Biology and Fishery for Atlantic Thread Herring, *Opisthonema oglinum*, along the North Carolina Coast

JOSEPH W. SMITH

Introduction

Thread herrings, *Opisthonema* spp., are small, nearshore, pelagic clupeid fishes that form dense, surface schools in tropical to subtropical coastal waters. Ecologically, thread herrings form an important forage base for many large, predatory fishes (Finucane and Vaught, 1986). Commercially, thread herrings are targeted by artisanal to moderate-sized seine fisheries off the coasts of Ecuador and Peru (Patterson and Santos, 1992), Costa Rica (Stevenson and Carranza, 1981), Venezuela, the continental margins of the Caribbean, the Gulf of Mexico, and near the islands of Cuba, Hispaniola, Puerto Rico, Jamaica, and Trinidad (Reintjes, 1978). Most of the catch is reduced to fish meal and fish oil (Patterson and Santos, 1992), although minor quantities are used for human consumption (Reintjes, 1978).

Along the northern Gulf of Mexico and southeastern Atlantic coasts of the United States, the Atlantic thread herring, *O. oglinum* (Fig. 1), is mainly harvested with purse seines. Directed fisheries for Atlantic thread herring (and other coastal herrings) in the northern Gulf of Mexico are concentrated along the northwestern coast of Florida where most of the catch is sold as bait or processed into pet food (Finucane and Vaught, 1986). Purse seine vessels of the Gulf menhaden, *Brevoortia patronus*, reduction fishery, centered off the coasts of Mississippi and Louisiana (Smith, 1991), catch minor quantities of *O. oglinum* during the summer while searching for Gulf menhaden (Reintjes, 1980). Studies in the Gulf report that Atlantic thread herring prefer "bluer" water, higher salinities, and higher water temperatures than menhaden (Finucane and Vaught, 1986). Additionally, schools of Atlantic thread herring are exceptionally fast and agile (Butler, 1961) and are more difficult to catch in purse seines than menhaden (Kinnear and Fuss, 1971).

On the U.S. east coast, Atlantic thread herring range from Florida to Cape Cod (Bigelow and Schroeder, 1953; Robins et al., 1986), although they are "not numerous" north of North Carolina (Hildebrand, 1963). During summer along the southeastern U.S. Atlantic coast, they are distributed ubiquitously in coastal waters from North Carolina to northern Florida to depths of about 9 m, while they concentrate off Georgia and north Florida during spring, fall, and winter (Wenner and Sedberry, 1989). Although small amounts of Atlantic thread herring are harvested off the east coast of Florida for bait (USDOC, 1984; Smillie, 1994), at present, commercial landings of Atlantic thread herring for reduction to fish meal and fish oil are restricted to coastal waters between Cape Hatteras and Cape Fear, N.C., during late summer and fall (personal observ.).

Pristas and Cheek (1973) recognized the significance of these autumnal schools as a supplement to the extant Atlantic menhaden, *B. tyrannus*, reduction fishery (Smith, 1991), and devised a tagging study to determine the distribution and movement of *O. oglinum* off the U.S. southeastern Atlantic coast. Internal ferromagnetic tags were in-

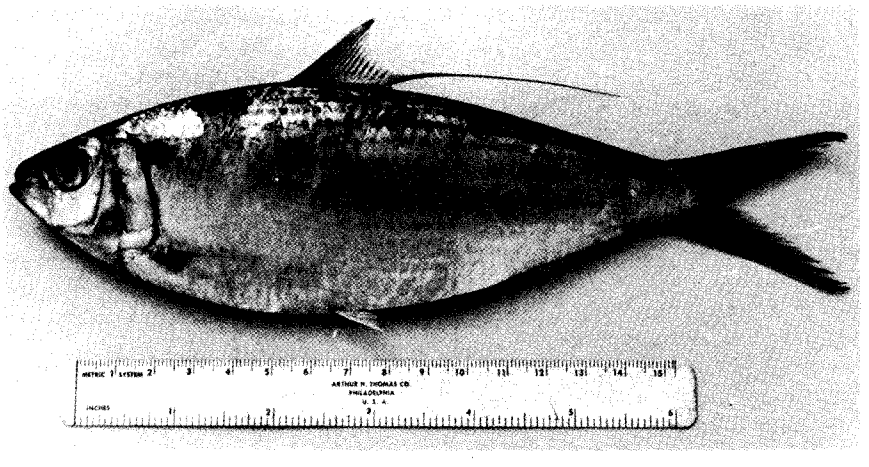

Figure 1. — Atlantic thread herring, *Opisthonema oglinum*.

Joseph W. Smith is with the Beaufort Laboratory, National Marine Fisheries Service, NOAA, Southeast Fisheries Science Center, 101 Pivers Island Road, Beaufort, NC 28516-9722.

jected into nearly 1,600 Atlantic thread herring off the North Carolina coast. Tag recoveries (from magnets at menhaden reduction facilities in North Carolina and Florida) indicated that schools of *O. oglinum* migrate south along the southeastern U.S. Atlantic coast during fall at up to 11 km per day.

The Atlantic thread herring resource, especially the stock in the eastern Gulf of Mexico (Houde, 1976), has been extolled as a latent resource and an alternative to menhaden for a reduction fishery (Bullis and Carpenter, 1968). Pristas and Cheek (1973) estimated that the population size off the southeastern U.S. Atlantic coast could vary between 22,000 and 92,000 metric tons (t). Objectives of this study were to 1) describe the purse seine reduction fishery for Atlantic thread herring in North Carolina and 2) determine the size, age composition, and reproductive condition of the catch.

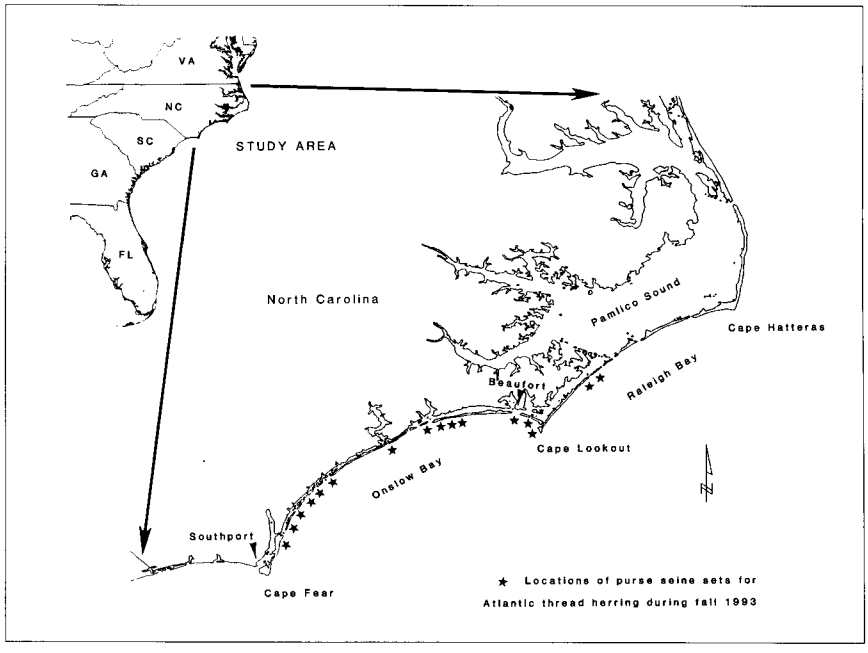

Figure 2. — Study area: Raleigh and Onslow bays, N.C. Stars indicate sites of purse seine sets for Atlantic thread herring, *O. oglinum*, during fall 1993; set locations exaggerated offshore for illustrative clarity.

Biology of the Atlantic Thread Herring

Sampling

Atlantic thread herring were collected from purse seine catches unloaded for reduction at Beaufort, N.C. (Fig. 2), between 1985 and 1990. Sampling routines for menhaden (Smith et al., 1987) were followed with minor adjustments. Briefly, a port agent acquired a bucket of fish from a purse seine vessel at dockside. Fish on top of the hold were assumed to be from the last purse seine set of the day. Date and location of the set were determined from a crew member.

At the laboratory, up to 50 Atlantic thread herring were randomly chosen from the bucket. Each fish was measured for total (TL), fork (FL), and standard (SL) length and weighed to the nearest gram; subsequent text references to length are fork lengths. From the first 25 fish measured, a patch of scales (from the midline below the dorsal fin) and the sagittal otoliths were removed and stored in labelled envelopes; each fish was sexed and macroscopically staged for maturity following Waltz et al. (1979). A few gonadal samples were prepared using standard histological techniques (Humason, 1972) to confirm gonad staging in the field. In 1988 juvenile Atlantic thread herring were collected with a cast net from the Newport River estuary, about 4 km from Beaufort Inlet (Fig. 2); these fish were processed similar to the purse seine samples.

Seasonality and Age/Size Composition

Twenty-one biological samples were collected from purse seine sets that directly targeted schools of Atlantic thread herring. A total of 12 samples were acquired in September (n=473 fish), 7 samples in October (n=175), and one each in June (n=50) and July (n=50). Specimens ranged from 125 to 200 mm and from 30 to 140 g. Length-length and length-weight relationships are shown in Table 1. Mean size of Atlantic thread herring in the samples increased across months sampled: 146 mm and 50 g in June, 154 mm and 62 g in July, 166 mm and 85 g in September, and 172 mm and 93 g in October. Specimens taken by cast nets near the laboratory from June through September ranged from 62 to 118 mm ($\bar{x}$ = 77 mm) and 3 to 27 g ($\bar{x}$ = 7 g). Juvenile Atlantic thread herring disappeared from this estuarine site by October.

Atlantic thread herring scales were projected on a macroprojector and were

Table 1.—Length-weight and length-length relationships (natural logs and functional regressions, Ricker, 1973) for Atlantic thread herring from North Carolina. *W* is weight in grams; FL, TL, and SL are fork, total, and standard lengths, respectively, in millimeters; I is immature fish; MSE is mean squared error.

Functional equation	Sex	No.	r^2	MSE	Size range (mm FL)
log *W* = -13.2 + 3.4 log FL	♂	179	0.93	0.0056	125–190
log *W* = -13.1 + 3.4 log FL	♀	297	0.94	0.0047	136–200
log *W* = -12.6 + 3.4 log FL	♂+♀+I	879	0.99	0.0068	62–200
TL = -0.5 + 1.2 FL	♂	179	0.98		125–190
TL = -3.9 + 1.2 FL	♀	297	0.98		136–200
TL = 4.0 + 1.2 FL	♂+♀+I	879	0.99		62–200
SL = 0.1 + 0.9 FL	♂	179	0.97		125–190
SL = -3.1 + 1.0 FL	♀	297	0.97		136–200
SL = -4.5 + 1.0 FL	♂+♀+I	879	0.97		62–200

scrutinized for annular rings using criteria developed for Atlantic menhaden (June and Roithmayr, 1960). Whole sagittal otoliths were embedded in black, opaque well plates (Pentilla et al., 1988) with a microscopy fixative and viewed under a dissecting macroscope with reflected light at 16× magnification (Fig. 3). Sagittae of Atlantic thread herring were nearly identical to sagittae of Atlantic herring, *Clupea harengus*, with narrow translucent zones adjacent wide opaque zones (Fig. 3), as documented in the latter species (Dery, 1988). I counted translucent zones in the posterior field of the sagitta as presumed annuli. Sagittae were "read" twice. Where discrepancies in the two readings occurred, the specimens were eliminated from further age analyses.

Mean fork length of Atlantic thread herring increased with increasing age estimates (Table 2); the oldest Atlantic thread herring was estimated at age 8. Modal age for the purse seine samples was age 1 (33.2%), followed by age 2 (30.4%) and age 3 (22.0%); 85.4% of the fish aged from purse seine samples were ages 1 to 3 (Fig. 4). Nearly all fish taken by cast net (91 of 92 fish, 98.9%) were young-of-year (age 0), except one specimen that was age 1. Paired age estimates, that is, otolith and scale ages, were only available for 46 specimens; 80.4% or 37 of 46 otolith:scale pairings were in agreement.

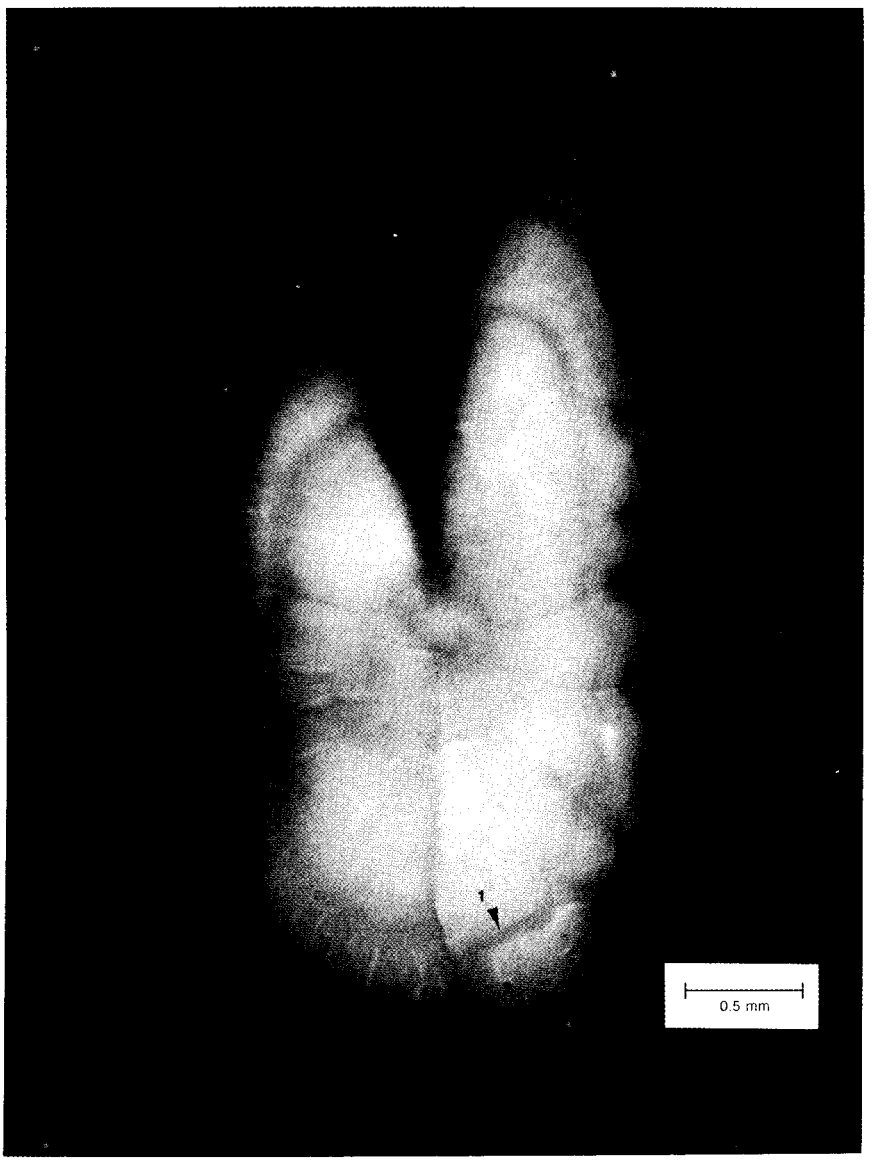

Figure 3. — Sagittal otolith from an Atlantic thread herring, age 2, 179 mm FL.

Reproduction

Paired determinations of sex using macroscopic and histologic observations agreed for 34 of 35 comparisons. The sex ratio of pooled purse seine samples was skewed toward females (♂ : ♀, 179:299). In June, 14 of 15 males from the purse seine sample were ripe. Also in June, ovaries from three females indicated recent spawning; post-ovulatory follicles were present with a large number of oocytes in various stages of atresia. Individuals of both sexes taken in September and October were staged as resting.

Description of the Fishery

In recent years Beaufort, N.C., has been the only port along the U.S. Atlantic coast where *O. oglinum* were harvested for reduction by a directed purse seine fishery. Locally the fish are called "hairy backs" because of the elongated last ray of the dorsal fin. Historical landings of Atlantic thread herring in North Carolina were often significant and occurred at a time when seasonal abundance of Atlantic menhaden during late summer had ebbed. During the 1960's and 1970's, reduction factories in Southport, N.C. (near Cape Fear), also processed Atlantic thread herring, but these plants closed by 1984. Landings of Atlantic thread herring for reduction in North Carolina since 1965 have fluctuated widely (Fig. 5), but averaged about 1.9 million kg annually between 1965 and 1994; record landings of 9.7 million kg occurred in 1972. Since 1986 only one reduction factory in Beaufort has operated, employing 2-3 purse seine vessels. Sparse landings during the late 1980's were attributable to low fish meal prices and consequently, reduced purse seining activity from the port of Beaufort.

In general, purse seine sets on Atlantic thread herring were made in the Atlantic Ocean within a few kilometers of

shore and in depths to 18 m between Cape Lookout and Cape Fear, N.C. From 1983 to 1993 most sets on Atlantic thread herring by vessels from Beaufort occurred between 2 September and 14 October. Two noteworthy sets occurred near Cape Hatteras, one in July 1986 and the other in June 1990.

Several aircraft spotter pilots and captains of purse seine vessels from North Carolina related that schools of Atlantic thread herring were rarely encountered during summer in the state's coastal waters (personal observ.). Occasionally, schools were sighted in the ocean along Virginia's Eastern Shore and in the vicinity of Cape Henry, Virginia, in late August. In general, large, fishable schools of Atlantic thread herring arrived in nearshore waters adjacent to Cape Lookout, N.C. (Fig. 2), in early September. Purse seine vessels from Beaufort harvested Atlantic thread herring during September, as the schools moved south and west along the coast toward Cape Fear, N.C. During most years, the purse seiners stopped pursuing the fish once they moved south of Cape Fear, which was usually by early to mid-October.

During September and October, catches of Atlantic thread herring supplement landings at the fish reduction plant in Beaufort at a time when the abundance of Atlantic menhaden in the vicinity has waned, and prior to the fall migration (mid to late October) of Atlantic menhaden from areas farther north (Smith et al., 1987). During fall, the visceral cavity of Atlantic thread herring is heavily lined with fat deposits. Accordingly, yields of fish oil from Atlantic thread herring in the fall are exceptional, averaging 9–10 U.S. gallons of fish oil per 670 pounds of fish (the menhaden industry's unit of measure; Smith, 1991), while yields of 15–16 gallons are common. By comparison, fish oil yields from Atlantic menhaden during late summer in the U.S. southeastern Atlantic average less than 2–3 U.S. gallons per 670 pounds of fish (personal observ.).

Menhaden vessel captains keep daily purse seining activity logs (Captain's Daily Fishing Reports, or CDFR's; Smith, 1991) that tabulate individual purse seine sets by location and distance from shore, and provide an at-sea estimate of the quantity of each purse seine catch. I examined CDFR's from two North Carolina vessels that logged data for sets on Atlantic thread herring during September and October 1993. I assumed that each purse seine set was made on only one school of Atlantic thread herring. Although captains are adept at judging the quantity of fish in each catch, individual at-sea catch estimates were adjusted slightly and converted to metric tons based on daily amounts offloaded at the fish plant (from company records). The mean weight of individual Atlantic thread herring in 1993 port samples was used to estimate numbers of fish caught per set.

CDFR data documented 48 successful purse seine sets on Atlantic thread herring schools by two North Carolina vessels between 28 September-14 October 1993. Sets were distributed from Core Banks near Cape Lookout to Wrightsville Beach near Cape Fear and from 0.4 to 2.4 km from shore (Fig. 2). Individual catch estimates ranged from 5.8 to 204.2 t, and the mean catch was 55.9 t. Mean weight of individual Atlantic thread herring in 1993 port samples was 85 g; thus, a school of av-

Table 2.—Mean size at estimated age for Atlantic thread herring from North Carolina. Values from the literature shown for comparison.

Est. age (yr)	Present Study[1] FL (mm) Mean	FL (mm) Range	Weight (g) Mean	Weight (g) No.	Houde et al. (1983)[1] mean FL (mm)	Fuss et al. (1969)[2] mean FL (mm)
0[3]	76	64–98	7	91		
1[4]	155	135–183	64	93	108.2	146
2	172	154–190	91	85	152.4	149
3	178	163–196	102	63	171.0	148
4	180	168–193	109	25	179.5	
5	183	171–190	114	8	186.8	
6	180	171–185	114	7	202.7	
7	186		108	1		
8	175		101	1		

[1] Aged using sagittal otoliths.
[2] Aged using scales.
[3] Specimens collected by cast net.
[4] Specimens age 1–8 collected from purse seines.

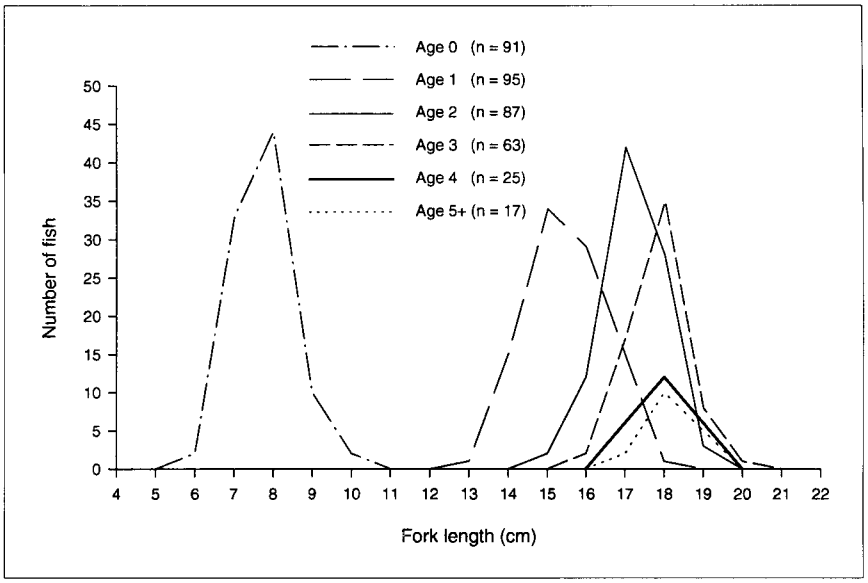

Figure 4. — Fork length frequency distributions of Atlantic thread herring by age from cast nets (age 0 fish) and purse seines (age 1–5+ fish).

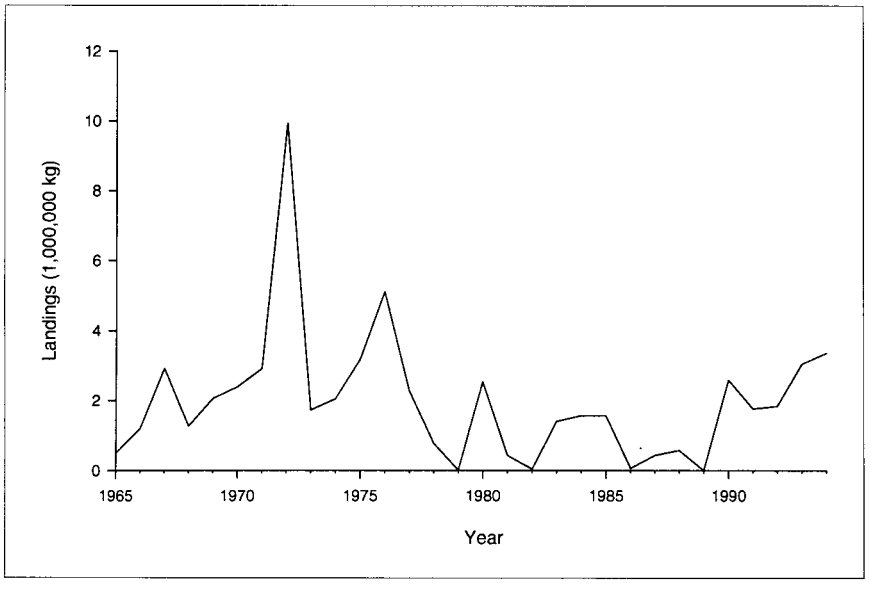

Figure 5. — Purse seine landings of Atlantic thread herring for reduction in North Carolina, 1965–94.

erage size was estimated to contain 657,650 fish, while extreme sets during 1993 were estimated to contain 68,250 to 2,402,350 fish.

Discussion

An autumnal migration of adult Atlantic thread herring along the southeastern U.S Atlantic coast begins in the nearshore ocean waters of Raleigh and Onslow bays in the vicinity of Cape Lookout, N.C. Purse seine vessels from Beaufort, N.C., opportunistically harvest Atlantic thread herring for reduction from September to mid-October in the vicinity of Cape Lookout to Cape Fear. On average, migrating schools consisted of about 56 t of fish each, and ranged up to 204 t. Proximate analyses have shown that the protein content of Atlantic thread herring (20.65%; Hale, 1984) is slightly higher than Atlantic menhaden (14.50-17.02%; Dubrow et al., 1976), and fish oil yields from Atlantic thread herring in the fall are exceptional. Together both factors contribute substantially to fish factory production at a time when local abundance of Atlantic menhaden has temporarily waned. By mid-October, schools of *O. oglinum* migrated south of Cape Fear, N.C., and were unavailable to the purse seine vessels from Beaufort. Results of tagging studies (Pristas and Cheek, 1973) and coastal trawl surveys (Wenner and Sedberry, 1989) suggest *O. oglinum* overwinter off northern Florida.

Commercially exploitable schools of Atlantic thread herring are apparently not available in coastal waters (<3 miles from shore) north of Cape Hatteras. Presumably, the menhaden purse seine fleet from Virginia, with up to 20 vessels collectively making 7,000–9,000 sets per year in coastal waters of the Mid-Atlantic states (unpubl. data), would have occasional encounters with schools of Atlantic thread herring. Instead, catches of Atlantic thread herring by Virginia vessels are rare, especially in Chesapeake Bay (personal observ.), except as by-catch (Austin et al., 1994).

Relative to ageing Atlantic thread herring, agreement was good for paired age estimates using scale:otolith pairs, but the sample size was small. Scales of Atlantic thread herring are highly deciduous. After the catch was pumped from the purse seine into the hold of the carrying vessel, key scales from the midline below the dorsal fin on sampled fish were difficult to find. Specimens were often naked or contaminated with scales from other fish. Sagittal otoliths are, therefore, a more reliable tool for ageing Atlantic thread herring.

Owing to the brief time when Atlantic thread herring were available in purse seine catches, I was unable to properly validate sagittae as ageing structures for Atlantic thread herring. Nevertheless, Houde et al. (1983) judged the "alternating hyaline and opaque zones" on sagittae of *O. oglinum* from the west coast of Florida to be annual marks, while Arce and Sanchez (1991) used otoliths to age *O. oglinum* from Yucatan, Mexico.

Similar to the results of Houde et al. (1983), I found that the mean size of *O. oglinum* increased with estimated age, and that age 1 was the modal age group in the samples. Estimates of mean size at age 1 and 2 (155 and 172 mm, respectively) for fish from North Carolina were considerably larger than for specimens from the Gulf of Mexico (108.2 mm at age 1 and 152.4 mm at age 2; Houde et al., 1983), although results of both studies were in closer agreement for age 3 (Table 2). Using scales, Fuss et al. (1969) tentatively estimated that age 1 fish along the west coast of Florida averaged 146 mm FL, which is in close agreement with this study. Atlantic thread herring are moderately long-lived, and I estimated the age of two fish at ages 7 and 8. Houde et al. (1983) aged fish up to age 6, and Arce and Sanchez (1991) reported fish of age 8 in their samples.

Based on the gonads of adult fish, Hildebrand (1963) determined that Atlantic thread herring spawned off North Carolina in May and June, whereas, spawning in the eastern Gulf of Mexico was protracted from April through September (Houde, 1977). I collected recently spent female *O. oglinum* from a purse seine set near Cape Hatteras in early June; this tends to confirm spawning in spring off North Carolina. Later in the year, the gonads of adults collected in autumn were resting, which suggests that the fall migration south along the southeastern U.S. Atlantic coast is for the purpose of overwintering (Pristas and Cheek, 1973; Wenner and Sedberry, 1989).

Otolith analyses indicated that *O. oglinum* taken by cast nets in the vicinity of Beaufort during summer were almost exclusively young-of-the-year;

average size was 76 mm. From "a few measurements" in the Beaufort area, Hildebrand (1963) surmised that Atlantic thread herring attained a length of 35–60 mm at age 1 and 90–120 mm by the end of their second summer. Wenner and Sedberry (1989) probably portrayed a more accurate description of the growth of *O. oglinum* through age 1, based on modal distributions of fish collected during a quarterly trawl survey in coastal waters (to 9.1 m deep) from Cape Fear to Cape Canaveral. They suspected that fish 4–6 cm FL during summer were young-of-year; this group grew to a modal size of 8 cm FL by fall and winter. During the following spring age-1 fish ranged from 9 to 13 cm FL and age-2 fish ranged from 13 to 16 cm FL.

As Atlantic thread herring migrate south along the southeastern U.S. Atlantic coast in fall, they represent an abundant forage species for several coastal pelagic fishes. DeVane (1978) found Atlantic thread herring in 28% of the king mackerel, *Scomberomorus cavalla*, stomachs that he sampled in Onslow Bay, N.C. Studies along other areas of the U.S. coast have identified *O. oglinum* in the diets of bluefish, *Pomatomus saltatrix* (Wilk, 1977; Naughton and Saloman, 1984); crevalle jack, *Caranx hippos* (Saloman and Naughton, 1984); and Spanish mackerel, *S. maculatus* (Klima, 1959). When juvenile Atlantic thread herring leave estuarine waters along the central North Carolina coast in fall, bluefish and Spanish mackerel voraciously feed upon them in ocean inlet areas (personal observ.).

During the 1950's up to nine menhaden reduction plants in the southeastern Atlantic states were located at Morehead City, Beaufort, and Southport, N.C.; Younges Island, S.C.; and Fernandina Beach, Fla. (Vaughan and Smith, 1988); most of these plants probably processed *O. oglinum* during the fall fishing season. Only the Beaufort plant remains today, although factories in Southport and Fernandina Beach survived until the mid-1980's. Coastal U.S. regions are experiencing unprecedented population growth and waterfront properties have become more valuable for resort, marina, and condominium development, rather than traditional uses such as boat yards and fish houses (Houlahan, 1987). In this developmental climate, it would be exceptionally difficult to site a fish reduction plant in the coastal Carolinas, Georgia, or north Florida. Moreover, South Carolina prohibits purse seining within its state territorial sea. Thus, further exploitation of Atlantic thread herring along the southeastern U.S. Atlantic coast, beyond the reduction fishery in Beaufort during September and October, would presumably and necessarily be seasonal, and in the form of modest operations for bait whose catch could be utilized in crab and crayfish trap fisheries, or as bait and chum for hook-and-line fisheries.

Acknowledgments

The author wishes to thank Neil McNeil and Pat Raves for their assistance in acquiring port samples. Dean Ahrenholz, James Waters, and Douglas Vaughan provided critical reviews of initial drafts. William Roumillat graciously processed histological samples. Jule Wheatly and Captains Bobby Martin and Elwood Willis of Beaufort Fisheries, Inc., generously shared their knowledge of the fishery for Atlantic thread herring.

Literature Cited

Arce, M., and J. Sanchez. 1991. Growth and mortality of the thread herring, (*Opisthonema oglinum* Le Sueur) from Celestun, Yucatan, Mexico (abstr.). Am. Fish. Soc. 121st Meet., San Antonio, Tex., p. 56.

Austin, H., J. E. Kirkley, and J. Lucy. 1994. By-catch and the fishery for Atlantic menhaden, *Brevoortia tyrannus*, in the Mid-Atlantic Bight: An assessment of the nature and extent of by-catch. Va. Sea Grant Mar. Resour. Advis. 53, 39 p.

Bigelow, H. B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. 53: 1–577.

Bullis, H. R., and J. S. Carpenter. 1968. Latent fishery resources of the central west Atlantic region. *In* The future of the fishing industry of the United States, p. 61–64. Univ. Wash. Publ. Fish., New Ser. 4.

Butler, J. A. 1961. Development of a thread herring fishery in the Gulf of Mexico. Commer. Fish. Rev. 23(9):12–17.

Dery, L. M. 1988. Atlantic herring *Clupea harengus*. *In* J. Pentilla and L. M. Dery (Editors), Age determination methods for Northwest Atlantic species, p.17–22. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 72.

DeVane, J. C. 1978. Food of king mackerel, *Scomberomorus cavalla*, in Onslow Bay, North Carolina. Trans. Am. Fish. Soc. 107(4):583–586.

Dubrow, D., M. Hale, and A. Bimbo. 1976. Seasonal variation in chemical composition and protein quality of menhaden. Mar. Fish. Rev. 38(9):12–16.

Finucane, J. H., and R. N. Vaught. 1986. Species profile of Atlantic thread herring, *Opisthonema oglinum* (Lesueur 1818). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-182, 30 p.

Fuss, C. M., J. A. Kelly, and K. W. Prest. 1969. Gulf thread herring: Aspects of the developing fishery and biological research. Proc. Gulf Caribb. Fish. Inst. 21:111–125.

Hale, M. B. 1984. Proximate chemical composition and fatty acids of three small coastal pelagic species. Mar. Fish. Rev. 46(1):19–21.

Hildebrand, S. F. 1963. Family Clupeidae. *In* H. B. Bigelow (Editor), Fishes of the western North Atlantic. Pt. Three, p. 257–454. Mem. Sears Found. Mar. Res. Yale Univ. 1.

Houde, E. D. 1976. Abundance and potential for fisheries development of some sardine-like fishes in the eastern Gulf of Mexico. Proc. Gulf Caribb. Fish. Inst. 28:73–82.

_____. 1977. Abundance and potential yield of the Atlantic thread herring, *Opisthonema oglinum*, and aspects of its early life history in the eastern Gulf of Mexico. Fish. Bull. 75(3):493–512.

_____, C. Grall, and S. A. Berkeley. 1983. Population parameter estimates for three shoaling pelagic fishes in the eastern Gulf of Mexico. Int. Counc. Explor. Sea, Pelagic Fish Committ., C.M. 1983/H:43, 11 p.

Houlahan, J. M. 1987. Urban waterfronts: Does every use have a place? *In* O. T. Magoon, H. Converse, D. Milner, L. T. Tobin, D. Clark, and G. Domurat (Editors), Coastal Zone '87, Proceedings of the fifth symposium on coastal and ocean management, p. 3987–3996. Am. Soc. Civil Engr., N.Y.

Humason, G. L. 1972. Animal tissue techniques. Freeman Publ. Co., San Franc. 641 p.

June, F. C., and C. M. Roithmayr. 1960. Determining age of Atlantic menhaden from their scales. Fish. Bull. 60:323–342.

Kinnear, B. S., and C. M. Fuss, Jr. 1971. Thread herring distribution off Florida's West Coast. Commer. Fish. Rev. 33(7–8):27–39.

Klima, E. F. 1959. Aspects of the biology and the fishery for Spanish mackerel, *Scomberomorus maculatus* (Mitchill), of southern Florida. Fla. Board Conserv., Mar. Res. Lab. Tech. Ser. 27, 39 p.

Naughton, S. P., and C. H. Saloman. 1984. Food of the bluefish (*Pomatomus saltatrix*) from the U.S. south Atlantic and Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-150, 37 p.

Patterson, K. R., and M. Santos. 1992. The thread-herrings, *Opisthonema* spp., off Ecuador: review and population dynamics. Fish. Res. 14:273–294.

Pentilla, J., F. Nichy, J. Ropes, L. Dery, and A. Jearld, Jr. 1988. Methods and equipment. *In* J. Pentilla and L. M. Dery (Editors), Age determination methods for Northwest Atlantic species, p. 7–16. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 72.

Pristas, P. J., and R. P. Cheek. 1973. Atlantic thread herring (*Opisthonema oglinum*)—Movements and population size inferred from tag returns. Fish. Bull. 71:297–301.

Reintjes, J. W. 1978. Pelagic clupeoid and carangid resources for fishery development in the Gulf of Mexico and Caribbean Sea. Proc. Gulf Caribb. Fish. Inst. 31:38–49.

_____. 1980. Marine herring and sardine resources of the northern Gulf of Mexico. *In* M. Flandorfer and L. Skupien (Editors), Proceedings of a workshop for potential fishery resources of the northern Gulf of Mexico, p. 4–17. Miss.-Ala. Sea Grant Consortium, Publ. MASGP–80-012.

Ricker, W. E. 1973. Linear regression in fishery research. J. Fish. Res. Board Can. 30:409–434.

Robins, C. R., G. C. Ray, J. Douglass, and E. Freund. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Co., Boston, 354 p.

Saloman, C. H., and S. P. Naughton. 1984. Food of the crevalle jack (*Caranx hippos*) from Florida, Louisiana and Texas. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-134, 34 p.

Smillie, R. 1994. Fish or cut bait? Fla. Sportsman 26(2):40–46.

Smith, J. W. 1991. The Atlantic and Gulf menhaden purse seine fisheries: Origins, harvesting technologies, biostatistical monitoring, recent trends in fisheries statistics, and forecasting. Mar. Fish. Rev. 53(4):28–41.

_____, W. R. Nicholson, D. S. Vaughan, D. L. Dudley, and E. A. Hall. 1987. Atlantic menhaden, *Brevoortia tyrannus*, purse seine fishery, 1972–84, with a brief discussion of age and size composition of landings. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 59, 23 p.

Stevenson, D. K., and F. Carranza. 1981. Maximum yield estimates for the Pacific thread herring, *Opisthonema* spp., fishery in Costa Rica. Fish. Bull. 79:689–703.

USDOC. 1984. Fishery statistics of the United States 1977. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Stat. Dig. 71, 407 p.

Vaughan, D. S., and J. W. Smith. 1988. A stock assessment of the Atlantic menhaden, *Brevoortia tyrannus*, fishery. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 63, 18 p.

Waltz, W., W. A. Roumillat, and P. K. Ashe. 1979. Distribution, age structure, and sex composition of the black sea bass, *Centropristis striata*, sampled along the southeastern coast of the United States. S.C. Mar. Resour. Cent. Tech. Rep. 43, 18 p.

Wenner, C. A., and G. R. Sedberry. 1989. Species composition, distribution, and relative abundance of fishes in the coastal habitat off the southeastern United States. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 79, 49 p.

Wilk, S. J. 1977. Biological and fisheries data on bluefish, *Pomatomus saltatrix* (Linnaeus). NOAA/NMFS Tech. Ser. Rep. 11, 44 p.