ANNUAL MARKS ON SHELL AND LIGAMENT OF SEA SCALLOP (*PLACOPECTEN MAGELLANICUS*)

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ABSTRACT

The annual rings on the shell of the sea scallop are frequently weak or obscured by other rings caused by some nonannual stress. Methods are presented by which it is possible to locate the true annual rings by reference to marks on the resilium, changes in shell curvature, changes in color pattern, weight of the shell, and areas of attack by boring organisms. The results obtained are validated by comparing a growth rate derived through location of the annual rings with one derived from the growth increments of a large sample which had been tagged and released and recaptured after a year at large. The objectivity of the criteria used to identify the annual rings was tested.

ANNUAL MARKS

Many investigators have been able to determine the growth rate of various species of mollusks by identifying those rings on the shell that are caused by some consistent annual phenomenon. Measuring the amount of shell between the rings provides data from which it is possible to estimate growth rates for various areas and year classes. Canadian investigators (Stevenson and Dickie, 1954; Dickie, 1955) succeeded in applying this technique to the sea scallop, *Placopecten magellanicus* (Gmelin), of the Bay of Fundy. Dickie (personal communication) also succeeded, with some difficulty, in locating annual rings on the sea scallops of Georges Bank. His difficulty was caused by the fact that the annual rings are usually rather weak and frequently masked by the presence of strong shock rings. Sea scallops are rather sensitive creatures, and any serious disturbance causes them to mark the event with a shock ring on the shell (Posgay, 1950). The grounds that interest us most are those on Georges Bank, which sustain the heaviest fishing pressure and where concentrated dredging operations may cause uncaught scallops to form many shock rings (fig. 1).

Because of the difficulties of interpreting the rings on the shell, we have examined some of the other hard parts of the sea scallop for characteristics that might offer clues to age. The most useful of these structures proved to be the calcareous part of the resilium. Areas attacked by boring organisms, weight of the shell, color changes, and changes in the curvature of the shell also provided valuable clues to age.

This paper describes the methods used to determine the position of the annual rings, gives the result of applying them to a sample of shells, compares the derived growth rate with the growth rate determined from tagged and recaptured animals, and gives the result of an experiment testing the objectivity of the criteria. Each phase of the work was carried out by a different investigator to avoid subjective bias.

RINGS ON THE SHELL

The surface of the shell of the sea scallop is covered with a series of fine concentric lines (circuli) as a result of the addition of new shell along the margin during growth. At intervals,

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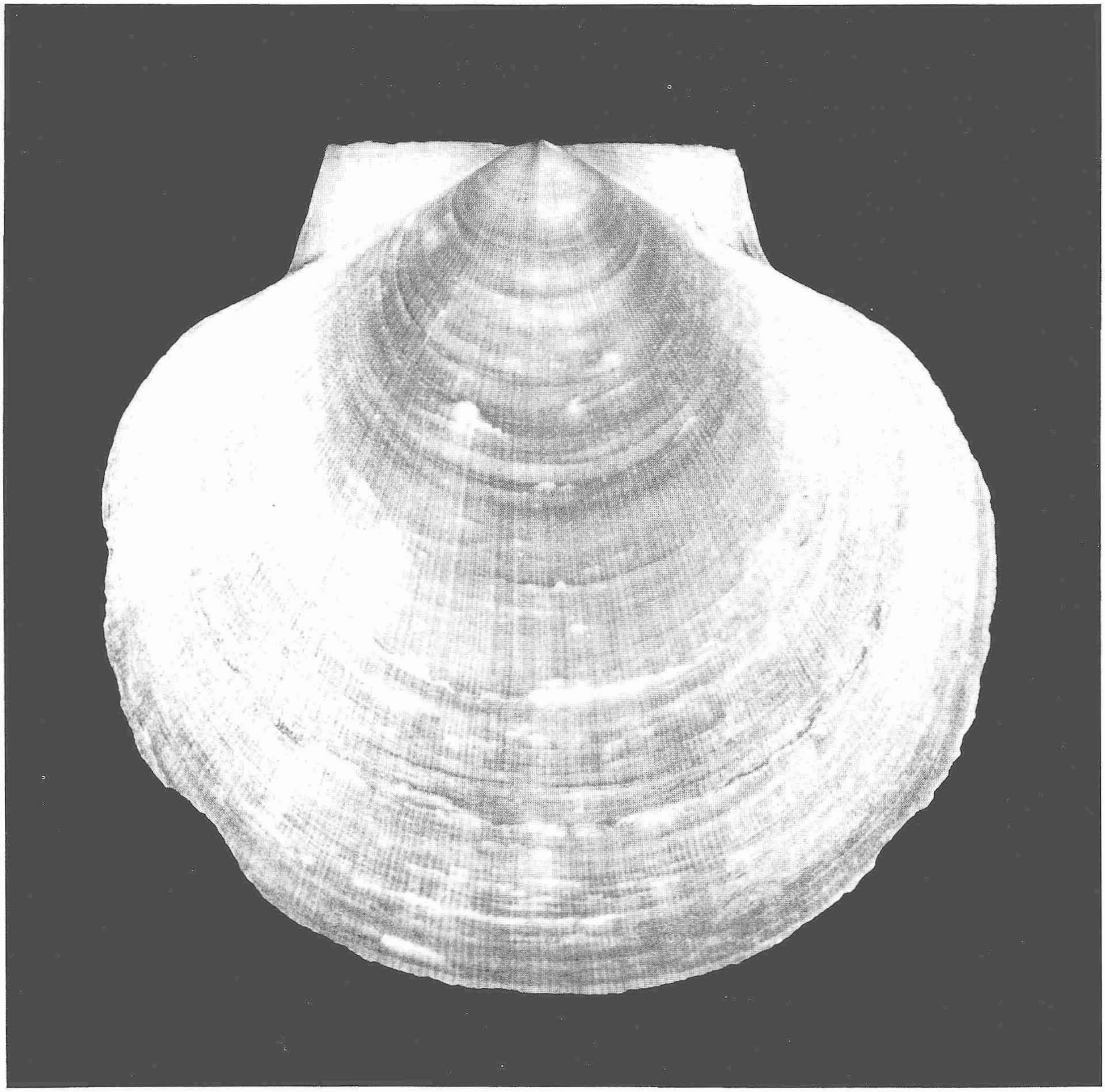

FIGURE 1.—Upper valve of sea scallop showing strong shock rings and weak annual rings.

the circuli are more closely spaced and give the appearance of a band or ring (fig. 2). These bands are laid down annually as the result of a decrease in the rate of growth much as has been demonstrated for tree rings and fish scales. Although the cause has not yet been demonstrated, we believe that it is low winter temperatures. Specimens from shallow water (fig. 3), where winters are more severe, have more prominent rings than those from deeper water where temperatures vary less. Georges Bank, with an average annual temperature range of 8°–12° C., has a particularly equable climate for sea scallops. Posgay (1953) has shown that sea scallops grow fastest at about 10° C. In his experiments, the rate dropped to about 95 percent of the maximum at 8° C. and to about 80 percent at 12° C.

In addition to the annual rings, most sea scallop shells exhibit other annuli which mark nonannual

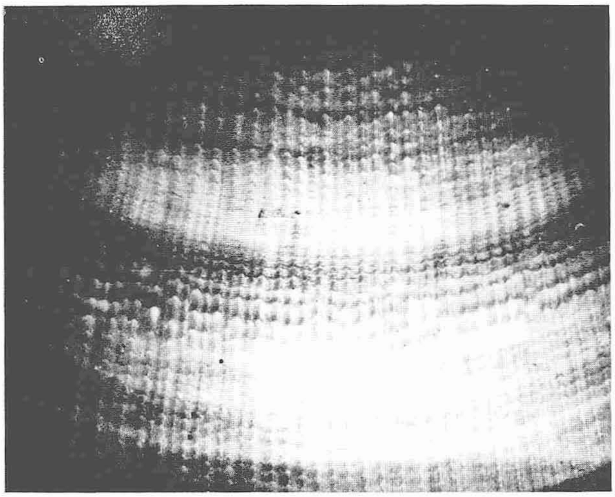

FIGURE 2.—Closeup view of a portion of the upper valve of a sea scallop, showing a band of narrowly spaced circuli between two areas of widely spaced circuli.

phenomena. In shallow water, a severe storm may cause sufficient disturbance on the bottom to cause the scallops to form shock rings. Offshore, shock rings are usually caused by dredging activities of the fishing fleet. Lightly fished areas yield unmarked scallops, while heavily fished areas yield scallops whose shells are a confusion of shock rings. These injuries are sometimes so severe as to distort the shape of the shell (fig. 4).

On Georges Bank, which provides more than 75 percent of the sea scallop catch, both phenomena, weak annual rings and many shock rings, combine to make the location of the annual rings difficult (fig. 1). Not all scallops, however, react in the same degree to the stress that causes the annual ring. Any reasonably large sample will contain some sensitive individuals bearing clear annual rings. Likewise, not all scallops are subjected to disturbances sufficient to cause many shock rings. It is usually possible, therefore, to sort out at least a few shells which are fairly easy to interpret. While such a small sample of selected individuals cannot give a valid estimate of the growth rate of the population, it can give an idea of what to expect from the rest of the sample. The more deeply curved valve, which is uppermost when the scallop is at rest, usually bears the clearest annual rings; but in some individuals, the lower valve will be more easily interpreted.

MARKS ON THE LIGAMENT

The structure and the function of the ligament in *Pecten* have been fully described by Trueman (1953a, and 1953b). The outer layer (fig. 5) unites the two valves and acts as a flexible hinge. The inner layer, the resilium, is composed of a large, dark-brown, conical, central structure of rubbery, noncalcareous material and two small lateral calcareous plates, which cement the resilium into a shallow socket, the resilifer, on each valve. The resilium acts as a sort of compressible spring working in opposition to the adductor muscle. When the muscle is relaxed, the resilium forces the margins of the valves apart.

As the scallop grows and adds new shell along the margins, it also adds new material to the ligament. When shell growth slows or ceases, ligament growth also slows or ceases producing a mark. The resilium, and the epithelial cells which produce it are well protected and less exposed to shock and injury than are the margins of the shell and the cells which produce it. Therefore, marks on the resilium caused by an annual period of slow growth are relatively more prominent compared with shock marks than are the corresponding marks on the shell. The spaces between the bands on the resilium are proportional to the spaces between the bands on the shell; hence, a specific area of the resilium can be referred to a corresponding part of the shell. This section of the shell can then be studied closely in search of the annual ring.

Figure 6 shows the upper valve of a sea scallop, selected because of its distinct annual rings and lack of strong shock rings, which has been sawed down the midline. The numbers indicate annual rings. Figure 7 shows the resulting cross section of the hinge area of the same scallop. The dark area in the center of the cross section is the resilium; the lighter areas immediately to the left and right are the calcareous plates. The numbered, darker bands on the plates and the constrictions of the resilium correspond to the five annual rings on the shell.

It is not necessary to make a cross section in order to observe the annual marks on the plates of the resilium. When the valves of a sea scallop are separated, the resilium usually splits down the middle. After drying for a few days, the remaining half of the resilium, including the attached

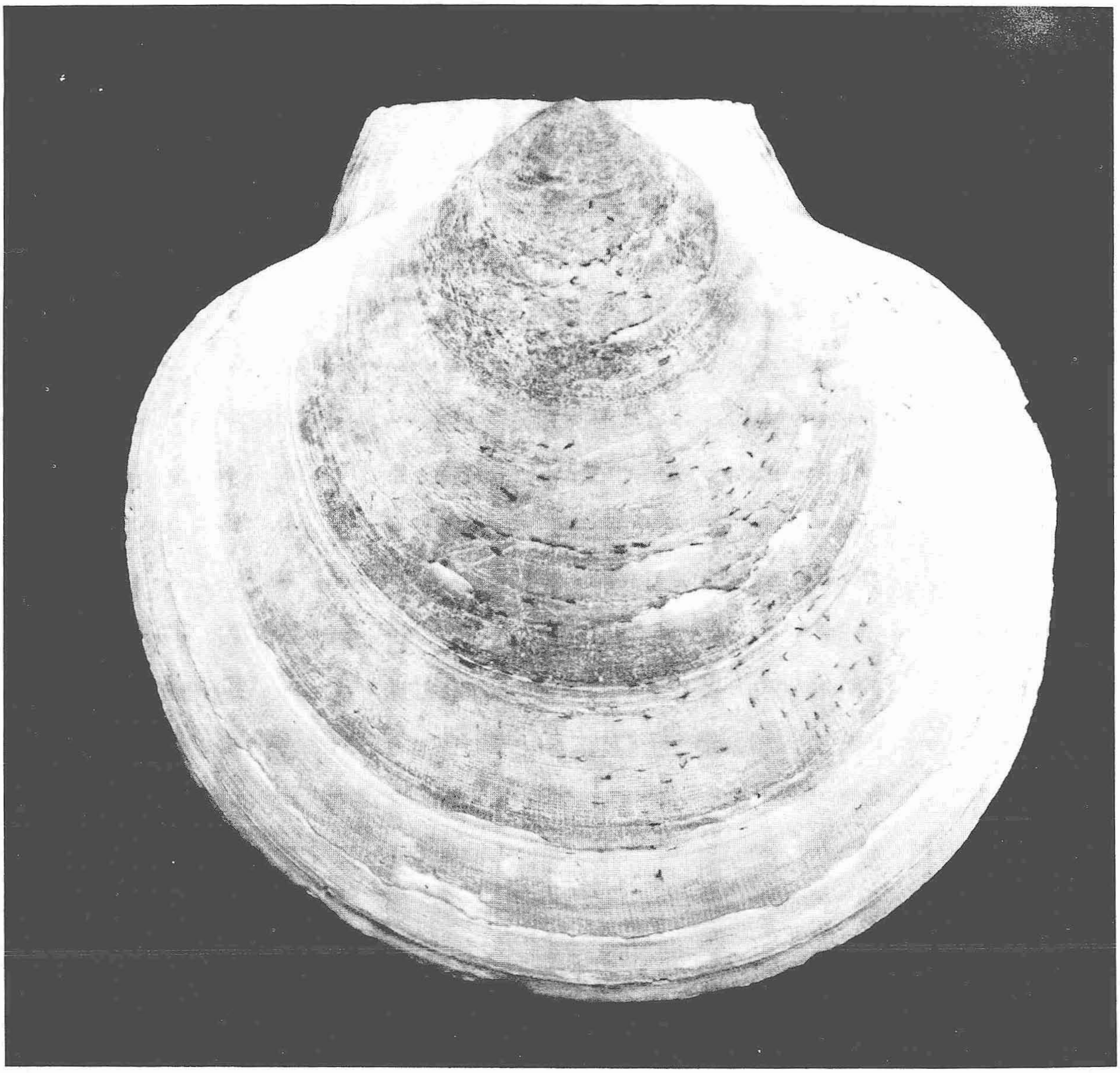

FIGURE 3.—Upper valve of a sea scallop taken from shallow water showing prominent annual rings.

calcareous plate, can be easily picked out of the resilifer. The plate can then be examined with a low-power microscope or hand lens (fig. 8). If the ligament has been lost, it is still possible to examine the corresponding impression on the resilifer.

OTHER SHELL CHARACTERISTICS

In some areas, annual invasions of boring organisms infect the upper valve of the sea scallop (figs. 6 and 9). The areas of heaviest infestation can be easily seen if the shell is held over a strong light. The annual rings can usually be located between the infected areas. The weight of the shell is sometimes an index of rate of growth. A thin shell is usually the sign of a fast growing individual; a thick, heavy shell usually means slow growth. Some shells exhibit areas of convex curvature between the annual rings (fig. 10). The profile of these shells, held at arm's length, show a series of hills and valleys. The annual rings can usually be found in the valleys. An occasional shell, or sample of shells from particular areas, will show changes in color pattern of an annual

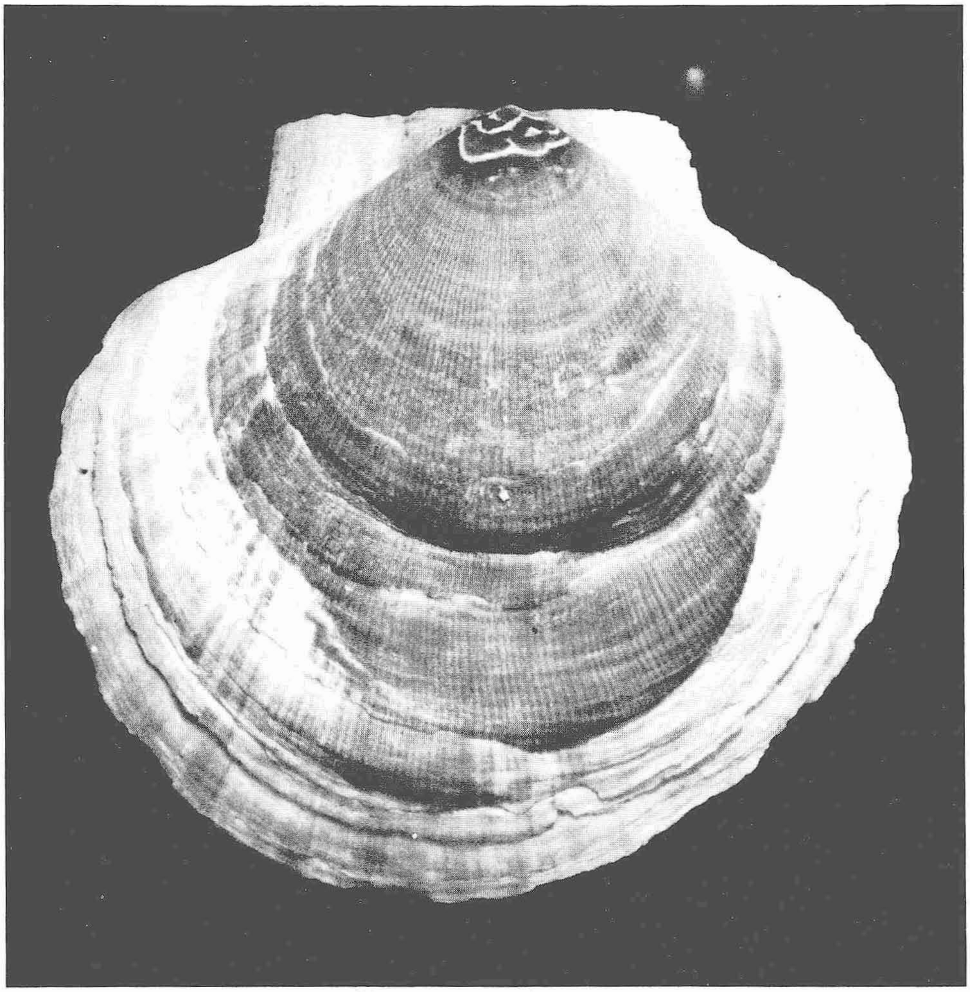

FIGURE 4.—Upper valve of a sea scallop taken from a heavily fished area, showing malformation as a result of injury to the mantle.

nature which may help to locate the rings (fig. 11). Figures 9, 10, and 11 represent selected individuals; obviously, not all shells are so strikingly marked.

READING A SAMPLE

The shells to be read must first be cleaned of all foreign matter. It is best to soak them in a strong solution of a nonbleaching detergent and then scrub them with a wire brush. The length frequency is determined to see if the sample is polymodal. We define length for these purposes as being measured along the greatest diameter of the shell from umbo to opposite margin. Shells that do not have a large number of shock rings and appear to have prominent annual rings are then sorted out. The shells and resilia of these individuals are studied first, and a preliminary table of length at time of annual ring formation is prepared.

With this table as a guide to the most probable location of the annual rings the rest of the sample is read. It is best to work from the smaller to the larger specimens. All of the clues mentioned previously are used as occasion demands and opportunity affords. The more difficult shells are set aside until the last when the averages and the deviations are more firmly established. These, as well as the larger, older shells with the annual rings near the margin crowded together, can usually be best interpreted by reference to the resilia.

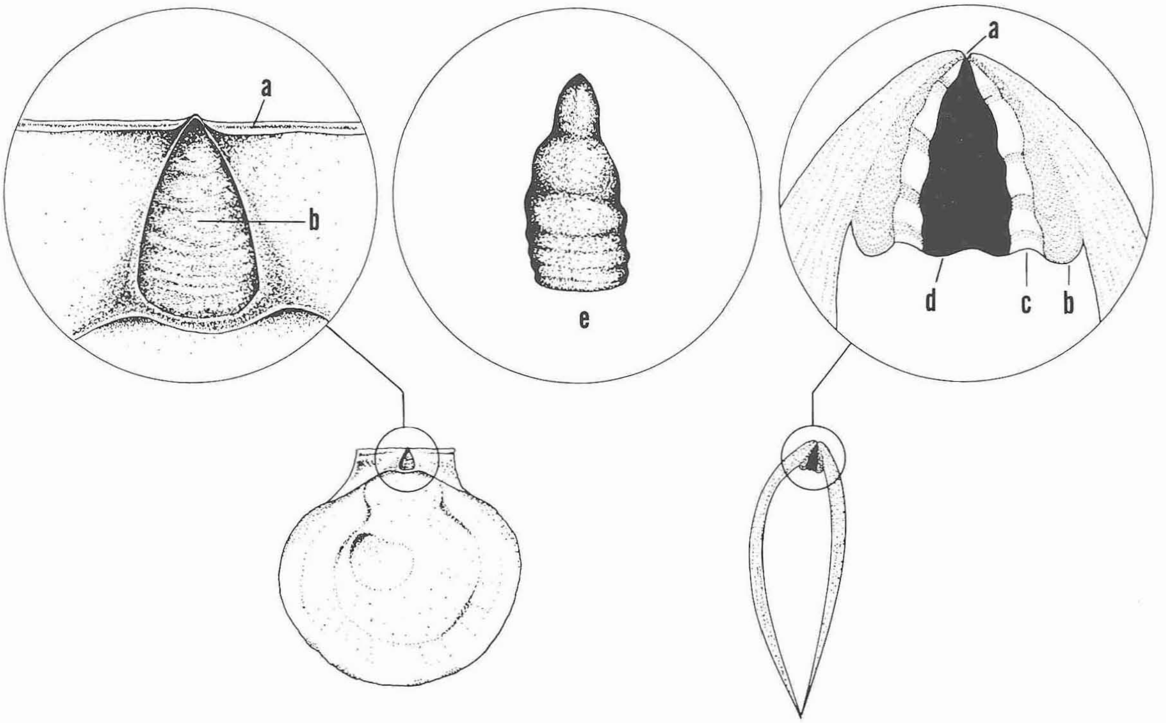

FIGURE 5.—Hinge and ligament of the sea scallop. (a) Outer layer of the ligament at hinge line, (b) resilifer, (c) calcareous plates of the resilium, (d) compressible part of the resilium, and (e) surface view of calcareous plate.

VALIDATION OF THE METHOD

In September of 1957, we had tagged and released 5,375 sea scallops on the northeast peak of Georges Bank. A fine hole is drilled in the ear of the upper valve just over the byssal notch in the lower valve. A stainless steel pin, bearing a numbered Petersen disc and a 6-inch yellow plastic streamer, is pushed through the hole and bent over to hold the tag securely (fig. 12). The animal is not wounded but the disturbance of dredging, handling, and tagging is sufficient to put a strong shock ring on the shell. The margin is nicked with a triangular file so that this tagging shock ring can be identified with certainty later. After recapture it is simple to measure how much new shell has been added since the date of tagging and, with a large enough sample, calculate the growth rate.

This particular tagging experiment had been very successful and we had a great many shells from recaptured animals. One group of 411 had been recaptured only a few weeks after release and therefore had added very little new shell. With the techniques described previously, the annual rings on this group were located and the shell lengths at the time of formation of each ring measured (table 1). The Walford (1946) regression equation calculated from the average length at the time of ring formation is: $L_{t+1}=42.4+0.706\ L_t$ (equation 1).

We also had 392 shells from animals that had been captured, tagged, and released at the same

TABLE 1.—*Average length (mm.) at time of ring formation for 8 year classes in sample of 411 sea scallops and average for all year classes combined*

Ring No.	Year class								Average
1	22.0	20.4	21.3	20.6	23.5	21.1	18.9	24.7	20.7
2	54.1	52.7	52.1	50.7	55.5	50.6	52.7	56.3	52.6
3	84.4	80.8	80.5	78.6	79.6	78.2	80.3	83.3	80.7
4	------	100.9	100.3	97.4	97.9	97.8	97.9	99.1	98.7
5	------	------	112.4	110.7	110.5	109.4	110.5	110.3	110.6
6	------	------	------	120.4	119.9	119.3	119.6	119.2	119.7
7	------	------	------	------	126.4	126.9	127.4	126.3	126.7
8	------	------	------	------	------	132.2	132.3	131.8	132.1
9	------	------	------	------	------	------	136.1	136.2	136.1
10	------	------	------	------	------	------	------	139.2	139.2
Number in year class	36	74	98	88	50	36	17	14	------

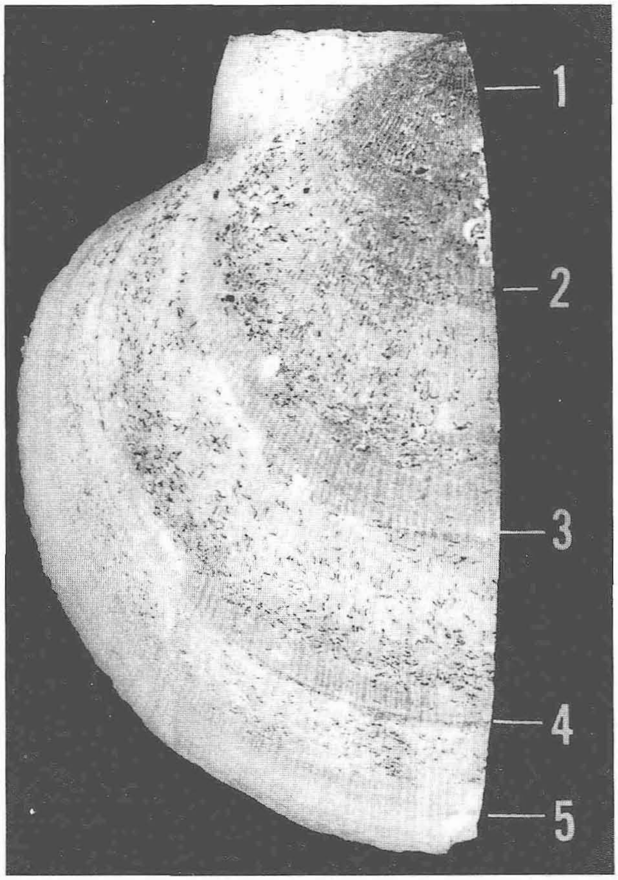

FIGURE 6.—Sea scallop shell with five prominent annual rings. The shell between the rings shows annual attacks by boring organisms.

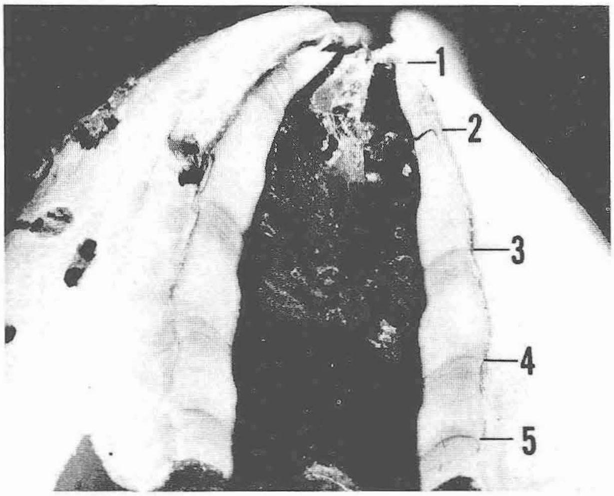

FIGURE 7.—Cross section of hinge of sea scallop showing annual marks in the calcareous plates of the resilium.

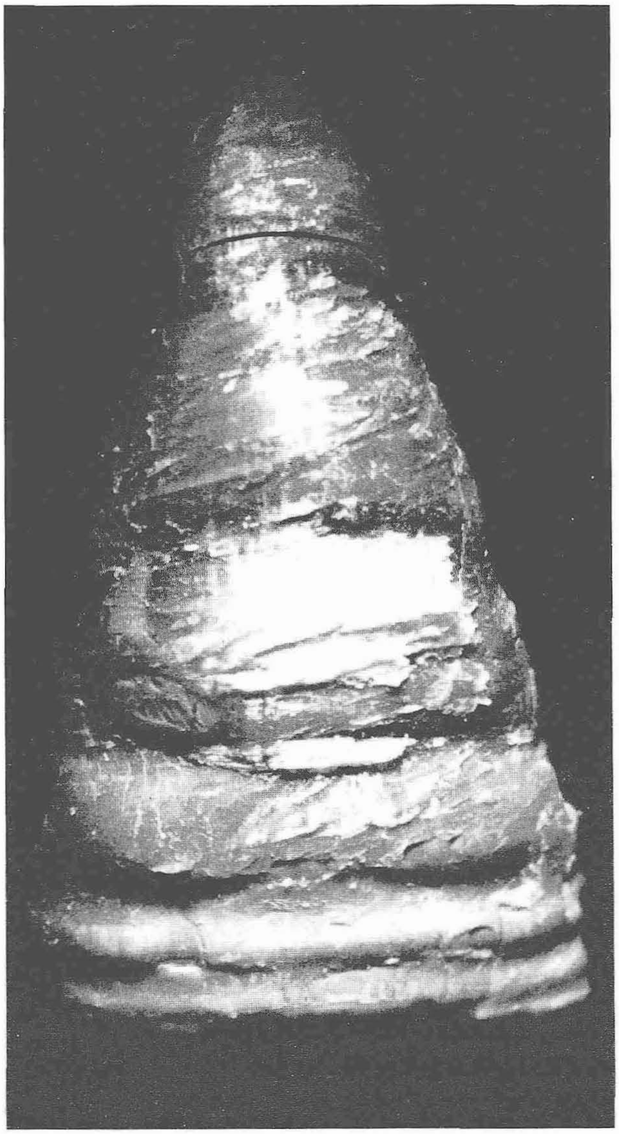

FIGURE 8.—Calcareous plate of a resilium showing banding and constriction in response to some annual stress.

time and location but which had been at large from 48 to 68 weeks before being recaptured. These shells were grouped by 2-week intervals, and the length when tagged (L_g) and the length when recaptured (L_r) measured on each one (table 2). The Walford (1946) regression of length at recapture on length when tagged was then calculated for each of the five groups. The tabulation below shows the number in each sample, the time at large, and the slope and intercept of the regression equations.

Sample No.	N	Weeks out	Slope	Intercept
1	140	49.6	0.6384	50.30
2	89	58.1	.6430	50.53
3	46	60.7	.6601	48.16
4	62	64.1	.5897	57.20
5	55	66.7	.5879	57.42

These regression equations, each of which represented growth for a different time interval, were then transformed to a common, 52-week, time interval using Lindner's (1953) method.

Sample No.	Weeks out	Slope	Intercept
1	52	0.6248	52.21
2	52	.6735	46.21
3	52	.7005	42.43
4	52	.6516	48.57
5	52	.6608	47.26

Taking an average slope and intercept gives $L_{t+1}=47.3+0.662\ L_t$ (equation 2) as the estimate of growth per year by this method.

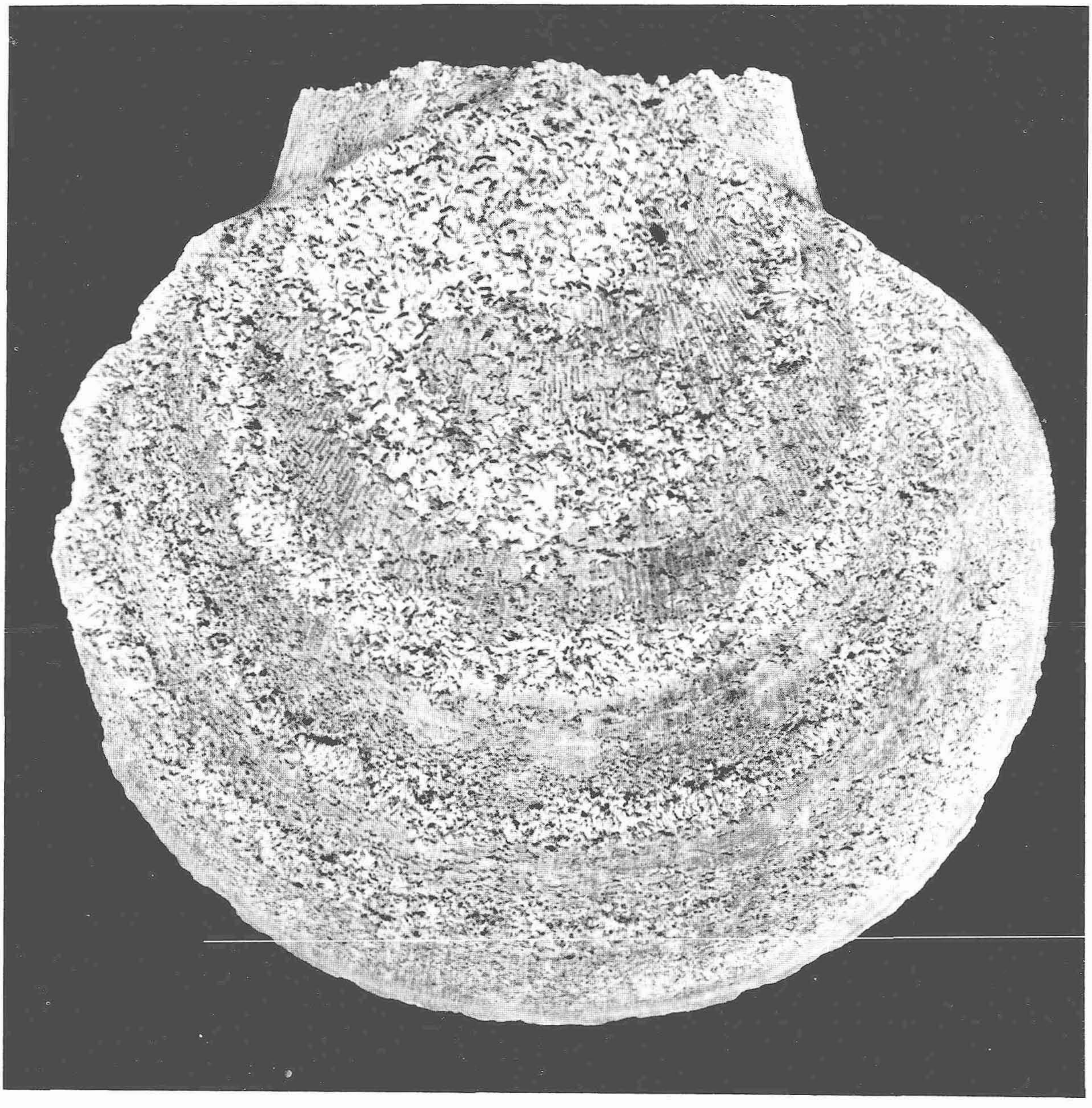

FIGURE 9.—Upper valve showing the result of heavy invasion of boring organisms. The annual rings are located between the areas of heaviest damage.

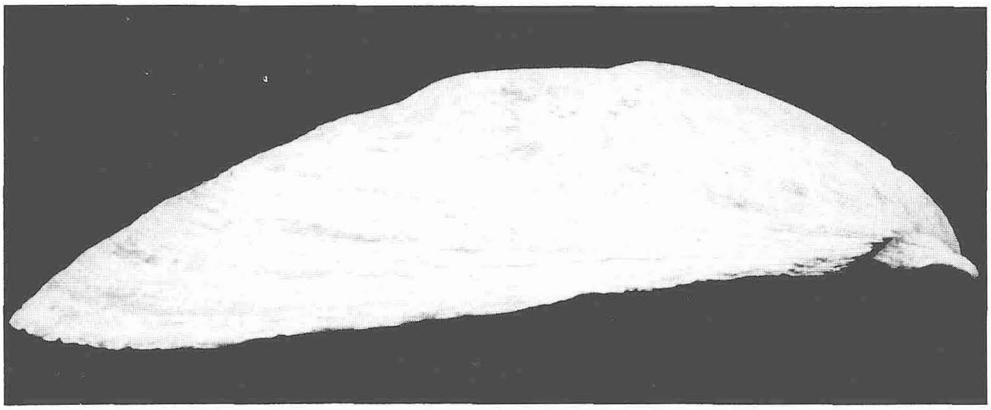

FIGURE 10.—Profile of the upper valve of a sea scallop. The annual rings are found in the areas of concave curvature.

TABLE 2.—*Length (mm.) of 392 sea scallops when tagged* (L_g) *and released at latitude 41°52′ N., longitude 66°23′ W., on Sept. 22, 1957, and when recaptured* (L_r) *about 1 year later*

SAMPLE 1, OUT 49.6 WEEKS

L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r
85.0	109.6	102.2	115.0	111.9	120.5	119.2	126.9	125.4	128.7
89.1	110.2	102.5	120.6	112.0	124.9	119.2	127.7	125.4	130.7
89.9	107.1	102.6	116.1	112.2	120.9	119.2	132.3	125.7	135.0
90.1	104.7	102.8	120.6	112.3	125.9	119.3	122.3	126.2	129.4
90.8	110.1	103.3	113.8	112.8	123.1	119.4	126.2	126.3	133.1
90.9	111.0	104.2	117.3	114.0	120.0	119.5	122.3	126.5	129.4
91.0	106.5	104.7	115.7	114.1	123.2	119.6	125.1	126.5	132.1
92.0	109.8	105.0	113.9	114.7	123.4	119.9	124.1	126.7	132.2
92.2	106.8	105.7	115.0	114.7	123.6	120.0	127.7	126.7	132.4
93.6	112.0	105.9	115.0	115.2	117.7	120.2	127.7	127.4	131.8
95.3	115.0	106.4	120.0	115.5	124.1	120.2	129.3	127.4	132.6
95.4	114.9	107.0	117.9	115.9	121.4	120.6	125.4	127.7	132.0
95.6	108.5	107.1	119.6	116.1	125.1	120.6	125.6	127.8	130.7
96.3	113.2	107.1	120.0	116.1	127.7	121.1	126.1	128.7	131.5
96.5	113.9	108.2	115.7	116.3	127.2	121.2	124.3	129.4	134.2
96.6	102.2	108.7	119.0	116.4	124.0	121.3	127.4	129.8	137.0
97.1	117.1	108.9	117.2	116.4	126.0	121.3	129.8	130.4	135.0
97.4	112.0	109.1	121.8	116.9	123.0	121.4	125.4	131.0	136.4
97.5	119.8	109.6	119.3	117.1	123.3	121.8	125.8	131.3	133.4
97.6	109.3	109.8	122.8	117.4	126.5	122.4	130.2	131.6	135.8
99.5	116.1	110.2	120.4	117.8	126.7	122.5	126.5	131.6	136.1
100.5	113.6	110.2	121.6	117.9	122.5	122.8	126.2	131.8	134.4
101.3	109.2	110.4	122.3	118.0	125.6	122.9	130.8	132.6	139.4
101.5	107.5	111.6	119.0	118.0	126.5	123.6	126.9	132.8	135.8
101.6	108.6	111.6	122.0	118.0	127.9	123.7	125.0	133.4	136.9
101.6	115.0	111.6	122.4	118.2	126.2	123.7	126.4	133.7	137.6
101.7	115.4	111.7	123.7	118.6	125.3	123.7	129.9	134.3	137.6
101.8	113.1	111.7	123.0	118.8	125.6	124.9	132.8	134.4	136.6

SAMPLE 2, OUT 58.1 WEEKS

L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r
85.6	106.0	100.7	120.0	111.8	120.4	119.2	125.0	127.1	134.7
86.9	107.3	101.7	115.8	112.4	120.5	119.7	129.1	127.2	133.5
87.9	105.1	101.8	111.6	112.6	126.2	120.0	129.3	128.5	136.4
88.8	113.9	103.0	116.6	113.3	120.4	120.6	129.9	129.7	133.4
90.3	115.3	103.5	115.2	113.5	119.4	121.0	126.0	130.7	137.6
90.9	103.0	104.5	115.2	113.9	123.8	121.3	126.0	130.9	135.0
90.9	108.3	104.9	115.6	114.4	120.6	121.4	128.5	131.0	134.5
90.9	114.4	105.0	117.2	115.0	125.6	121.9	127.0	131.0	135.3
91.8	105.7	106.2	117.4	115.4	123.9	122.8	134.1	132.9	135.4
91.9	112.3	106.3	118.5	115.6	125.4	122.9	127.9	133.7	136.7
94.7	107.5	107.1	121.8	115.9	127.1	124.0	133.8	133.8	138.3
95.0	115.3	107.2	118.9	115.9	127.5	124.6	129.7	133.9	136.4
95.3	113.3	109.1	116.9	116.1	124.0	124.9	128.1	134.0	137.3
98.6	110.4	109.4	118.7	116.2	125.6	125.0	128.9	134.4	140.6
98.6	116.1	110.7	118.5	117.4	123.3	126.0	133.4	134.6	136.1
99.4	114.8	110.8	124.0	117.8	123.5	127.0	131.5	136.1	136.7
99.6	116.2	111.1	121.2	118.2	124.7	127.0	133.8	141.1	143.1
100.5	118.9	111.7	126.0	118.7	121.9	127.1	130.9	-------	-------

TABLE 2.—*Length (mm.) of 392 sea scallops when tagged* (L_g) *and released at latitude 41°52′ N., longitude 66°23′ W., on Sept. 22, 1957, and when recaptured* (L_r) *about 1 year later*—Continued

SAMPLE 3, OUT 60.7 WEEKS

L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r
85.5	106.0	99.3	113.2	108.3	123.3	117.7	122.7	127.1	131.7
90.4	106.8	100.8	114.3	109.7	117.0	119.1	128.8	129.8	131.9
93.0	109.4	102.1	111.5	110.7	121.2	120.8	127.8	130.4	132.9
94.8	111.0	102.1	116.5	110.9	117.2	121.5	126.5	133.1	137.6
96.3	114.9	104.8	117.3	111.4	116.8	121.9	126.3	133.3	136.0
97.7	113.9	104.9	118.2	112.9	125.9	123.4	131.4	133.9	137.1
97.8	119.6	105.5	119.8	113.0	119.8	123.9	129.9	135.4	140.1
98.0	110.0	106.4	118.1	114.2	126.5	124.6	131.7	135.9	137.3
99.0	106.5	108.2	124.4	116.0	124.0	126.7	130.1	147.3	147.7
99.0	115.7	-------	-------	-------	-------	-------	-------	-------	-------

SAMPLE 4, OUT 64.1 WEEKS

L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r
86.2	110.3	99.3	120.8	109.2	123.3	116.4	123.3	125.4	131.4
87.6	107.3	99.7	118.3	109.3	115.5	116.4	125.1	127.5	131.6
88.9	110.9	99.7	118.5	109.9	119.6	117.9	125.7	128.9	130.8
90.2	110.0	100.5	113.1	110.9	120.3	118.4	125.2	129.1	136.5
93.1	117.3	101.2	117.0	111.5	122.9	119.2	125.2	129.2	134.6
93.5	115.6	101.3	118.1	111.5	123.5	120.5	131.4	129.7	134.4
93.9	113.3	104.1	121.0	111.6	124.0	121.3	133.6	130.3	132.5
95.9	114.0	104.3	119.5	111.9	123.0	122.0	128.5	133.3	140.2
97.4	114.0	105.1	120.7	113.3	122.4	122.5	132.4	136.6	138.3
97.6	114.3	105.7	121.5	113.9	122.8	122.9	128.2	137.9	139.0
97.6	121.8	106.0	118.5	115.5	119.3	123.4	129.2	138.4	140.1
98.2	113.2	107.6	112.9	115.7	124.1	123.8	129.2	143.7	145.5
98.5	108.1	108.4	117.4	-------	-------	-------	-------	-------	-------

SAMPLE 5, OUT 66.7 WEEKS

L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r	L_g	L_r
86.8	104.8	104.2	116.2	111.5	126.1	117.9	125.1	128.5	130.1
92.2	117.9	105.7	119.2	112.9	121.1	120.9	130.6	128.6	130.5
93.1	114.5	105.9	115.3	114.2	126.5	121.0	128.8	129.5	131.0
94.8	117.5	106.7	119.2	114.9	121.7	122.1	127.7	129.7	131.1
95.1	116.2	107.6	123.3	115.1	120.4	122.3	128.0	129.8	132.7
95.1	117.7	107.8	120.1	115.2	127.5	123.5	127.4	130.3	134.0
98.6	115.3	109.3	120.3	115.3	126.7	124.7	127.7	130.4	136.8
100.1	113.3	109.4	120.6	116.7	124.9	125.6	133.2	136.7	138.2
100.8	116.0	110.2	119.2	116.8	123.9	126.9	132.2	139.3	140.2
100.8	116.8	110.3	127.5	117.2	128.9	127.0	137.5	141.8	143.7
100.9	113.0	110.4	124.2	117.8	125.5	128.2	132.4	149.3	150.1

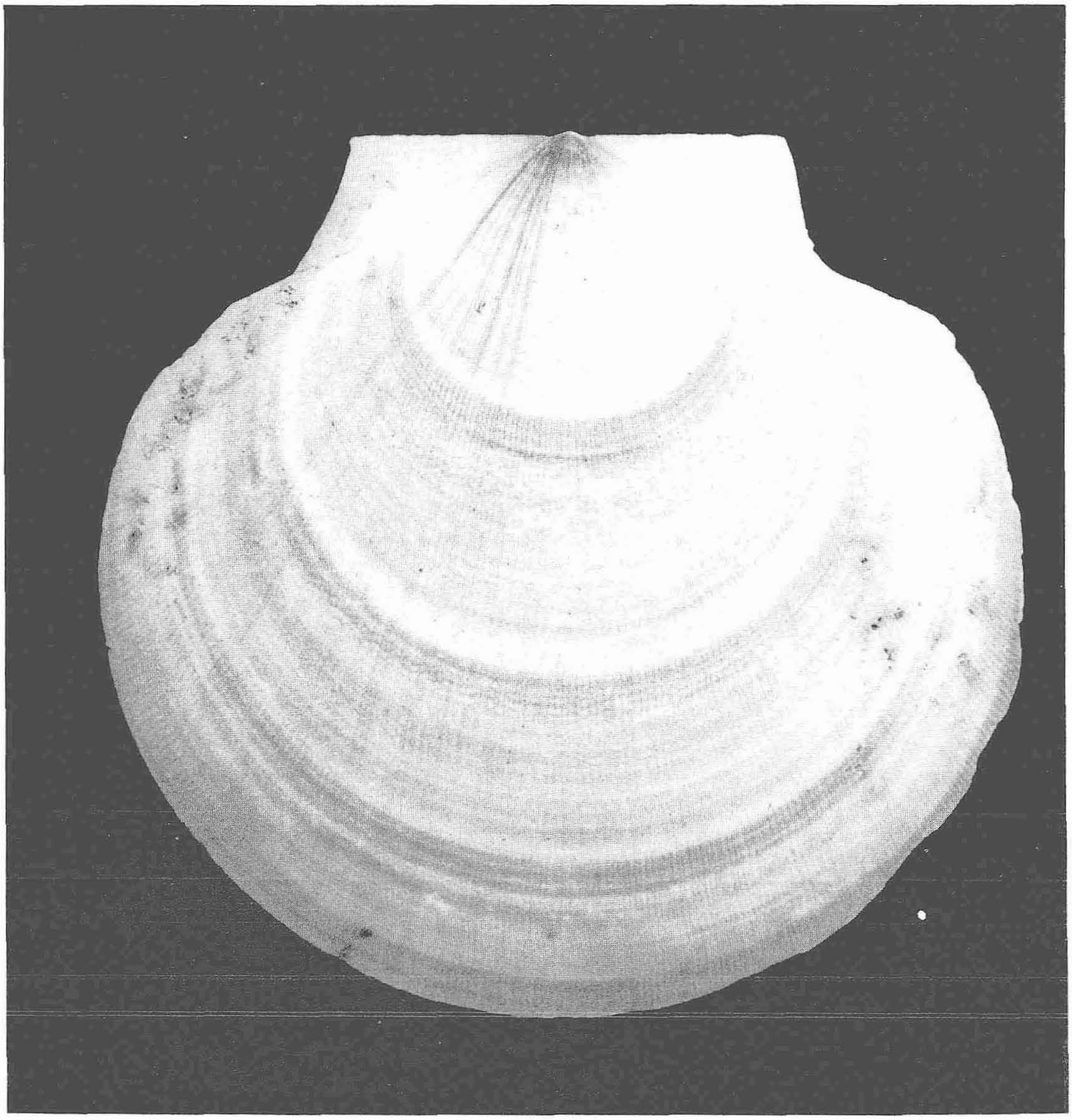

FIGURE 11.—Upper valve of a sea scallop showing seasonal change in color.

We have calculated the length at age for the 4 years following recruitment of sea scallops to the fishery using both growth-rate equations.

Item	Age				
	t	$t+1$	$t+2$	$t+3$	$t+4$
Equation 2	85.0	103.7	116.1	124.3	129.7
Equation 1	85.0	102.4	114.7	123.4	129.5

It is clear that the two equations, derived by different methods, give essentially the same results. We, therefore, have confidence in growth rates calculated by either method, and that our methods of locating annual rings are valid.

AGE AT RING FORMATION

It is interesting to note that, despite the strong check mark put on the shell at time of tagging, the tags apparently did not inhibit growth. Also, if we assume that there is little seasonal variation in the growth rate on Georges Bank, for those scallops that had been out for about a year, we can estimate the time of year when the annual ring is laid down from the position of the ring on the shell between the check mark made at time of tagging and the margin. On this basis, the 1958 ring appears to have been laid down about 27 weeks after the date of tagging. This places ring formation at March 30, just 6 months after October 1, which is the usual date of spawning by sea scallops in this area (Posgay and Norman, 1958). The true age at the time of ring formation in this area is, therefore, the number of the ring minus one-half year. There is a possibility, now under investigation, that the first definable ring, at about 20 mm., is not laid down during the first year of life but rather in the second.

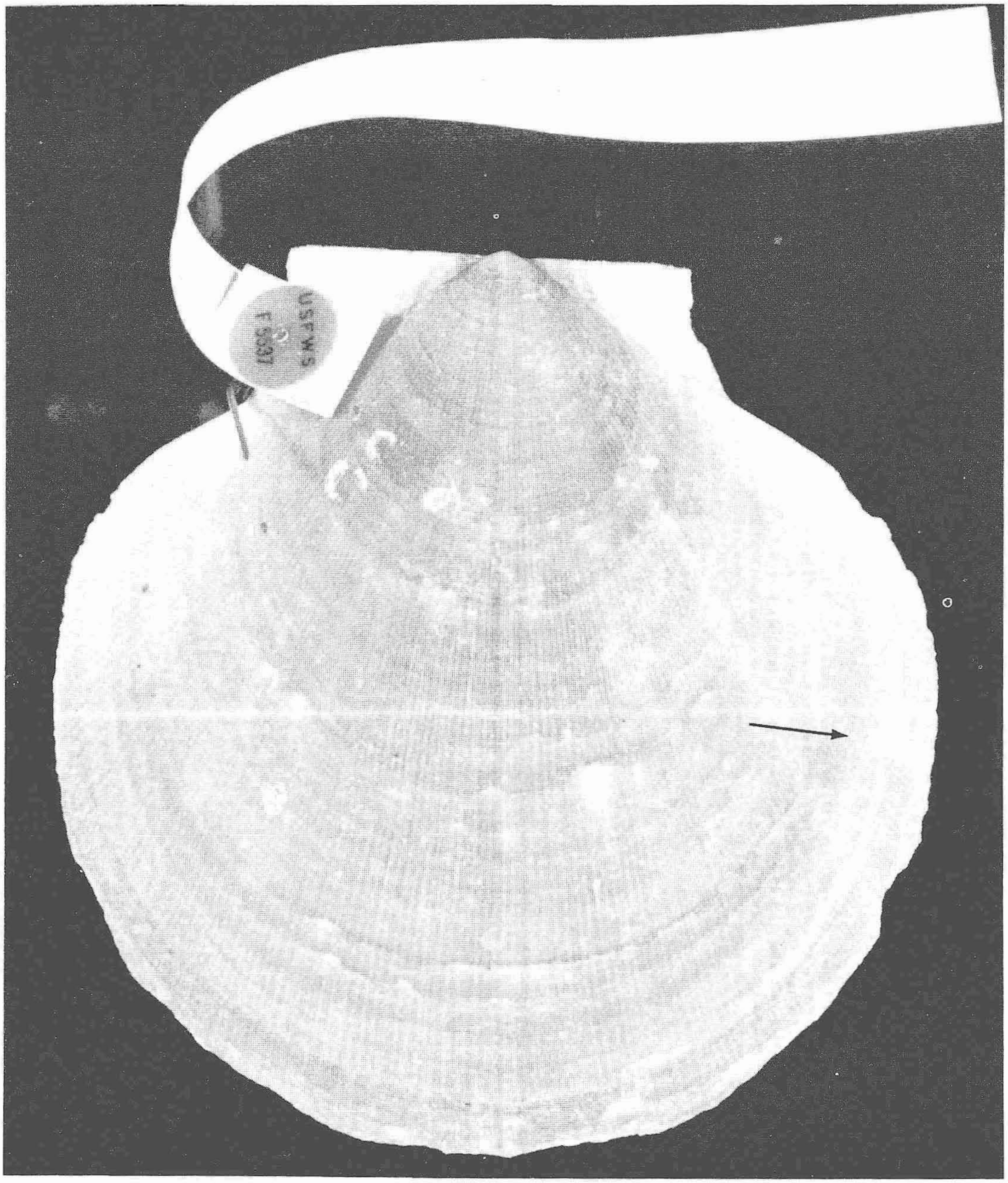

FIGURE 12.—Upper valve of a sea scallop that has been tagged, released, and recaptured. (The arrow points to the nick which was made in the margin at the time of release.)

TABLE 3.—*Age structure and average length (mm.) at time of ring formation in sample of 351 sea scallop shells determined independently by 2 readers*

Number of rings on the shells	Average length							Grand average
	3	4	5	6	7	8	9	
Reader No. 1:								
Ring number								
1	21.6	20.4	19.6	19.8	19.6	18.0	17.9	19.6
2	58.3	54.6	53.9	55.4	55.2	53.2	54.7	55.0
3	84.5	80.8	79.9	83.4	81.0	81.3	80.1	81.6
4	----------	95.9	96.0	99.3	98.3	100.9	95.9	97.7
5	----------	----------	106.9	109.9	110.3	113.3	109.2	109.9
6	----------	----------	----------	116.8	117.6	122.4	117.9	118.7
7	----------	----------	----------	----------	123.0	128.1	125.4	125.5
8	----------	----------	----------	----------	----------	131.2	131.5	131.3
9	----------	----------	----------	----------	----------	----------	133.8	133.8
Number in ring group	85	71	75	57	37	17	9	----------
Reader No. 2:								
Ring number								
1	21.2	20.5	20.0	19.7	19.7	19.9	18.2	19.9
2	56.1	53.2	53.8	55.0	54.9	51.5	54.9	54.2
3	85.8	83.5	81.2	82.5	81.2	79.7	80.8	82.1
4	----------	98.7	98.3	99.8	98.6	98.7	97.7	98.6
5	----------	----------	109.2	111.9	110.6	110.5	109.1	110.3
6	----------	----------	----------	118.6	118.4	120.4	118.4	118.9
7	----------	----------	----------	----------	123.8	126.7	125.6	125.4
8	----------	----------	----------	----------	----------	130.1	131.5	130.8
9	----------	----------	----------	----------	----------	----------	133.5	133.5
Number in ring group	93	87	66	47	34	12	12	----------

OBJECTIVITY OF THE CRITERIA

To test whether our criteria for determining which annuli were annual rings were sufficiently objective, a summer assistant, William Evoy of Reed College, was trained in the reading technique. He was then given a sample of 351 shells to age and measure, after which the same sample was read by the senior author.

The correspondence of results was very good (table 3). There was disagreement on the number of rings, but never by more than one, on about 10 percent of the shells and a few additional disagreements as to position of the annual ring. The growth-rate equations calculated from the two sets of data were virtually indistinguishable, as shown in the following formulae:

$$L_{t+1}=37.49+0.7384L_t$$

$$L_{t+1}=36.75+0.7467L_t$$

SUMMARY

The shell of the sea scallop, in common with many other mollusks, bears annual rings but they are frequently weak and ill-defined or masked by the presence of other annuli caused by nonannual phenomena. By using annual marks on the resilium, changes in shell curvature, changes in color pattern, weight of the shell, and areas of attack by boring organisms it is usually possible to localize the position of the annual rings so that they can be found by intensive examination.

These methods have been validated by showing that a growth rate calculated from the annual rings was almost identical with a growth rate calculated from the growth of tagged and recaptured animals from the same area.

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