Age and Growth of Bluefish *Pomatomus saltatrix* from the Northern Gulf of Mexico and U.S. South Atlantic Coast

Lyman E. Barger
Panama City Laboratory, Southeast Fisheries Center
National Marine Fisheries Service, NOAA
3500 Delwood Beach Road, Panama City, Florida 32408

The bluefish *Pomatomus saltatrix* is a migratory coastal pelagic fish generally found in temperate and warm continental shelf waters of all oceans (Briggs 1960). The species occurs along the east coast of the United States and the coast of the Gulf of Mexico. Important commercial and recreational fisheries for bluefish exist throughout the U.S. range (Wilk 1977).

Age and growth studies have been conducted on bluefish from U.S. Atlantic waters (Hamer 1959, Backus 1962, Lassiter 1962, Richards 1976, Wilk 1977), but not from the Gulf of Mexico. The primary purposes of this study were to evaluate and use the best of several bony structures to estimate the age and determine growth of bluefish from the northern Gulf of Mexico (hereafter referred to as Gulf) and from the U.S. Atlantic coast.

Methods

Bluefish from the northern Gulf gillnet fishery were sampled monthly from 1978 through 1982 (Feb–Nov) and in the Atlantic along the southern U.S. east coast in 1980 and 1981 (Jan–July). These samples were augmented by catches from the seine and hook-and-line fisheries. The Gulf samples were collected from the coastal waters off northwest Florida and Louisiana, while Atlantic samples were taken along the coast from South Carolina to Florida.

Fork length (FL) to the nearest millimeter (mm), weight (W) to the nearest gram (g), and sex were recorded from 1190 Gulf and 842 Atlantic bluefish, and one or both otoliths (sagittae) were removed, wiped clean, and stored dry in vials. A subsample of 100 fish representing the entire size range of bluefish caught in the Gulf during May and June 1978 was selected for comparison among ageing structures. From these 100 fish, in addition to otoliths, the tenth vertebra anterior to the hypural plate was removed and scales were taken from the left side under the pectoral fin. Vertebrae were cleaned and air-dried. Both vertebrae and scales were stored dry in envelopes.

Otoliths were placed in glycerol, sulcus acousticus down, in a black dish and were examined under reflected light using a binocular-dissecting microscope with an ocular micrometer. The most legible otolith from each fish was examined for age marks. The second otolith from 25 of the bluefish was sectioned to allow interior examination. The otoliths were embedded in Lakeside 70C thermoplastic cement and, to include the locus, 2 or 3 thin sections (0.15 mm) were cut along the transverse plane, using a Buehler isomet slow-speed saw. The cement was dissolved with isopropyl alcohol, and then the otolith sections were mounted on glass slides and examined on a black background in the manner of whole otoliths.

On whole or sectioned otoliths an opaque zone (mark) preceded by a translucent (hyaline) zone (Fig. 1a) was assumed to be an age mark. Measurements (OR) were made along the longitudinal axis of the rostrum from the focus to the distal edges of the marks and of the otolith. A determination of the edge character (opaque or translucent) was made, and marks were counted. A mark was not considered complete, so not counted or measured, unless the portion of the otolith distal to it was translucent. The rostrum was selected for examination because the postrostrum had an uneven edge which proved difficult to measure.

Vertebrae were stained with crystal violet following the technique of Johnson (1979). To facilitate the observation of age marks, the vertebrae were cut in half, anterior-posteriorly, with a Dremel saw. Both halves of the vertebrae were examined under a binocular-dissecting microscope using reflected light. The most legible posterior centrum was used.

An age mark on the vertebral cone surface was counted if a prominent concentric ridge preceded by a depression was observed (Fig. 1b). Measurements were made from the vertex (focus) of the centrum to the distal edge of each mark as well as to the terminal edge of the vertebra.

Scales were cleaned in a weak solution of water and liquid detergent, then mounted between two glass slides. Scales from 15 bluefish were also impressed on plastic slides with a cold roller press. Both

Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Manuscript accepted 16 May 1990.
Fishery Bulletin, U.S. 88:805–809.

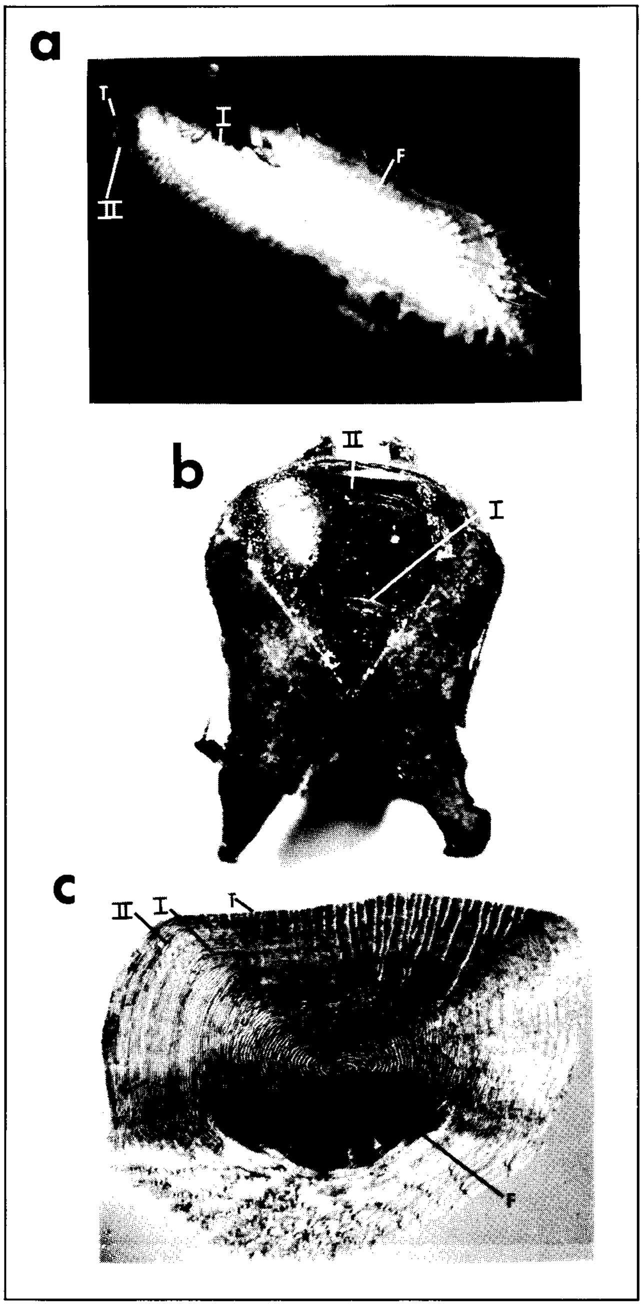

Figure 1
Otolith (a), vertebral section (b), and scale (c) from a 2+ year-old bluefish, 375 mm FL, captured in May. Distal edges of age marks are indicated by Roman numerals. F = focus; T = translucent edge.

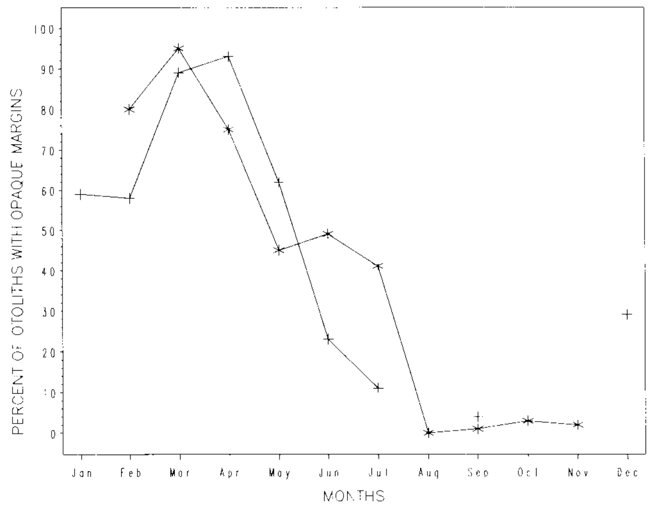

Figure 2
Percent of otoliths with opaque edges by month from Gulf of Mexico bluefish, 1978–82 (*), and U.S. South Atlantic coast, 1981–82 (+).

slides and impressions were viewed on an Eberbach scale reader. The most legible unregenerated scale was examined for age marks.

On scales and scale impressions an age mark was considered to be a band of widely spaced circuli, usually with broken circuli in the anterior field and/or anastomosis (crossing over) in the lateral field, followed by a series of closely spaced circuli (Fig. 1c). Measurements were made on the projected image from the focus along a radius in the center of the anterior field to the distal edge of the marks and scale edge.

Two investigators each made one reading of a set of otoliths, vertebrae, and scales from 100 bluefish. All examinations were made without reference to fish length or interpretations of the other investigator.

Computer analyses and plots were accomplished using SAS (Ver. 6.03) software. Backcalculations of length-at-age were accomplished with a program written by the author using means weighted by multiplication of number of samples. Gulf and Atlantic bluefish were analyzed separately. Separate analyses by sex included regressions of fork length and natural log of fork length on otolith length. Least-squares regressions were used to backcalculate length-at-age for males and females separately (Ricker 1975). Multiple regression of sex and age was run to determine difference in length-at-age by sex. Von Bertalanffy theoretical growth curves were calculated using weighted-mean backcalculated fork lengths. The growth equation (von Bertalanffy 1938, 1957) was the following:

$$l_t = l_\infty (1 - e^{-k(t-t_0)})$$

where l_t = length at age,
l_∞ = asymptotic length,
k = growth coefficient, and
t_0 = time when length would theoretically be zero.

Table 1
Backcalculated weighted mean fork lengths of bluefish.

Estimated age group	Number	Mean length at capture (mm)	Mean backcalculated length-at-age (mm)							
			1	2	3	4	5	6	7	8
From northern Gulf of Mexico, 1978–82										
1	389	364	322							
2	69	441	284	400						
3	30	640	307	415	488					
4	27	719	285	430	515	575				
5	50	745	272	411	510	572	622			
6	29	766	283	424	517	579	628	673		
7	11	766	295	423	512	576	627	668	708	
8	6	767	275	423	530	598	650	695	728	766
Weighted mean			308	413	509	576	627	675	715	766
Annual increment				105	96	67	51	48	40	51
Number			611	222	153	123	96	46	17	6
From U.S. Atlantic coast, 1980–81										
1	389	382	299							
2	161	394	275	362						
3	26	446	265	350	412					
4	12	536	261	342	421	473				
Weighted mean			290	361	415	473				
Annual increment				69	56	58				
Number			588	199	38	12				

Results and discussion

Agreement between investigators in enumeration of marks was highest (92%) with whole otoliths. Lower agreements were attained for scale impressions (67%), vertebrae (33%), and scales (24%). In comparison of whole otoliths with cross-sections taken from the other otolith of a pair, investigators agreed 70% of the time. The close spacing of marks in the sections caused more disagreement in mark enumeration than did the wider spacing in the rostrum of the whole otolith. Also, fractures sometimes occurred in preparation of thin sections, making enumeration of marks on cross-sections of otoliths a less viable option. In addition, 30 otoliths were examined and no difference was found in mark counts on either the rostrum or postrostrum of the otolith or between pairs of otoliths.

To use otoliths, or any structure, for age determination, the deposition of regular detectable age marks is essential. Because samples were obtained from catches of the fishery, no accepted method of direct validation could be employed. However, indirect evidence was established by correlation of the observed mark formation at the distal edge of the rostrum with month. Despite the lack of samples for all months, the results suggested that opaque marks were formed annually in late winter or early spring around March and April in the Gulf and Atlantic samples, respectively (Fig. 2). Gulf bluefish show an unexpected flattening of the curve in June and July. The reason is not known, but a likely hypothesis is a stress-induced check from environmental causes. An alternate hypothesis could be a multiple spawning. However, there are no reports of a summer spawn of bluefish in the Gulf. Backcalculation of length at the time of mark formation is dependent on the relationship between the size of the ageing structure and fish length. Improved fit of the otolith radii (OR) to length relationship occurred when natural log transformation was used for fork length. The equation for Gulf bluefish was $LOG(FL) = 4.200 + 0.389 \times OR$ ($r^2 = 0.86$). The equation for Atlantic bluefish was $LOG(FL) = 4.822 + 0.248 \times OR$ ($r^2 = 0.61$).

Sexes were pooled for analysis because no significant difference ($\alpha > 0.10$) was found between mean backcalculated fork lengths of sex at age. Studies of Hamer (1959) in the New York Bight, Lassiter (1962) off North Carolina, and Richards (1976) off Long Island also showed no appreciable difference in growth between sexes. The length-weight equation for Gulf bluefish was $W = -10.02 \times FL^{2.80}$ and was $W = -9.18 \times FL^{2.77}$ for Atlantic bluefish.

Backcalculated lengths-at-age from Gulf and Atlantic bluefish were similar to the respective lengths at capture (Table 1). The differences were attributed to growth after mark formation. Gulf bluefish were consistently greater in length for age compared with Atlantic bluefish. The difference gradually increased through age-4, the maximum age of the available Atlantic samples.

The Gulf samples included large fish (>600 mm FL) in relatively large numbers (>30% of the sample) only in May and June 1978. During other years, the large fish made up only 4% or less of the Gulf samples. Bluefish of this size are not commonly found in the Gulf. Fable et al. (1981) reported that these fish were decidedly larger than Gulf bluefish observed in 1973 and 1977. Atlantic samples included fish estimated to be no older than age 4 and FL less than 600 mm.

A general comparison with some previous bluefish studies was made (Fig. 3). All other studies used scales to age bluefish and did not report validation. Scale studies were used, as no similar otolith studies could be obtained. Wilk (1977) analyzed scales from bluefish sampled along the Atlantic coast. His results showed slower growth to age-1 than either Gulf or Atlantic samples from this study. By age-2 a larger rate of growth had converged his reported lengths to just short of the Gulf samples from this study, a relationship maintained until age-7 at which point small sample sizes may have contributed to errors. Reported lengths-at-age from scales of Long Island Sound bluefish (Richards 1976) were similar to those of this study. North Carolina spring-spawned bluefish aged by scales (Lassiter 1962) fall within range of Gulf bluefish from this study, but have shorter lengths at each age.

The von Bertalanffy (1938, 1957) theoretical growth parameters derived from this study are:

$$\text{Gulf: } k = 0.180,\ l_\infty = 944,\ t_0 = -1.033$$
$$\text{Atlantic: } k = 0.096,\ l_\infty = 1{,}019,\ t_0 = -2.493.$$

Growth coefficient (k) for Gulf bluefish is within the range of those reported by Lassiter (1962) for North Carolina spring-spawned (0.103) and summer-spawned (0.342) and by Manooch (1979) for Gulf and Atlantic maximum age-8 (0.230) and maximum age-9 (0.340) bluefish. The high growth coefficient of Gulf bluefish reflects the relatively rapid initial growth. The large bluefish taken in the summer of 1978 may influence this coefficient.

Otoliths appear to be better than either scales or vertebrae for ageing Gulf bluefish. Based on the percent of opaque edge occurrence and the close fit with other studies, it appears that age marks on the otoliths of Gulf bluefish are formed annually. Direct validation of age, which was not possible in this study, should be included in future studies. The cause of a higher percent of otoliths with opaque edges in the months of June and July in Gulf bluefish should also be a point of further investigation.

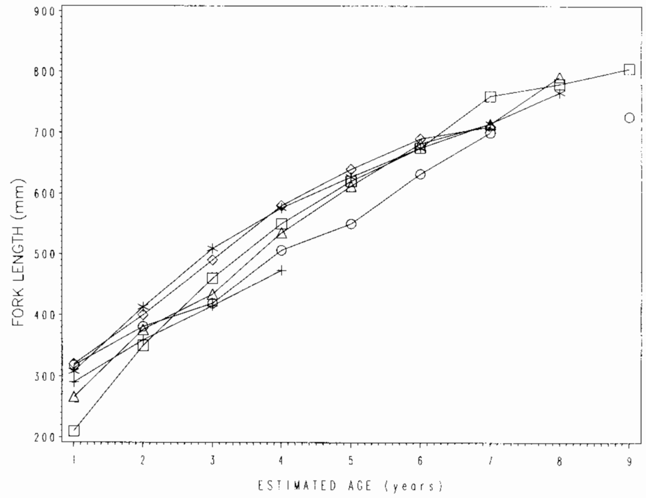

Figure 3

Mean length of bluefish from the Gulf of Mexico and the U.S. Atlantic coast by age in years from this and other published studies. Northern Gulf of Mexico, this study (*); U.S. South Atlantic coast, this study (+); Long Island Sound, NY (Richards 1976), (◇); New York Bight (Hamer 1959), (○); Atlantic coast (Wilk 1977), (□); North Carolina (Lassiter 1962), (△).

Acknowledgments

I wish to thank Drs. Charles S. Manooch III of the National Marine Fisheries Service, Stephen Bortone of the University of West Florida, and Michael J. Van Den Avyle of the University of Georgia for their critical reviews of the original manuscript. I would like to thank Drs. Allyn G. Johnson and J. Jeffery Isely of the National Marine Fisheries Service for assistance in reading structures and guidance in statistical analysis.

Citations

Backus, R.A.
1962 Age in a small sample of bluefish (*Pomatomus saltatrix* Linneaus). Breviora 159:1–4.

Briggs, J.C.
1960 Fishes of worldwide (circumtropical) distribution. Copeia 1960:171–180.

Fable, W.A. Jr., H.A. Brusher, L. Trent, and J. Finnegan Jr.
1981 Possible temperature effects on charter boat catches of king mackerel and other coastal pelagic species in northwest Florida. Mar. Fish. Rev. 43(8):21–26.

Hamer, P.E.
1959 Age and growth studies of the bluefish (*Pomatomus saltatrix* Linnaeus) of the New York Bight. M.S. thesis, Rutgers Univ., New Brunswick, NJ, 27 p.

Johnson, A.G.
1979 A simple method for staining the centra of teleost vertebrae. Northeast Gulf Sci. 3(2):113–115.

Lassiter, R.R.
1962 Life history aspects of the bluefish, *Pomatomus saltatrix* (Linneaus), from the coast of North Carolina. M.S. thesis, North Carolina State College, Raleigh, 103 p.

Manooch, C.S. III
1979 Recreational and commercial fisheries for king mackerel, *Scomberomorus cavalla*, in the South Atlantic Bight and Gulf of Mexico, U.S.A. *In* Nakamura, E.L., and H.R. Bullis Jr. (eds.), Proceedings: Colloquium on the Spanish and king mackerel resources in the Gulf of Mexico, p. 33–41. Gulf States Mar. Fish. Comm. 4.

Richards, S.W.
1976 Age, growth and food of bluefish (*Pomatomus saltatrix*) from east-central Long Island Sound from July through November 1975. Trans. Am. Fish. Soc. 105:523–525.

Ricker, W.E.
1975 Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191, 382 p.

von Bertalanffy, L.
1938 A quantitative theory of organic growth (inquiries on growth laws. II). Hum. Biol. 10(2):181–213.
1957 Quantitative laws in metabolism and growth. Q. Rev. Biol. 32(3):217–231.

Wilk, S.J.
1977 Biological and fisheries data on bluefish, *Pomatomus saltatrix* (Linneaus). Tech. Ser. Rep. 11, Sandy Hook Lab., Northeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Highlands, NJ 07732, 56 p.