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Proceedings of the Summer Flounder *(Paralichthys dentatus)* Age and Growth Workshop, 20-21 May 1980, Northeast Fisheries Center, Woods Hole, Massachusetts

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Because accurate information on age and growth of summer flounder was needed to prepare a fishery management plan, a subcommittee of the State/Federal Summer Flounder Scientific and Statistical Committee, was established to resolve the conflicting results of past research. A two-day workshop was held on May 20 and 21, 1980, at the Northeast Fisheries Center, Woods Hole, Massachusetts. This report documents the subcommittee's efforts to meet the following objectives: (1) Review summer flounder age/growth studies; (2) Compare growth patterns on scales, otoliths, and finrays; (3) Resolve interpretation of age when first and second annuli are formed, taking into consideration both length frequencies and time of spawning. (Author extracted)

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Proceedings of the Summer Flounder *(Paralichthys dentatus)* Age and Growth Workshop, 20-21 May 1980, Northeast Fisheries Center, Woods Hole, Massachusetts

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INTRODUCTION

At a meeting of the State/Federal Summer Flounder Scientific and Statistical Committee on October 18 and 19, 1979, the subject of age and growth estimates of summer flounder was discussed. After reviewing available literature, it became apparent that results of past studies were not in total agreement.

Because accurate information on age and growth of summer flounder was needed to prepare a fishery management plan, a subcommittee was established to resolve the conflicting results of past research. A two-day workshop was held on May 20 and 21, 1980 at the Northeast Fisheries Center, Woods Hole, Massachusetts. This report documents the subcommittee's efforts to meet the following objectives:

1. Review summer flounder age/growth studies.
2. Compare growth patterns on scales, otoliths, and fin rays.
3. Resolve interpretation of age when first and second annuli are formed, taking into consideration:

    a. length frequencies
    b. time of spawning

The following individuals were members of the summer flounder age/growth subcommittee:

Ronal Smith, Chairman	DE Division of Fish & Wildlife
Paul Scarlett, Rapporteur	NJ Division of Fish, Game & Wildlife
John Poole	NY State Dept. of Environmental Conservation
John Musick	VA Institute of Marine Science
Mark Chittenden	TX A&M University
Steve Murawsli	NEFC - Woods Hole Laboratory
Gary Shepherd	Rutgers University
Doug DeVries	NC Division of Marine Fisheries
Allyn Powell	SEFC - Beaufort Laboratory
Louise Dery	NEFC - Woods Hole Laboratory
John Mason	Mid-Atlantic Council
Stuart Wilk	NEFC - Sandy Hook Laboratory
Doris Jimenez	MA Division of Marine Fisheries
Emma Henderson	NEFC - Woods Hole Laboratory
Ambrose Jearld, Jr.	NEFC - Woods Hole Laboratory
Joseph Smith	SC Wildlife & Marine Resources Dept.
Michael Fogarty	NEFC - Woods Hole Laboratory
Wally Morse	NEFC - Sandy Hook Laboratory
Brenda Fields	NEFC - Woods Hole Laboratory

ZONE FORMATION ON SUMMER FLOUNDER OTOLITHS, FIN RAYS, AND SCALES AS A BASIS FOR AGE INTERPRETATION

A literature review of summer flounder age and growth studies by Poole (1961), Eldridge (1962), Powell (1974), Smith and Daiber (1977), and Shepherd (1980) indicated signficant differences in the interpretation of growth zones on otoliths (sagittae). According to Muguja (1966), the otolith is composed primarily of calcium carbonate crystals in aragonite form in a protein matrix. He found that in the otolith fluid of a flatfish, there was a seasonal increase in the concentration of protein causing a decrease in the free calcium concentration; and this occurred at a time corresponding to opaque zone formation in the otolith. Blacker (1974) citing Yokoyama and Yamada (1967) suggested that this decrease in calcium concentration in the otolith fluid is due to the increased rate of calcium deposition on the otolith, but research in this area is not conclusive.

As noted by Blacker (1974), there has been confusion in the meaning of the terms "opaque" and "hyaline" in the description of growth zones on otoliths. Under reflected light, heavily calcified zones in the otoliths will appear white/opaque; while less calcified zones, with a higher organic content appear dark/hyaline (Figure 1). The use of transmitted light would tend to reverse this terminology, but standard terminology described by Jensen (1965) is based upon the use of reflected light.

Investigators of fishes from temperate waters generally agree that the densely calcified or "opaque" zones are indicative of rapid fish growth (Panella, 1974; Blacker, 1974). A major study by Irie (1960) seems to contradict the interpretation of growth association with hyaline and opaque zones generally accepted, but there are indications that these terms may be reversed in his work. Irie's statement that "organic matter is contained more abundantly in the opaque zone than in the translucent zone" contradicts observations as discussed by Blacker (1974) that it is the translucent zone (hyaline zone) which darkens when the otolith is heated.

In general, most temperate fish otoliths have wide opaque zones while their hyaline zones are quite narrow. Opaque material begins to appear on these otoliths some time during the spring months and continues to be deposited through the summer when most rapid fish growth is evident. There are, however, fluctuations in the time at which opaque edge begins to form, and this may often be correlated with changes in latitude. Opaque edge usually appears earlier in the season the further south in latitude (Williams and Bedford, 1974), and this is very evident on the otoliths of such species as silver and red hake. Summer flounder otoliths seem to deviate from this generalized pattern, with hyaline zones being widest and their formation occurring during the spring and summer (it is assumed that summer flounder grow most rapidly during the warmer months).

According to Dery (pers. comm., 1980), summer flounder otoliths appear poorly calcified, with generally poor contrast between hyaline and opaque zones. There is often erosion at the surface of the otolith. If poor calcification or resorbtion of opaque zones does occur periodically during the late spring, summer, and fall, hyaline zones would appear wide in relation to opaque zones. This lack of opaque zone presence would disguise the typical indication that fish growth had occurred during the warmer months, assuming opaque zone is actually associated with rapid growth. DeVries (pers. comm., 1980), reported he found evidence of opaque zone resorbtion with otoliths from the southern flounder (P. lethostigma).

Dery and Shepherd both found that summer flounder scales and fin rays seem to indicate a moderate to rapid growth period occurring between early summer and the following spring. Observing fin ray thin sections under dark field transmitted light, wide growth zones of dense protein appear opaque (white) after staining with clove oil while the narrow, slow growth zones remain hyaline (dark) (Figure 2). Hyaline edge appears on the fin ray at approximately the same time hyaline edge appears on the otolith -- in the spring. In early summer, however, opaque edge begins to form on the fin ray, while hyaline edge persists on most otoliths.

On summer flounder scale impression zones of fast and slow growth are reflected by the wide or narrow spacing, respectively, of circuli markings from the sculpted upper surface of the scale (Figure 3). Among summer flounder, growth patterns are often variable, but yearly growth patterns seem to be consistent for individual fish. This variability of growth patterns could cause considerable confusion when attempting to locate annuli but for the consistent annual appearance of "cutting over"[1] on the scale edge beginning the second spring following hatching (Figure 4). This marking seems to occur between late March and June and corresponds to the appearance of hyaline edge on both otoliths and fin rays. An abrupt decrease in growth, therefore, seems to be indicated during these months, or else there is a lag between the growth event and the formation of the growth mark.

In conclusion, scales and fin rays follow the generalized temperate water growth pattern and indicate that rapid growth in summer flounder begins in early summer, continuing (probably intermittently) into the following winter. Growth rate interpretation based upon otolith zones may not be reliable due to problems with poor calcification and/or with resorbtion. It would seem reasonable to count lines of "cutting over" on the scales as indicative of annual spring periods of slow growth. In order to determine fish age on the fin rays the corresponding zones would be hyaline annuli. On the otoliths, the zone corresponding to scale "cutting over" would be the outside edge of the opaque zone or the beginning of the hyaline zone bordering this previously deposited opaque zone.

During the first afternoon session of the workshop, participants examined several scales, otoliths, and fin rays of individual fish sampled during spring, summer, and fall from waters off Massachusetts to South Carolina. Participants compared growth zone development on the three structures, particularly the rate of growth indicated on the edge in relation to the sample collection season. There was general agreement that zone development among the three structures tended to follow the pattern described above and that age determinations using the three structures were comparable.

A demonstration of scale impression preparation was also presented by Woods Hole summer flounder age readers involving the use of laminated plastic and a roller press. This has been described by Dery and Rearden (1979).

REVIEW OF SUMMER FLOUNDER AGE AND GROWTH STUDIES

There are five studies (Table 1) that have examined the age and growth of summer flounder. All researchers used the left otolith (Figure 1) for aging and agree that specific growth zones or marks shown were annular (Shepherd, 1980, also used scales and fin rays for aging). While Shepherd used the otolith hyaline zone for his annular mark and the other researchers used the opaque zone, the primary disagreement between studies is in the interpretation of age at the first distinct annulus away from the otolith core.

The otolith center area or core (Figures 1 and 5) is essentially opaque. This lack of differentiation could be due to the otolith's thickness and/or unique development during the flounder's first year growth. Poole (1961) and Powell (1974) collected and aged fish they considered age "0+" and "1+" from Long Island and North Carolina waters, respectively. Both selected the first opaque zone or ring away from the core as the first annulus and both used length-frequency distributions to corroborate this annulus. However, their age "0+" and "1+" length frequencies did not agree for comparable time periods. At the workshop, it was decided that Powell's length frequency data agreed with that reported by most others (Table 2) while Poole's data represented an atypical fast growing year class. Lengths selected as being most representative of fish at age "1" and age "2" were 170-180 mm and 280-290 mm, respectively (Table 2).

Eldridge (1962), Smith and Daiber (1977), and Shepherd (1980) collected and aged fish they considered age "2+" or older. Smith and Daiber considered the first distinct opaque zone away from the core as being formed at age "2" (2nd annulus), because fish having this growth mark were thought too large to be in the "1+" year class when compared to reported length frequencies. Shepherd also considered this first distinct otolith opaque zone past the core as being formed just after the second birthday because of comparative work he did with scales and fin rays. Eldridge, basing his aging on observed length frequencies at the end of year "1" and "2", considered this first otolith opaque zone away from the core as being formed at the end of the flounder's third year (3rd annulus) when summer flounder were thought to mature and spawn for the first time.

Both Shepherd, and Smith and Daiber thought the first annulus could be at the outside edge of the core, however, calculated lengths for an annulus at the edge did not approximate observed length frequencies, except possibly for the extreme northern part of the range (Shepherd). Some otoliths examined by Smith and Daiber had thin opaque zones that may have represented a first annulus (Figure 5) but they occurred too infrequently to be meaningful. Since Poole and Powell were the only researchers able to distinguish a first annulus; and they were the only ones who worked with fish under age "2+", there seems to be a good possibility that the first annular mark becomes obscure and/or resorbed as discussed in the previous section.

In general, past the core area, the hyaline (clear or translucent) zone grades into the opaque (white) zone and then the opaque zone ends abruptly leaving a distinct line of demarcation with the following hyaline zone. After the first few opaque zones, the succeeding opaque zones become relatively narrow and uniform, leaving only a fine white ring as compared to the hyaline zone (Figure 1). All researchers utilizing the opaque zone as the annulus measured to the outer edge of this zone where the line of demarcation occurred. Shepherd measured to the outside edge of the succeeding hyaline zone for his annulus. It is uncertain why Shepherd's calculated lengths were similar to those of other researchers (Table 1).

In conclusion, the workshop participants felt that the first distinct opaque zone away from the core on summer flounder otoliths from fish age "2+" and older normally represents the second annulus; however, this determination should be made on a study-by-study basis using length frequency ranges as given in Table 2. It is probable that age "1+" flounder could show a distinct first annulus past the core. Otolith opaque zones representing annuli past number 2 are usually easy to distinguish on most otoliths.

The calculated lengths given in Table 1 for Powell, Smith and Daiber, and Shepherd are considered realistic estimates for normal summer flounder growth, especially up to age 5 or 6 where more adequate sample sizes were available. Poole's lengths, while considered valid, are thought to be representative of very rapid growth not normally found. Eldridge's age groups should be adjusted back one year to fit the growth pattern selected. However, his lengths are still different, probably because he used a somewhat different method for back-calculation. Participants agreed that there is a direct proportion between otolith and body growth, and use of a correction factor may be necessary when back-calculating lengths using the standard linear relationship,

Work by Shepherd showed the validity of using scales and fin rays as useful aging structures; however, special care and materials must be used in making scale impressions in order to distinguish the annuli. For ease of sampling commercial and recreational catches, the scale offers the best aging structure, provided the method for scale processing is adequate as mentioned.

Summer flounder spawn from late September through March, with spawning beginning in the northern part of their range and moving southward. For uniformity, 1 January is considered the birthday and fish are not considered one year old unless they have passed their first summer, thereby eliminating the possibility of an October hatched fish being considered one year old the following January. Under normal conditions, the minimum observed mean length frequency of one and two year old January fish should be approximately 170-180 mm and 280-290 mm, respectively (Table 2).

SUMMARY OF AGING CRITERIA

I. Annulus Identification

A. Otolith

1. If opaque zones are counted as annuli, the first distinct opaque zone away from the core in fish greater than 30 cm. represents the second annulus. If this distinct zone is present on otoliths of much smaller fish, it could represent the first annulus.

2. If hyaline zones are counted as annuli, these zones are located at the outer edge of the opaque zones defined above.

B. Scale

1. The "cutting over" mark is considered the annulus.

2. The first distinct "cutting over" mark on the scale represents the first annulus.

C. Fin Ray

1. If opaque zones are counted as annuli, the first opaque zone following the central crystalline zone represents the first annulus.

2. If hyaline zones are counted as annuli, the first hyaline zone after the central crystalline zone represents the first annulus.

II. Correspondence of Annulus Formation Among Scales, Otoliths, and Fin Rays

The scale "cutting over" mark appears on the scale edge at approximately the same time as hyaline edge appears on otoliths and fin rays, in the spring. The "cutting over" mark therefore corresponds in location to the interface between the opaque and hyaline zones of otoliths and fin rays as described above.

III. Common Birthday

A. 1 January is established as the birthday with the provision that all fish must pass through a summer period to be considered one year old.

1. Spawning relative to birthday (1 January).

Since spawning occurs from October through March beginning earliest in the northern part of the range and progressing southward, the following are given as age examples:

October hatch - Age 1 = 15 months
November hatch - Age 1 = 14 months
December hatch - Age 1 = 13 months
January hatch - Age 1 = 12 months
February hatch - Age 1 = 11 months
March hatch - Age 1 = 10 months

POST WORKSHOP AGE AND GROWTH STUDY OF YOUNG SUMMER FLOUNDER

by Louise Dery[2]

INTRODUCTION

Workshop participants recommended that there be documentation of age structure growth patterns among young summer flounder. Participants agreed to provide scales, otoliths and fin rays from young fish. An attempt was made to collect approximately 30 individuals in the 15 to 30 cm. range, about two per cm. From growth studies reviewed during the workshop, summer flounder collected during the summer months in this length range should include age groups "0+" and "1+".

COLLECTION OF AGE SAMPLES

A list of samples collected by date and location is as follows:

LOCATION	DATE	NUMBER OF SAMPLES
Great Bay, NJ	7/19/80	12
	7/22/80	11
	7/24/80	8
Silver Bay, NJ	8/07/80	6
Delaware Bay	6/20/80	3
	6/23-25/80	5
	7/14-15/80	3

Indian River, DE	7/80	6
Assawoman Bay Ocean City, MD	8/05/80	9
Isle of Wight Bay	6/08/80	10
Ocean City, MD	7/13/80	7
Rappahannock River, VA	8/80	47
York River, VA	7/80	14
South Carolina locations	6/03/80	5
	7/21-23/80	4
	8/05-06/80	9
	TOTAL	159

Fish samples received were in the 10-36 cm. range. Fish were not available from locations north of New Jersey. Whole fish, with the exception of those collected in South Carolina, were processed at the Northeast Fisheries Center, Woods Hole Laboratory for fish length and sex. Scales, otoliths, and fin rays were also removed. Where scales were not provided for fish sampled, e.g., South Carolina, those samples were omitted. Only scales and otoliths were used in this study because of the extensive preparation time required for fin ray sections.

METHOD OF PREPARING AND AGING SCALES AND OTOLITH SAMPLES

Scale impressions on laminated plastic were viewed on a microprojector at 40X. In accordance with the agreement reached during the workshop regarding aging criteria, scales were aged as "0+" if no "cutting over" mark was observed on the scale. Scales with one cutting over mark were aged as "1+", those with two marks as "2+".

Otoliths were stored dry but viewed whole in ethyl alcohol at 15X using reflected light against a dark background. These structures were aged separately from the scales and later the zone formation on both structures were compared. Following the consensus reached during the workshop, the first distinct opaque-hyaline interface after the opaque core was interpreted as the first annulus in fish less than 30 cm.

GROWTH PATTERN TYPOLOGY

A preliminary examination of the scales indicated that their growth patterns could be classified into six types based upon two aspects of scale growth which seemed to vary among samples from different latitudes. These two aspects were rate of scale growth prior to "cutting over" and overall rate of scale growth. Scales of "1+" year olds (at least one full year of growth completed) were evaluated for these growth rate characteristics within the first year. If the circuli were straight or minimally curved, and horizontal bands of circuli segments narrowly spaced, this zone was considered indicative of slow growth. If, however, circuli were curved and/or fragmented and widely spaced, then rapid growth was indicated (Figure 3).

Table 3 and Figures 6-10 describe the six possible types of scale growth patterns based upon the above variables: rapid before "cutting over"/ rapid overall (RR), rapid before "c.o."/slow-moderate overall (RS), rapid before "c.o."/mixed overall (RM), slow-moderate before "c.o."/slow-moderate overall (SS), slow-moderate before "c.o."/rapid overall (SR), and slow-moderate before "c.o."/mixed overall (SM). Overall scale growth was termed "mixed" if sharp changes in scale growth during the first year were observed. A fish scale representative of each growth pattern type except "SR" (unsuccessful) was mounted between glass slides and photographed.

METHOD OF BACKCALCULATION

Age "1+" scales were backcalculated to determine actual fish length when the first "cutting over" mark was formed, corresponding to the second spring period following hatching. Scales were measured from the focus to the anterior edge of the scale, and from the focus to the "cutting over" mark. The regression of fish length against scale length was easily fit by eye with a straight line intersecting the origin. The problem of allometric scale growth encountered by Shepherd (1980) was seemingly avoided as only small scales from one year olds were used. Backcalculated fish length at the first annulus was therefore determined by direct proportion.

RESULTS AND DISCUSSION

A comparison of growth zone formation on scales and otoliths revealed that with a few exceptions scale edges indicated moderate to rapid growth ("+" edge) while the edges of most of the corresponding otoliths were clearly hyaline. When "0+" scales and otoliths were examined, the single wide hyaline zone of the otolith extending from the opaque central core to the edge of the otolith seemed to be inclusive of all corresponding "+" growth on the scales. The severe irregularity and crystalline aspect of these otoliths' edges indicated that either calcium was being resorbed or that normal accretion of calcium along the surface of the otolith was being disrupted. A similar process was evident on the edges of the otoliths of the "1+" year olds. Beyond what was assumed the "0+" hyaline zone surrounding the central core and the first opaque zone away from the core, there were two closely spaced hyaline zones separated by a thin opaque zone. From the above evidence and the overall crystalline aspect of many otoliths of adult summer flounder, it seems likely that some resorbtion may occur from spring into the summer on both otoliths and scales (cutting over). Resorbtion of the scale edge is probably quite limited, as no scale erosion was observed later than early June, but it may be extensive on otoliths from some areas. Opaque zones seen on otoliths were probably formed between fall and the following spring, perhaps intermittently. Among the otoliths collected for this study, resorbtion was most severe on otoliths from Virginia and South Carolina waters (Table 3). Unfortunately, no documentation on fish otolith resorbtion is available from published studies, although resorbtion of inner ear calcareous deposits may occur in other vertebrates (Simkiss, 1974). Scale resorbtion, however, during periods of starvation has been observed for a number of species (Crichton, 1935; Ichikawa, 1954; Bilton, 1974).

Table 4 summarizes the age/length distribution of the summer flounder samples used in this study by sampling area and sex. In cases of age disagreement between scales and otoliths (only 1%), the most likely age was assigned. Although few "0+" year olds were processed, length distribution of these young of the year and "1+" year olds indicated two well defined modes; "0+" fish were distributed between 10 and 21 cm., "1+" fish between 15 and 36 cm. These age/length distributions were dependent upon sampling area. Few "2+" fish occurred in the samples, as collections were not requested over 30 cm. Greatest observed mean lengths at age "1+" were 29 and 30 cm. for males and females, respectively, from New Jersey. Differences in mean length at age with sampling area could not be substantiated using basic length at age, possibly due to differences in time of sampling (June through August) and limitations placed upon the sample size and length range of the samples collected. An examination of the scale edges indicated a large variation in the amount of "+" growth after "cutting over". Far more "+" edge was typically present on age "1+" scales from southern locations (Figures 6 and 7). Later in this study backcalculated lengths were employed to detect differences in growth between areas more effectively.

Results of the scale growth pattern study indicated a definite shift in pattern type with change in latitude (Table 3). In age and growth studies it is assumed that the growth of the fish scale reflects the growth of the fish. Therefore, New Jersey scale samples of "1+" year olds indicated an overall rapid fish growth rate during the first year, as "mixed" overall growth was predominantly rapid. A total of 92% of these samples exhibited this type of growth. Rapid fish growth before April-May "cutting over" was characteristic of both New Jersey and Delaware/Maryland samples (86%), although larger numbers of fish exhibited slow-moderate overall growth in the latter (32%). A marked decrease in overall first year growth rate was observed on scale samples from Virginia. Consistent slow-moderate growth during the entire first year was indicated on 44% of the samples. Only 36% of South Carolina scale samples (including the "SM" type) indicated slow-moderate overall growth, but growth rate prior to "cutting over" was slow-moderate for both Virginia and South Carolina, 75% and 58%, respectively. Unfortunately, the sample size was small for South Carolina. A summary of the above data indicated that with the exception of South Carolina, overall fish growth rate tended to decrease from north to south. Growth rate prior to cutting over also tended to decrease with no exceptions.

A distribution of backcalculated fish lengths at age "1" (Table 5), indicated that mean fish length tended to decrease, with the exception of the "SR" type, when the scale growth types were ranked predictively from the fastest to the slowest overall growth. Backcalculated fish lengths were used in order to standardize lengths to the time interval when cutting over occurs (April-May), as samples were collected during the months of June through August with varying amounts of "+" growth. It may be concluded that the faster fish growth rate in more northern areas results in larger "1" year olds, but differences in spawning time relative to first annulus formation is also an important factor in total growth attained. The backcalculated fish lengths distributed according to sampling area indicate the importance of this factor (Table 6). Although overall fish growth rate was faster for South Carolina age "1+" fish relative to those of Virginia, mean backcalculated fish length at age "1" was smaller for the South Carolina samples; 19 and 16 cm., respectively. These data indicate a substantial shift in size at age "1" from 26 cm. (mean length) for New Jersey samples to 16 cm. for those from South Carolina. Two important factors explaining the shift in size appear to be rate of fish growth, possibly dependent on local environmental conditions, and differences in spawning times. As mentioned during the workshop, peak spawning occurs in New Jersey waters in November while in South Carolina spawning may occur as late as March. Additionally, rapid fish growth prior to "cutting over" indicated significant winter season growth for northern fish.

The results of this study seem most useful in the establishment of aging criteria regarding the interpretation of the first annulus. However, the observed first year growth patterns could be of some use in establishing probable nursery locations and stock differentiation for adult summer flounder. Many questions have arisen in published studies concerning stock boundaries and migration patterns (Poole, 1966; Smith, 1973; Chang and Pacheco, 1976; and Smith and Daiber, 1977). The two extreme growth pattern types "RR" and "SS" are particularly characteristic of New Jersey and Virginia age "1+" fish, respectively (Figures 6 and 7). At the Northeast Fisheries Center, Woods Hole Laboratory, scale samples from summer flounder collected north of New Jersey (as far as Massachusetts) tended to exhibit the rapid overall growth pattern "RR" similar to the New Jersey samples. Unfortunately, relatively few scales were examined in this study and therefore firm conclusions about growth pattern differences among areas cannot be made.

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FOOTNOTES

1. Refers to scale edge erosion forming a white line across the anterior edge of the scale impression.

2. This section is a separate piece of research completed by this author after the workshop.

Table 1. Comparison of summer flounder, Paralichthys dentatus, age studies (Otoliths used for aging except as noted).

Study	Study Area	Location of Annulus and Estimated Time of Annulus Formation	Estimated Age at Distinct Annulus	Mean Calculated Total Length(mm) at Successive Annuli								
				1	2	3	4	5	6	7	8	9
						MALE						
Poole (1961)	Great South Bay Long Island, N.Y.	Outer edge - opaque zone February - March	one	251	326	387	427					
Eldridge (1962)	Winter Trawl Fishery Hampton, Va.	Outer edge - opaque zone February - March	three	170^a	240^a	319	357	381	399	414	426	
Powell (1974)	Pamlico Sound, N.C.	Outer edge - opaque zone January - February	one	164								
Smith & Daiber (1977)	Delaware Bay, DE	Outer edge - opaque zone February - March	two		260	345	397	448	493	517		
						FEMALE						
Poole (1961)	Great South Bay Long Island, N.Y.	Outer edge - opaque zone February - March	one	271	377	465	531	644				
Eldridge (1962)	Winter Trawl Fishery Hampton, Va.	Outer edge - opaque zone February - March	three	170^a	240^a	377	424	471	518	566	613	657
Powell (1974)	Pamlico Sound, N.C.	Outer edge - opaque zone January - February	one	170	290	380						
Smith & Daiber (1977)	Delaware Bay, DE	Outer edge - opaque zone February - March	two		280	380	453	511	565	618	661	
Shepherd (1980)	Martha's Vineyard Sound, Mass.	Outer edge - hyaline zone March (otolith) Circuli scale crossover March - April (scale)	two	114^b 113^c	284^b 242^c	392^b 365^c	447^b 453^c	501^b 524^c	590^c	691^c		

(a) Lengths are estimates or means of observed length frequency.
(b) Lengths as calculated from otoliths.
(c) Lengths as calculated from scales.

Table 2. Reported length frequencies of young-of-the-year and age "1" summer flounder, Paralichthys dentatus over its range.

Study	Location	YOY or age "1"	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
							Total length (mm)							
Pearcy & Richards (1962)	Connecticut-Mystic River	YOY			39-66	---------97-137--------								
Poole (1961)	N.Y.-Great South Bay	YOY					140	185	225					
NMFS	New York Bight	YOY									180	---------180----------		
NMFS inshore spring cruises	New York-Cape Hatteras	"1"	---170-200----											
Smith(Pers. comm.)& DeSylva, Kalber & Shuster (1962)	Delaware Bay	YOY				90	110	120					175	
Smith (Pers. comm.)	Del.-Indian River Bay	YOY				84								
Casey (Pers. comm.)	Maryland-Coastal Bays	YOY			78	102	119	150	158	164				
		"1"			275	290	316	313	342	348				
Hildebrand & Schroeder (1928)	Chesapeake Bay	YOY			---22-60----		75-125					-120-180		
Eldridge (1962)	Chesapeake Bay	YOY				101	-----154-------------			--------170-------------				
	Va.-York River	YOY				94							180	
Powell (1974)	N. Carolina-Pamlico Sound	YOY				95	115	148	156	162	171	166		
		"1"	178	174	195	204	224				280-290			
Summary[a]		YOY			40-80	80-105	110-140	120-155	155-160	160-170	170	- -	180	
		"1"		200			125				280	290		

[a] Does not include Poole (1961) data for August and September.

Table 3. Percent and number of six types of scale growth patterns, by sampling area, for age "1+" summer flounder, *Paralichthys dentatus*. Also included are percent and number of age "1+" otoliths with "not appreciable," "moderate," or "severe" resorbtion, by sampling area.

Growth rate preceding "cutting over"	Overall growth rate	Scale pattern abbreviations	Sampling areas							
			New Jersey		Delaware Maryland		Virginia		South Carolina	
			%	(No.)	%	(No.)	%	(No.)	%	(No.)
Rapid	Rapid	RR	48	(14)	23	(8)	4	(2)	27	(3)
Rapid	Mixed	RM	31	(9)	34	(12)	11	(5)	0	(0)
Slow-Moderate	Rapid	SR	3	(1)	3	(1)	11	(5)	36	(4)
Slow-Moderate	Mixed	SM	10	(3)	9	(3)	20	(9)	18	(2)
Rapid	Slow-Moderate	RS	7	(2)	29	(10)	9	(4)	9	(1)
Slow-Moderate	Slow-Moderate	SS	0	(0)	3	(1)	44	(20)	9	(1)
Total number examined				29		35		45		11
Amount of Otolith "Resorbtion"										
Not appreciable			18	(5)	47	(17)	9	(4)	0	(0)
Moderate			72	(21)	39	(14)	38	(17)	8	(1)
Severe			10	(3)	14	(5)	53	(24)	92	(11)
Total number examined				29		36		45		12

Table 4. Age/length distribution of summer flounder, Paralichthys dentatus, samples by sampling area and sex. (*u* = unsexed samples). Ages were determined from both scales and otoliths.

Length	New Jersey							Delaware/Maryland							Virginia							South Carolina								
	Age 0+			Age 1+		Age 2+		Age 0+			Age 1+		Age 2+		Age 0+			Age 1+		Age 2+		Age 0+		Age 1+			Age 2+			
	M	F	*u*	M	F	M	F	M	F	*u*	M	F	M	F	M	F	*u*	M	F	M	F	M	F	M	F	*u*	M	F	*u*	Totals
cm																														
10																	*1*													1
11																	*2*													2
12																	*1*													1
13																	*3*													3
14										*1*							*1*													2
15										*1*							*1*								2	*1*				4
16			*1*														*5*								1					7
17										*1*							*1*								2					5
18			*1*							*2*														1						4
19			*1*																						1					2
20			*3*					1																						4
21								1			1																			2
22																								1						1
23											2							2	1											5
24											1	1						1	2								1			6
25											4	1						5	2											12
26					1						4	1						6	2					1	1			1		17
27					1						5	3						4	1						1					15
28				5	1						3	3						5	2											19
29				4	2						1	4						1	2										*1*	15
30				1	8							2							2	1								1	*2*	17
31				3	3	1												2	1											10
32					1														2											3
33																														
34																														
35																			1											1
36																			1											1
Totals			6	13	17	1		2		5	21	15					15	27	18	1				3	8	1	1	2	3	159
Mean			*19*	*29*	*30*			*21*		*16*	*26*	*28*					*15*	*27*	*30*					*22*	*19*			*28*	*30*	

Table 5. Distribution of age "1" summer flounder, *Paralichthys dentatus*, first year scale growth pattern types with backcalculated fish length. Growth pattern types are arranged from left to right in order of predicted decreasing rate of fish growth.

	Scale Growth Pattern Types					
Fish length	"RR"	"RM"	"SR"	"SM"	"RS"	"SS"
cm						
8						
9						
10			1			1
11						
12						
13			2	1		1
14					1	3
15	1	1	1			1
16	2		1	2	2	4
17		1		2	2	5
18	1	1		2	1	3
19					4	2
20		2			2	1
21	1	1			2	
22	1	2		3	2	1
23	4	2	1			1
24	6	8	2	1		1
25	5	2	1	3		
26	2	2		2		
27	2	3	1	1		
28	1	1		1	1	
29	1	1				
30			1			
31						
Total	27	27	11	18	17	24
Mean	23	23	20	22	19	17

Table 6. Distribution of yearling summer flounder, *Paralichthys dentatus*, backcalculated fish length at age "1" by sampling area.

Fish length	Sampling area			
	New Jersey	Delaware/ Maryland	Virginia	South Carolina
cm				
8				
9				
10				1
11			1	
12				
13			1	3
14			3	1
15		2	2	
16		2	6	3
17		1	6	2
18		3	5	1
19		4	2	
20		3	2	
21	2	1	1	
22	1	3	5	
23	3	2	3	
24	3	10	3	2
25	5	3	3	
26	3	2	1	
27	7			
28	3		1	
29	2			
30			1	
Total	29	36	46	13
Mean	26	21	19	16

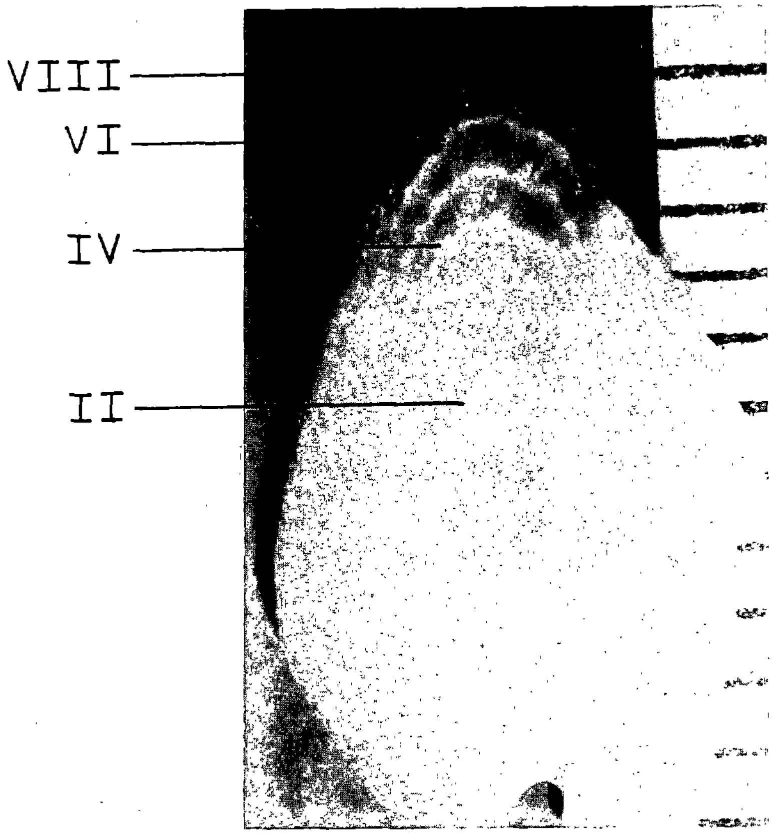

Figure 1. Left otolith from an age "8+" summer flounder, total length 69 cm, taken on 18 August. Estimated age indicated against respective opaque annuli (rule marking in mm.)

Figure 2. Fin ray thin section of an age "4+" summer flounder, total length 53 cm., taken in July. Estimated age indicated against respective hyaline annuli. (Fin ray under dark field transmitted light after treatment with clove oil.)

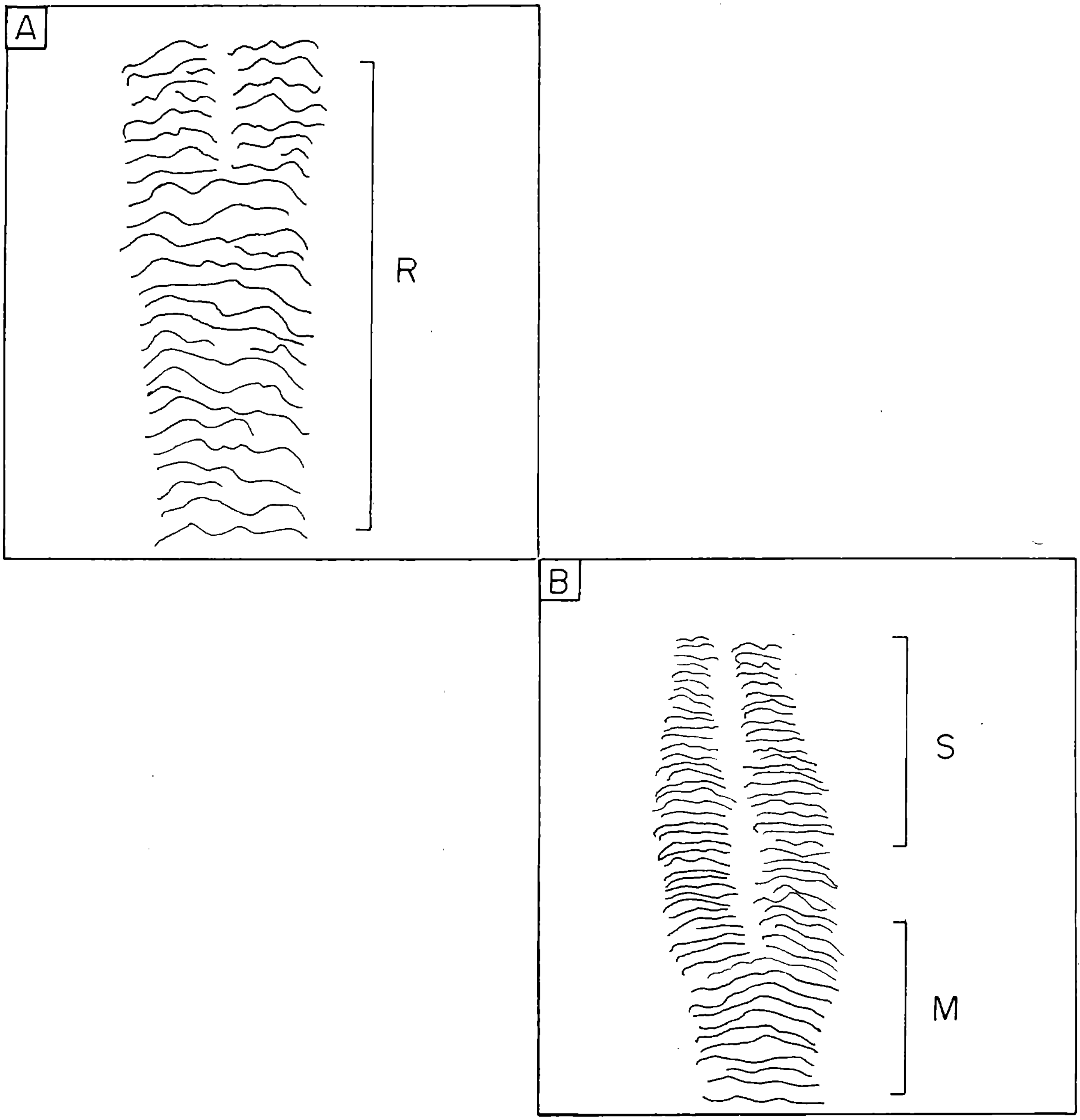

Figure 3. Summer flounder scale circuli patterns indicative of rate of growth. A. Circuli segments curved, fragmented, and widely spaced, indicating rapid fish growth (R). B. Circuli segments straight and narrowly spaced, indicating slow fish growth(s). Moderate growth (M) is also shown.

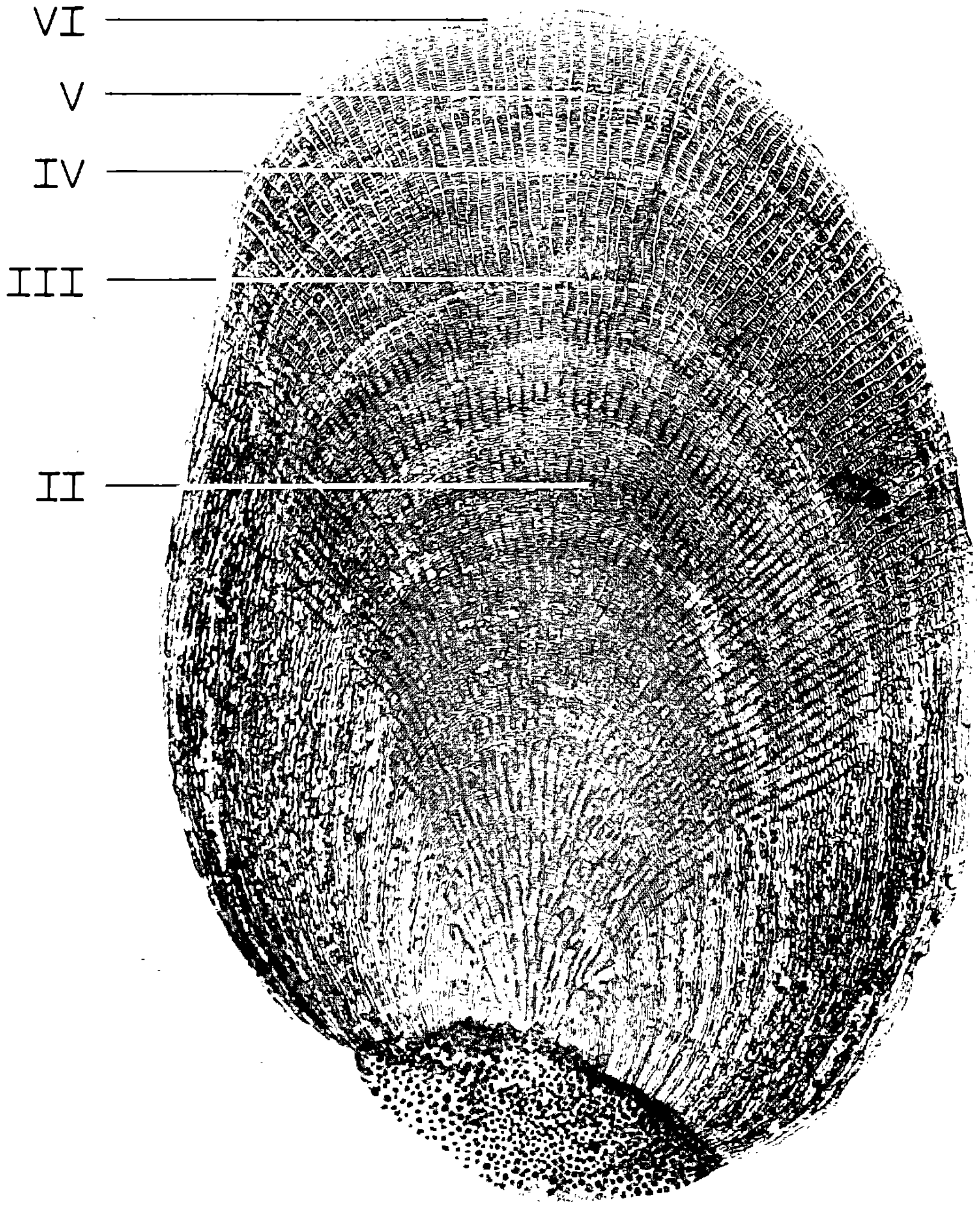

Figure 4. Scale of an age "6+" summer flounder, total length 66 cm., taken in July. Estimated age indicated against respective "cutting over" marks clearly defined from the third annulus to the edge. ("Cutting over marks of annuli one and two are obscure, as the entire scale was photographed, not the impression.)

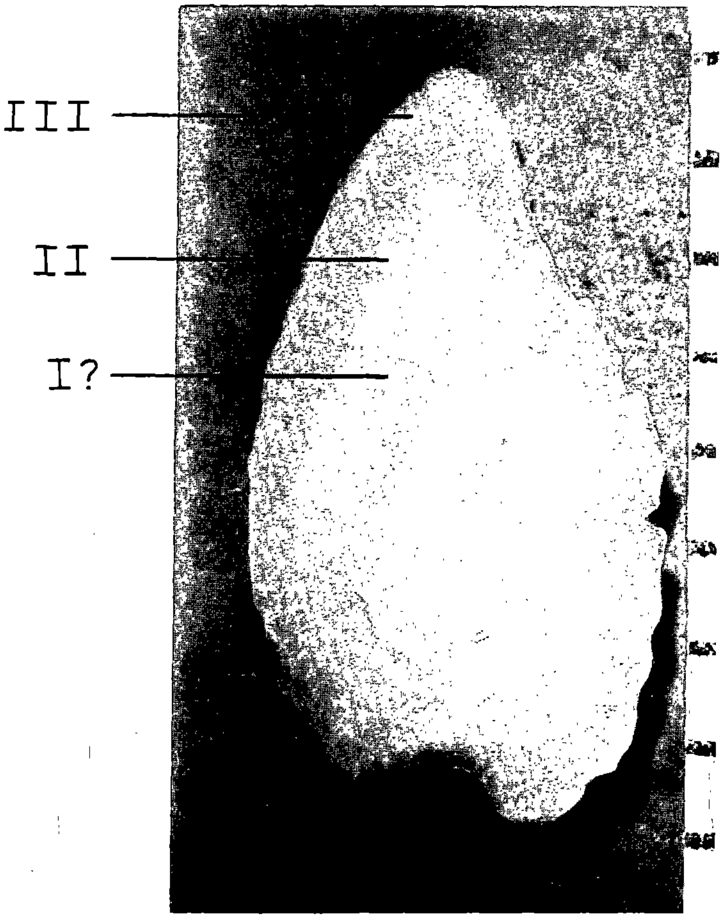

Figure 5. Left otolith from an age "3" summer flounder, total length 39 cm., taken on 15 June. Estimated age indicated against respective annuli (rule marking in mm.).

Figure 6. Age "1+" scale, growth pattern type "SS", of a 28 cm. summer flounder collected from the Rappahannock River, VA, in August.

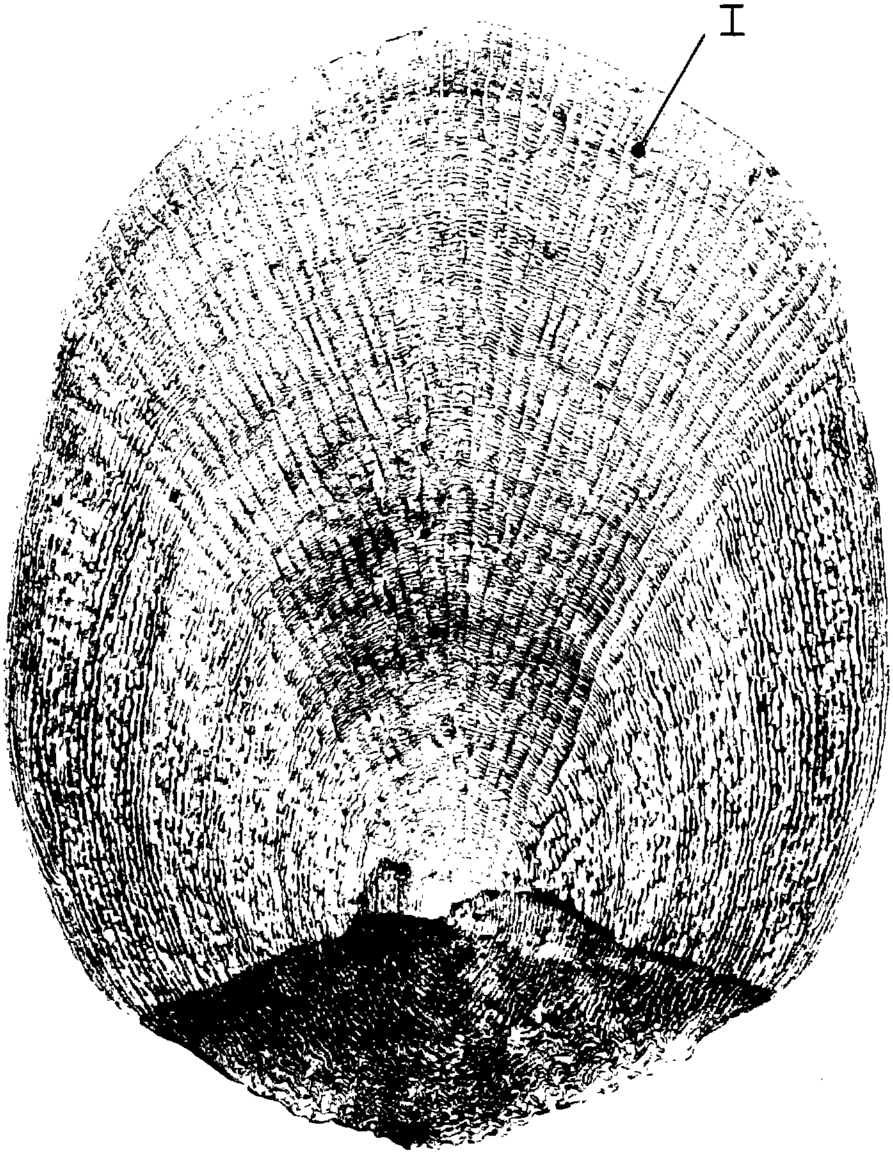

Figure 7. Age "1+" scale, growth pattern type "RR", of a 31 cm. summer flounder collected from Great Bay, NJ, in July.

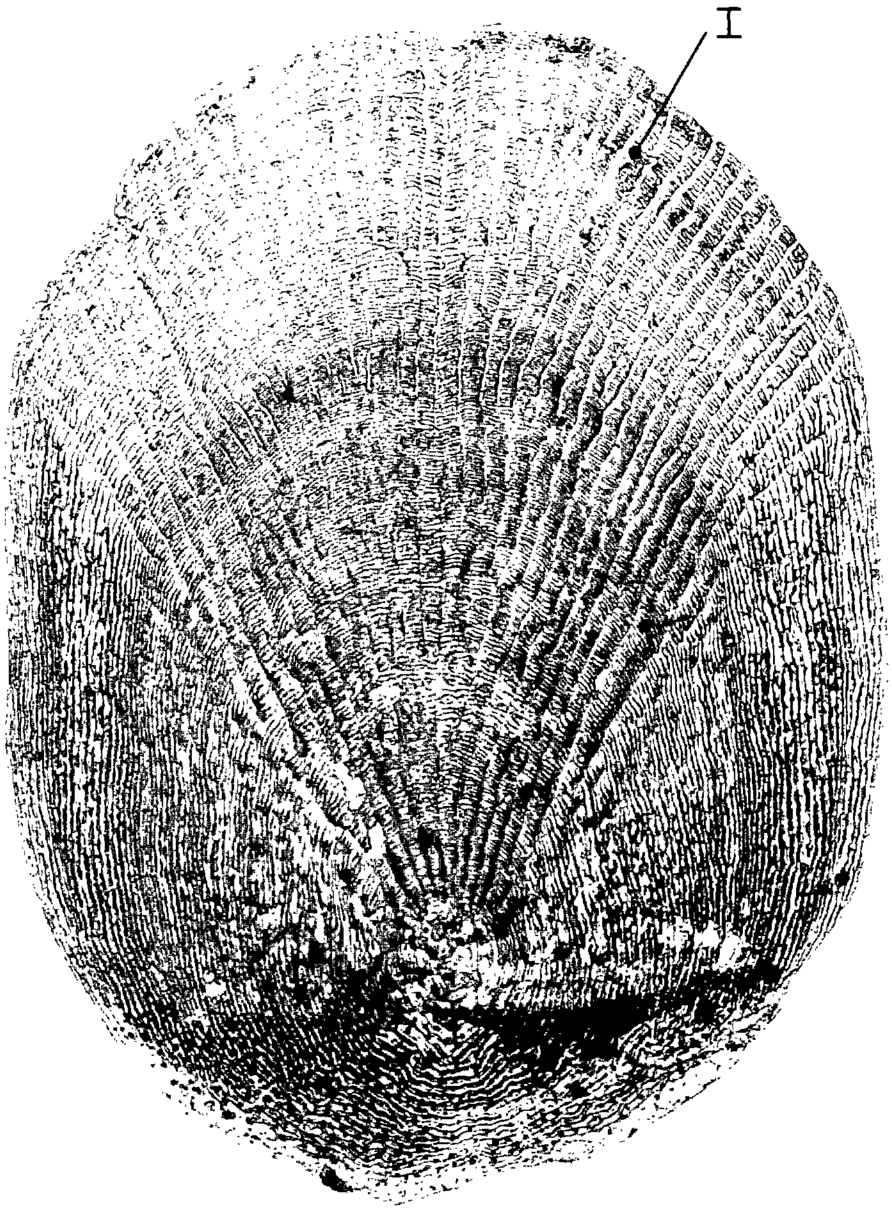

Figure 8. Age "1+" scale, growth pattern type "RM", of a 27 cm. summer flounder collected from the Indian River, DE, in July.

Figure 9. Age "1+" scale, growth pattern type "SM", of a 32 cm. summer flounder collected from the York River, VA, in July.

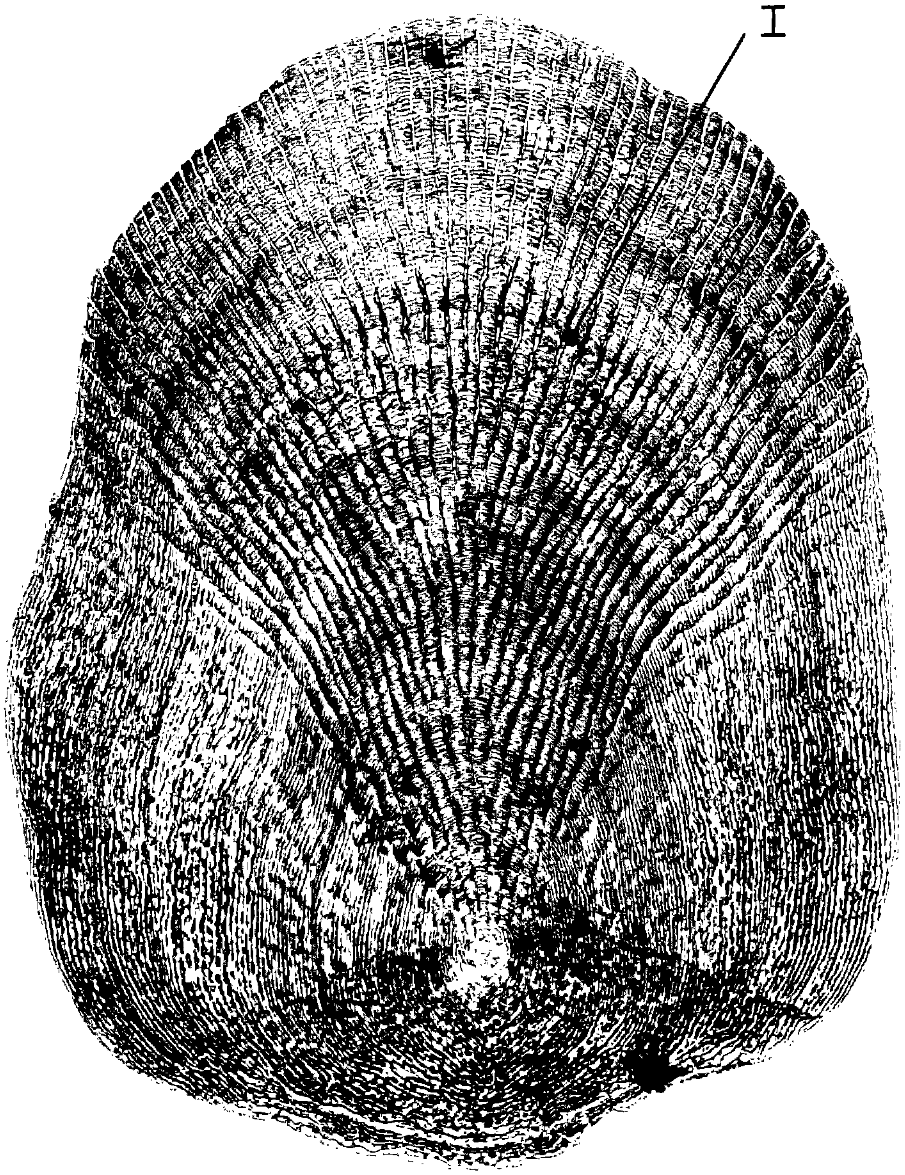

Figure 10. Age "1+" scale, growth pattern type "RS", of a 29 cm. summer flounder collected from Isle of Wight Bay, MD, in July.