0	0	0	0	0	0
Beaufort, NC							
Fall Fishery	9,920	3,961	607	69	12	3	1
Southport, NC	0	0	0	0	0	0	0
Fernandina Bch., FL	0	0	0	0	0	0	0

^a Plant did not operate in 1967 or after 1969.

^b Plant did not operate after 1969.

TABLE 4. Number of tags recovered from 13,660 Atlantic menhaden tagged in 1967 and 21,458 in 1968, June-October, New Jersey area, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered						
	0	1	2	3	4	5	6
Portland, ME	0	0	0	0	0	0	0
Gloucester, MA	0	0	0	0	0	0	0
Pt. Judith, RI	0	0	0	0	0	2	0
Amagansett, NY	125	149	25	^a	^a	^a	^a
Port Monmouth, NJ	4,563	435	61	34	8	3	0
Wildwood, NJ	299	112	9	^b	^b	^b	^b
Reedville, VA	6	196	22	12	1	2	0
Beaufort, NC							
Summer Fishery	0	0	0	0	0	0	0
Beaufort, NC							
Fall Fishery	1,672	160	15	1	1	0	0
Southport, NC	0	0	0	0	0	0	0
Fernandina Bch., FL	0	0	0	0	0	0	0

^a Plant did not operate in 1967 or after 1969.

^b Plant did not operate after 1969.

TABLE 5. Number of tags recovered from 2,093 Atlantic menhaden tagged in 1967, 2,370 in 1968, and 8,468 in 1969, April-August, New York area, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered						
	0	1	2	3	4	5	6
Portland, ME	0	0	0	0	0	0	0
Gloucester, MA	0	0	2	0	0	0	0
Pt. Judith, RI	0	0	24	1	11	0	0
Amagansett, NY	1,407	155	24	^a	^a	^a	^a
Port Monmouth, NJ	613	149	190	59	18	2	0
Wildwood, NJ	0	0	1	^b	^b	^b	^b
Reedville, VA	0	0	0	0	0	0	0
Beaufort, NC							
Fall Fishery	381	40	29	4	0	0	0
Beaufort, NC							
Summer Fishery	0	0	0	0	0	0	0
Southport, NC	0	0	0	0	0	0	0
Fernandina Bch., FL	0	0	0	0	0	0	0

^a Plant did not operate in 1967 or after 1969.

^b Plant did not operate after 1969.

TABLE 6. Number of tags recovered from 4,053 juvenile Atlantic menhaden tagged in the Florida-Georgia area, September-October, 1970-71, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered					Total
	0	1	2	3	4	
Port Monmouth, NJ	0	0	6	7	0	13
Reedville, VA	0	23	34	4	1	62
Beaufort, NC	0	61	4	0	0	65
Southport, NC	0	155	5	0	0	160
Fernandina Bch., FL	0	55	1	0	0	56
Total	0	294	50	11	1	356

prior to 1963. The only major plant in the New York area, at Amagansett, did not operate in 1967 and closed permanently after the 1969 season. Plants in New England, which processed few menhaden from 1964 to 1969, began processing increased catches in 1970, and thereafter accounted for all menhaden processed north of the New Jersey area. Most fish were tagged in Long Island Sound.

In the year of tagging, tags were recovered only at Amagansett, N.Y., Port Monmouth, N.J., and Beaufort, N.C., during the fall fishery (Table 5). Most (59%) were recovered at Amagansett. None were recovered south of Port Monmouth during the summer.

In the year following tagging, 88% of the returns were from Port Monmouth and Amagansett, while 12% were from the N.C. fall fishery.

In the second and succeeding years after tagging, tags were recovered from the same plants as in previous years, plus some recov-

eries from New England plants, principally from fish tagged in 1969.

JUVENILE TAGGING

By late September or early October menhaden that had been spawned the previous winter are preparing to leave the estuaries. Their length, depending on when they were spawned and the area of the coast in which they were reared, ranges from about 55 to 140 mm. Most are between about 75 and 110 mm. Because fish in this size range usually die if marked with the large adult tags, they were marked with a specially developed small juvenile tag. All tagging was done from October to January.

During the season of tagging, juveniles tagged in the New York, New Jersey, and Chesapeake Bay areas were recovered at Beaufort plants during the North Carolina fall fishery and at Chesapeake Bay plants, which operated until mid-December (Tables 6-10). Fish tagged in the North Carolina area

were recovered only at North Carolina plants. No fish tagged in the Florida-Georgia area were recovered.

In the year following tagging, when fish were age-1, tags from fish in all areas were recovered at plants from Florida to Port Monmouth, although only one tag was recovered at Port Monmouth—from a fish tagged in the

North Carolina area. The majority of tags recovered at the Reedville plants were of fish tagged in the New York, New Jersey and Chesapeake Bay areas. Most tags recovered at the Beaufort, Southport and Fernandina Beach plants were of fish tagged in the North Carolina and Florida areas.

In the second year after tagging when fish

TABLE 7. Number of tags recovered from 22,851 juvenile Atlantic menhaden, tagged in the North Carolina area in September–October, 1970–73, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered					Total
	0	1	2	3	4	
Port Monmouth, NJ	0	1	15	8	1	25
Reedville, VA	0	79	106	16	0	201
Beaufort, NC	107	171	70	6	1	355
Southport, NC	0	498	80	8	0	586
Fernandina Bch., FL	0	114	8	3	0	125
Total	107	863	279	41	2	1,292

TABLE 8. Number of tags recovered from 7,300 juvenile Atlantic menhaden tagged in the Chesapeake Bay area in September–October, 1970–73, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered					Total
	0	1	2	3	4	
Port Monmouth, NJ	0	0	10	1	1	12
Reedville, VA	53	202	146	16	1	418
Beaufort, NC	43	34	21	0	1	99
Southport, NC	0	69	16	1	0	86
Fernandina Bch., FL	0	47	1	1	0	49
Total	96	352	194	19	3	664

TABLE 9. Number of tags recovered from 23,573 juvenile Atlantic menhaden tagged in the New Jersey area in September–October, 1970–73, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered					Total
	0	1	2	3	4	
Port Monmouth, NJ	0	0	20	26	3	49
Reedville, VA	145	247	236	43	1	672
Beaufort, NC	149	89	52	10	0	300
Southport, NC	0	155	67	5	0	227
Fernandina Bch., FL	0	186	9	0	0	195
Total	294	677	384	84	4	1,443

TABLE 10. Number of tags recovered from 28,022 juvenile Atlantic menhaden, tagged in the New York area in September–October, 1969–73, by port and year of recovery (year 0 = year of tagging).

Port	Year Recovered					Total
	0	1	2	3	4	
Port Monmouth, NJ	0	0	8	6	0	14
Reedville, VA	1	91	61	4	1	158
Beaufort, NC	4	21	4	0	0	29
Southport, NC	0	11	4	0	0	15
Fernandina Bch., FL	0	3	0	0	0	3
Total	5	126	77	10	1	219

were age-2, 2% of the returns were from Florida plants, 33% from North Carolina, 59% from Virginia, and 2% from New Jersey.

In the third and fourth years after tagging, most tags were recovered at Reedville and Port Monmouth. Those recovered at Fernandina and Southport probably had been retained from previous seasons.

Discussion and Conclusions

There can be little doubt that Atlantic menhaden constitute a single population that intermixes during the winter in ocean waters south of Cape Hatteras, N.C. Juveniles from each area were subsequently recaptured at age-1 only in the Chesapeake Bay, North Carolina, and Florida plants. As the fish aged, the number recaptured decreased in the more southern plants and increased in the more northern plants. Adults tagged in the Florida-Georgia and North Carolina area were recovered in subsequent years at plants in Chesapeake Bay, New Jersey, New York, and New England, but were not recaptured after 2 years at plants in N.C. or Florida except during the fall fishery; adults tagged in the Chesapeake Bay area were recovered at plants in New Jersey, New York, and New England; adults tagged in the New Jersey area were recovered at plants in Chesapeake Bay, New Jersey, New York, and New England; and adults tagged in the New York area were recovered at plants in New Jersey, New York, and New England. Most significantly, adults from all areas were recovered in the year of release and in subsequent years during the North Carolina fall fishery.

Tag returns also confirm that Atlantic menhaden stratify along the coast by age and size during late spring and summer. Fish tagged as juveniles, regardless of location, were rarely recovered after 2 years at plants south of Cape Hatteras or before 2 years at plants north of Chesapeake Bay, or seldom after age-1 at Florida plants, where nearly all of the fish in catch samples are age-1. Adults tagged south of Cape Hatteras were rarely recovered at plants in that area after 2 years, but were recovered in substantial numbers after two years at plants from Chesapeake Bay northward. Adults tagged in the Chesapeake Bay area were never recovered during the summer season at plants south of

Chesapeake Bay, but were recovered at plants north of the Bay. Adults tagged in the New Jersey area were rarely recovered, and adults tagged in the New York area were never recovered at plants south of Port Monmouth, N.J. The longer a fish had been tagged, the farther north it was likely to be recaptured.

Recoveries of both adult and juvenile tags confirmed the existence of a southward movement along the coast during the fall. Juveniles from New York, New Jersey, and Chesapeake Bay areas were recovered in the North Carolina fall fishery during the season of release, and in the following year at N.C. and Fla. plants. Adults tagged in the Chesapeake Bay, New Jersey, and New York areas were recovered during the year of release and in subsequent years in the North Carolina fall fishery.

Dispersal from the area south of Cape Hatteras and movement northward along the coast in late winter and spring was confirmed by the recovery of tags at Chesapeake Bay and New Jersey plants during the year of release of fish tagged in the North Carolina area in late winter and spring. It also was confirmed, indirectly, by fish tagged north of Cape Hatteras being recovered at N.C. plants during fall and not being recovered at these plants the subsequent summer. Movement of fish northward from south of Cape Hatteras probably ceased sometime in June, since almost no fish tagged in the North Carolina area after June were recovered during the year of release at Chesapeake Bay or New Jersey plants.

Tags recovered during the release year show that some fish from Chesapeake Bay northward continue moving northward during the summer. Fish tagged in the New Jersey area were recovered at a plant in the New York area. Fish tagged in Chesapeake Bay before September were recovered at New Jersey and New York plants. The majority of the returns probably were of age-2 and -3 fish, since fish of these ages decrease in Chesapeake Bay catches as the summer progresses, and age-1 fish are seldom landed at New Jersey plants.

Within the region south of Cape Hatteras, there appears to be little movement north or south from about June to November. No fish tagged in the North Carolina area were re-

covered at plants in Florida during the year of release. Some of the fish tagged in the Florida-Georgia area were recovered at North Carolina plants during the release year, but the number was not large and most were of fish tagged in April or May. Also most recoveries were at the Southport plant, whose vessels often ranged southward close to the tagging area.

Tag returns also point out the dependence of fisheries from New Jersey northward on the escapement of age-1 and -2 fish from the South Atlantic and Chesapeake Bay areas. Only one fish tagged as a juvenile was recovered at Port Monmouth at age-1, but many were recovered at age-2 or older. Few adults tagged in the Florida-Georgia and North Carolina areas were recovered north of Chesapeake Bay in the year of tagging, but relatively large numbers were recovered in subsequent years. Some adults tagged in Chesapeake Bay were recovered at New Jersey and New York plants during the same year they were tagged, but a much greater number were recovered in subsequent years. Since few age-1 fish are caught from New Jersey northward, the age-2 and older fish that are caught must have spent their first year in the South Atlantic or Chesapeake Bay areas. Since almost no fish older than age-2 are caught in the South Atlantic and few are caught in Chesapeake Bay, the fish in these areas at age-2 must be the same ones that eventually occur at older ages from New Jersey northward.

Management regulations designed to sustain the catch of Atlantic menhaden at a level considerably higher than has occurred over the past decade must take into account, among other things, population structure, movements, and seasonal distribution. Recoveries of tagged fish confirm that Atlantic menhaden constitute a single population, that they are segregated by age and size during the fishing season, and that their abundance in northern waters is dependent not only on

overall population abundance, but also on escapement of one- and two-year-old fish from more southern waters.

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