

color; very smooth and moderately glossy; ultimate whorl practically smooth; growth striae very faint to lacking completely; no spiral sculpture. Apex parabolic, smooth and straight; embryonic whorls nearly two, visible both posteriorly and anteriorly; $4\frac{1}{2}$ whorls, all smooth and evenly rounded; four sutures visible anteriorly; whorls below sutures only slightly beveled; calcareous deposits near sutures very thin; proximal sulcus short and much wider below than above; short, nearly straight, columella (wider below than above) and sulcus lighter, but of same color as rest of shell; outer peristome thin and nearly straight. Total length 9.5 mm; greatest diameter 3.5 mm; spire length 3.0 mm; aperture length 5.25 mm; greatest width of aperture 2.0 mm.

Indices: Length/diameter—2.71. Length/spire—2.17. Length/aperture length—1.80. Spire/aperture width—1.50. Ultimate whorl/penultimate whorl depth—5.3.

In general contour this species is reminiscent of *S. meridana* (Morelet), with which it is assumed to be mostly related. It differs from the latter in being taller and more slender; in having a relatively longer spire and more narrow aperture and a much shorter and more truncate columella.

GONAD DEVELOPMENT AND SPAWNING OF BRACHIDONTES RECURVUS IN CHESAPEAKE BAY

By J. FRANCES ALLEN
(Concluded from April no.)

During the period from January 16, 1950, through April 16, 1951, the temperature ranged from 1.8° C. to 24.5° C., and the salinity from 16.24 o/oo to 2.85 o/oo (Parts per 1000). See table II and graphs. As would be expected, the higher temperature prevailed during the summer period, and the lower temperature during December, January, and early February. The highest salinity of 16.24 o/oo was recorded on October 9, 1950 and the lowest salinity 2.85 o/oo on February 19, 1951. The lower salinities occurred during spring and summer, whereas, the higher salinities prevailed during the fall and winter. The salinities of the spring of 1950 were not as low as those of the corresponding dates in 1951. On February 16, 1950, it was 11.6 o/oo, while on February 19, 1951, it was 2.85 o/oo. The latter condition is considered abnormal in the area and was due to the heavy spring rains. The temperature varied from a high of 24.5° C. on July 31, 1950 to a low of 1.8° C. on February 19,

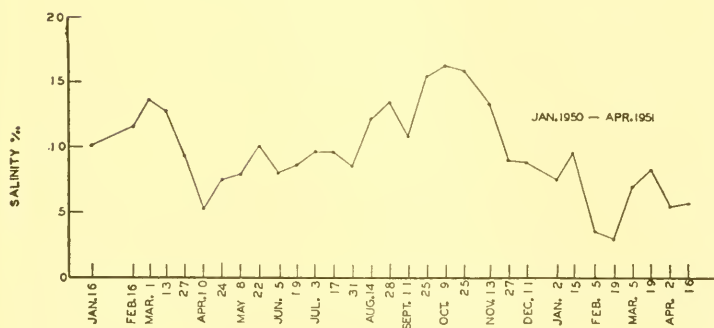
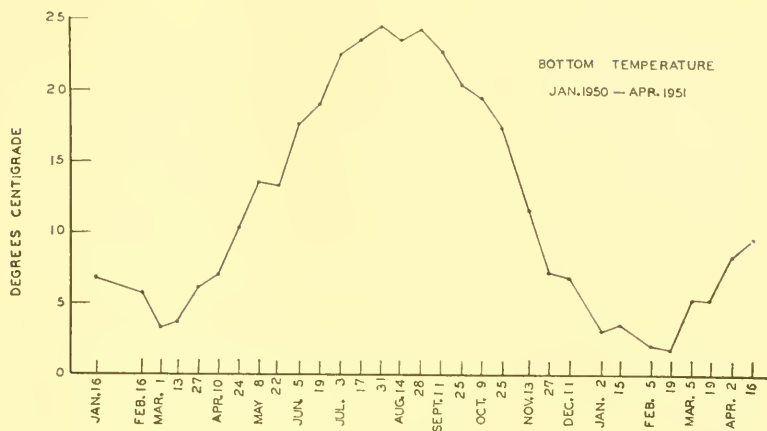
TABLE II

BOTTOM TEMPERATURE AND SALINITY AT HACKETT'S BAR
 JANUARY 16, 1950 THROUGH APRIL 16, 1951

DATE	TEMPERATURE ° C.	SALINITY ‰
1950 - Jan. 16	6.8	10.10
Feb. 16	5.7	11.60
Mar. 1	2.7	13.60
13	3.6	12.70
27	6.1	9.30
Apr. 10	7.0	5.20
24	10.3	7.50
May 8	13.6	7.90
22	13.3	10.10
Jun. 5	17.7	8.00
19	19.0	8.64
Jul. 3	22.5	9.64
17	23.5	9.63
31	24.5	8.51
Aug. 14	23.5	12.05
28	24.3	13.44
Sept. 11	22.2	10.75
25	20.4	15.41
Oct. 9	19.5	16.24
25	17.4	15.81
Nov. 13	11.6	13.28
27	7.2	8.86
Dec. 11	6.8	8.77
1951 - Jan. 2	3.1	7.48
15	3.6	9.47
29	2.1	3.84
Feb. 5	2.1	3.48
19	1.8	2.85
Mar. 5	5.3	6.91
19	5.2	8.21
Apr. 2	8.4	5.44
16	9.6	5.84

1951. In early June 1950, the temperature was 17.7° C., rising to a high of 24.5° C. on July 31, 1950, finally dropping to 11.6° C. on November 13, 1950.

It was observed that spawning began in early June at a temperature of 17.7° C. and continued throughout the summer and fall, at least until the middle of November when the temperature had dropped to 11.6° C. The older larvae present during



December were able to survive at a temperature as low as 6.8° C. recorded on December 11.

The data presented with respect to larval distribution leads to the conclusion that the spawning period of *B. recurvus* extends from early June until November. The greater number of larval stages was observed in late summer which indicates that the greater percentage of setting takes place during late August and September. This observation is supported by the observa-

tions on the development of the gonads and the small size range of the mussels collected in October.

The distributional data on the larval stages also point to the existence of three relatively distinct periods of spawning: an early spawning in June, a mid-season spawning in late July and August, and a late spawning in November. As noted (table I) in following the seasonal variation of the pre-hinge stage, the larval stages increase during June and early July, but are then absent from the plankton. They occur in abundance during August and September, but are again absent in late October. Finally, they are present in mid-November. This seasonal pattern of distribution is followed also by the hinge and post-hinge stages. Acceptance of the three distinct spawning periods would explain the absence of the post-hinge stage during late July and early August.

Explanation of three such periods on the basis of environmental factors is not possible. Whedon (1936) and Young (1942, 1946) reported similar observations on *Mytilus californianus*. Numerous other investigators have made similar observations on other species of pelecypods, and have shown that either a rise or a drop in temperature may induce spawning in these forms (Berner 1935). In lamellibranchs, spawning is usually associated with rising temperature. The conclusion of Pelseener (1938) and Nelson (1928b) is that when a critical temperature is reached, spawning occurs above that point, but below that temperature it does not occur. Galtsoff (1938, 1940), however, points out that in the oyster, "There exist several 'critical' temperatures for spawning of males and females, apparently determined by their physiological conditions . . . The idea (therefore) of a single critical temperature effective in inducing spawning in all oysters of a given population . . . should be abandoned."

Possibly, considering the long period of sexual maturity of the gonads in *B. recurvus*, the physiological conditions result in different spawning periods for individual mussels.

Discussion: The gross morphology of *Brachidontes recurvus* is apparently the same as that observed by Field (1922) for *Mytilus edulis* and as that given by Wiborg (1946) for *Modiola modiolus*. Personal observation has indicated that the same is true for

Modiolus = *Volsella demissus*.

The location of the gonad tissue in the curved mussel is essentially the same as that observed in the above mentioned forms. Wiborg (1946) states that in *Modiola modiolus* the gonad tissue has the same arrangement as in the sea mussel with the exception of the mantle lobes which are thin and membrane-like, similar to the condition existing in the young sea mussel. The gonad tissue, however, of *B. recurvus* does penetrate into the mantle to such an extent that at the time of maturity the mantle is actually a large gonad.

Coe (1943) observed that the majority of pelecypods have separate sexes with an occasional hermaphrodite making its appearance. He found that a study of juveniles was necessary to ascertain the sexual condition of the individual. In addition to these two forms, examination was made of specimens of *Modiolus demissus*, *Mytilus edulis*, and *M. californianus*. In none of these species did he find any evidence of ambisexuality except in undifferentiated gonads and only an occasional hermaphrodite. The occurrence of males and females was about equal. Wiborg (1946) found that the sexes of *Modiolus modiolus* are usually separate with hermaphrodites occurring in 2 to 8% of the individuals. In some hermaphrodites of this species, the female tissue is located as a ball in the middle of the mesosoma and is surrounded by the male tissue, while in others the male and female tissue is evenly distributed.

In *B. recurvus*, resemblance to the above forms is evident in that the sexes are separate in those observed and are also approximately evenly divided. Of all the specimens examined, there were no hermaphrodites and there was no ambisexuality.

Loosanoff and Davis (1951) have observed resorption of gonad tissue following spawning in *Mercenaria* = *Venus*. This condition was not noted in any of the curved mussels; the reproductive tissue merely becomes degenerate.

The protracted spawning period is similar to conditions reported by Young (1946) on *Mytilus californianus* although different seasons of the year are involved. Engle and Loosanoff (1943) discuss the setting of *M. edulis* from early June to the end of August at Milford, Conn., thus indicating a relatively short spawning period for this form. Battle (1932), while as-

sociating spawning of *M. edulis* and *Macoma balthica* in Passamaquoddy Bay with lunar tidal cycles, gives their spawning period as extending from mid-June to mid-September. Sullivan (1948) notes the occurrence of larvae of *Mytilus edulis* from late May until the end of August in Malpeque Bay. In regard to the instances mentioned, the spawning period of *B. recurvus* in Upper Chesapeake Bay extends at least 2 or 3 months longer than that of the forms previously mentioned.

Wiborg (1946) says that *Modiolus modiolus* spawns in March and April and that spawning may be completed within a single day, all individuals in a specific bed spawning simultaneously. This is not true of the curved mussel at Hackett's Bar, as spawning continues there throughout the summer and fall.

The question of critical temperatures and spawning of the curved mussel has already been considered. The observations reported in this study support those of Young (1946) and others on *Mytilus californianus*. Nelson (1928b) who reported that lamellibranchs fall within the group which breed at a definite temperature, observed that the curved mussel spawns along the coast of New Jersey when the water temperature reaches 25° C. I observed that *B. recurvus* spawns at much lower temperatures in the upper Chesapeake Bay. The highest temperature recorded during the period of this study was 24.5° C.

SUMMARY

Specimens of the curved or hooked mussel, *Brachidontes recurvus* (Rafinesque), used in this study were collected from Hackett's Bar, located on the western shore of the Chesapeake Bay, approximately two nautical miles above the mouth of the Severn River.

A group of mussels representing the size range at each collection from March, 1959, through April, 1951, were fixed in Bouins and stained with hematoxylin and eosin or with Mallory's Triple stain for examination of the gonads and internal anatomy.

Plankton samples were taken simultaneously with collection of mussels in order to determine the seasonal distribution and relative abundance of the larval stages. At the same time, determinations of salinity and temperature of the water just above the bar were made.

B. recurvus is dioecious and does not show alternation of sex

or hermaphroditism in any specimens examined. The gonad tissue of both sexes of the mussel, when mature, occupies the entire mantle and mesosoma and penetrates into the digestive diverticula, where it is found adjacent to the liver canals. There is no evidence of resorption as it occurs in some bivalves.

Sexual maturity exists from June through October, and perhaps even longer in some cases. Spawning occurs from June until November with the greater degree of the spawning in summer and early fall.

Spawning is not influenced by any single critical temperature.

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PUERTO RICAN LAND OPERCULATES

By H. BURRINGTON BAKER

The symbols for Puerto Rican localities have been explained recently (1961).

Alcacia (Striatemoda) striata (Lamarck) and form *subfusca* (Menke). Typical form (with thickened peristome) infrequent; shells usually yellowish unicolor (En1, Er3, Es4, Jn1, Pr1-3, Wr3) but also bicolor fulvous, with light sutural and (weaker) peripheral bands and basal spot (Pr6, Ps2, Wn, Wr3; and Ws, but paler); good climber, up to 10 ft.; males and females subequal in size. Paedogenetoid (with "immature" shell but often sexually mature) form *subfusca* common, almost everywhere. (Ee, Es, Jn, Js, Pn, Pr, Ps, Wn, Wr, Ws); climbing but also under leaves on ground, 0-4000 ft. Animal dark above, bluish black on dorsum of head and tentacles; tail lighter, attenuate; sole weakly tripartite; secretes copious mucus.

Alcacia (Hjalmarsona) hjalmarsoni (Pfeiffer). Terrestrial; Pr3, 4, 6, Wr; western highlands, 1800-3400 ft.; males and females subequal in size; shell uniformly yellowish, tinged with fulvous, which becomes stronger near peristome. Animal greenish, with dark olive blotches and darker tentacles; sole weakly tripartite.

Alcacia (Schrammia) alta (Sowerby). Subarboreal, aestivating in dead *Cecropia* leaves, caught in vines, etc., 4-10 ft. above ground; Es, Jn, Pn, Pr; 100-4000 ft.; absent from wettest (Er) and driest places; males commonly smaller and higher but intergrading widely with females; yellowish and fulvous forms subequal in numbers, but some lots all fulvous. Foot with some grayish blotches on sides; sole as in preceding.

Helicina (s. s.) phasianella "Sowerby" Pfeiffer. Rare, but good climber up trees on dampish lowlands (En, Jn, Ws; 0-400 ft.) but commoner and subarboreal (often roosting in folded pinnae of palms) at western (driest) end of Cordillera Central (Wr3, around 3000 ft.); males and females subequal in size. Shell color