LIFE HISTORY OF THE BLUE CRAB

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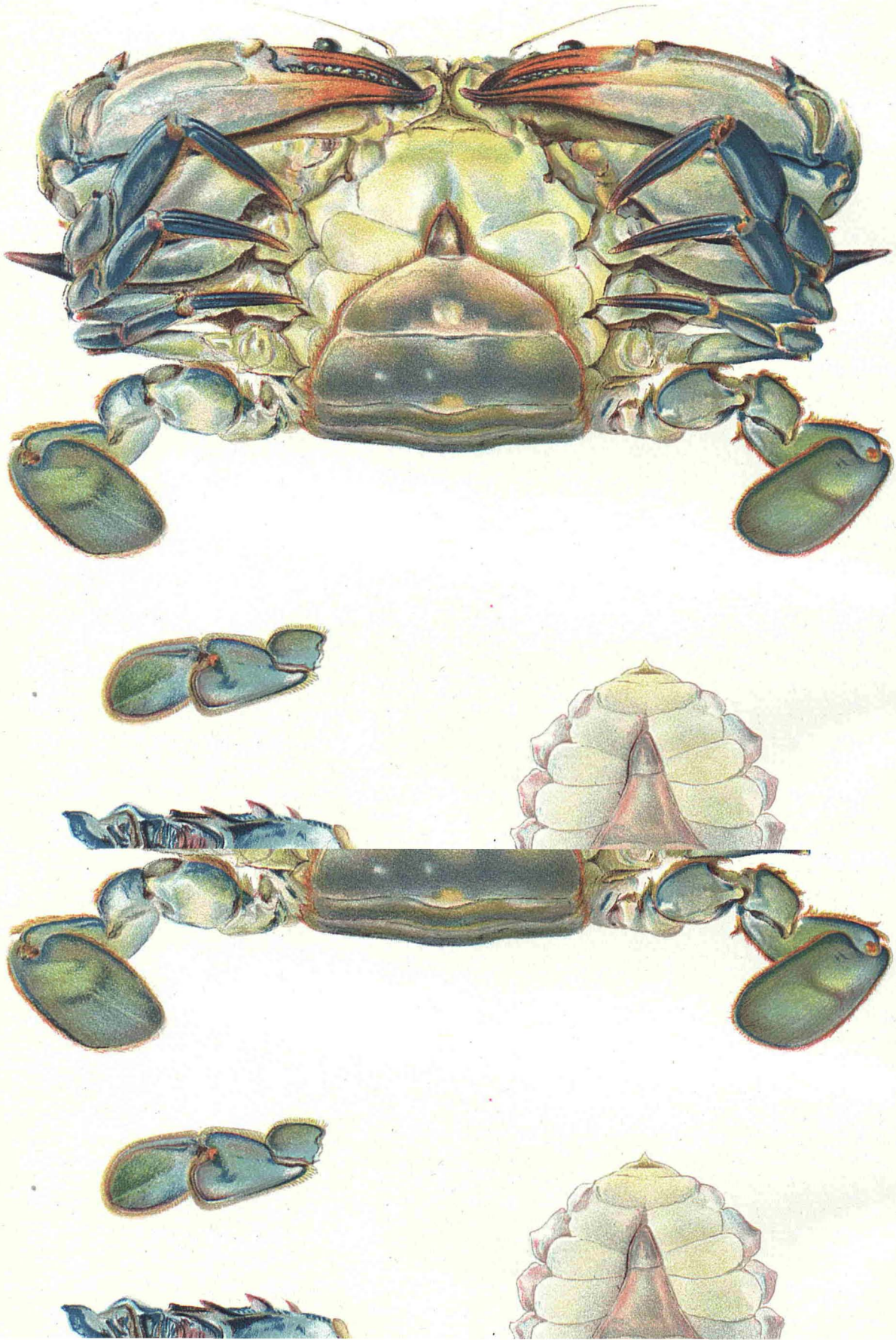

LIFE HISTORY OF THE BLUE CRAB.

By E. P. CHURCHILL, JR.,
Assistant, United States Bureau of Fisheries.

NAME.

The crab commonly used as an article of food on the eastern coast of the United States belongs to the species known as *Callinectes sapidus*.[a] This name may be freely translated as "savory graceful swimmer." Those who have eaten this crab in either its hard or its soft-shelled state can give ample testimony that the term "savory" is well applied. It is known generally as the blue crab from the fact that considerable blue color is usually found on its upper surface, especially on its claws. In Chesapeake Bay regions, where it forms the basis of an extensive crabbing industry, it is referred to simply as the "crab," other species of crabs having some common distinctive name, as the "fiddler," "sea spider," etc.

The blue crab belongs to the family known as Portunidæ, or swimming crabs, from the fact that the posterior pair of legs, or back fins, are flattened for use in swimming. All crabs of this family, in which the abdomen, or apron, of the male is ⊥-shaped, belong to the genus Callinectes. The species *Callinectes sapidus* includes only the edible, or blue, crab of the Atlantic coast of the Americas.

HABITAT AND DISTRIBUTION.

The blue crab is found on the Atlantic coast from Massachusetts Bay to at least as far south as the northern part of South America. In the United States it is common from Massachusetts to the southern extremity of Texas.[b]

Although occurring at most points on that part of the coast, it is especially abundant in the bays and mouths of the rivers. It is found during the summer in relatively shallow water but at greater depths during the winter. Although its natural medium is salt water, instances are known in which specimens have been found in brackish,[b] and even in fresh, water.[c]

The adult crabs tend to remain in deep water, but the young, especially, come inshore to a point where the water is only a few inches in depth. In general, the closer inshore the observations are made, the smaller the size of the crabs found.

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a This name was established by Dr. Mary J. Rathbun in The Genus *Callinectes*. Proceedings, U. S. National Museum, vol. 18, 1895. Washington, 1896.

b Hay, W. P.: The Life History of the Blue Crab (*Callinectes sapidus*). Report of the U. S. Bureau of Fisheries, 1904, p. 400. Washington, 1905.

c A crab dealer of Hampton, Va., related to the author that he found numerous crabs in Back Bay, Va., on Nov. 15, 1917, the water there being fresh enough to drink.

The blue crab is especially abundant in Chesapeake Bay. This body of water is of sufficient size to afford a breeding ground for an immense number of crabs. The young are very abundant in the region extending from the vicinity of Tangier Island, Va., to Baltimore, Md., the bottoms underlying the shallower waters of this part of the Bay forming, during the summer, a ground especially suited to the growth and molting of the maturing crabs. In the deeper waters of the southern part of the Bay the adult crabs lie on the bottom in vast numbers throughout the winter months. During the summer they frequent the more shallow waters, where they spawn in great abundance.

DEVELOPMENT OF THE YOUNG.

The young of the crab are hatched from eggs (Pl. XLVIII, figs. 1 and 7, and Pl. LII, fig. 30), which measure about 1/100 of an inch in diameter,[a] not as large as the period at the close of this sentence. When first laid, the eggs are yellow or orange in color, due to the color of the yolk granules within them, which serve as food for the young as development proceeds. As the eggs near hatching, this color disappears, and, since the eyes of the young are comparatively large and are of a very dark color, the mass of the eggs appears almost black.

As the eggs are extruded from the body of the female they become attached to the fine hairs of the swimmerets on the under side of the abdomen. There are no swimmerets on the anterior segment of the abdomen, but there is a pair each on the second, third, fourth, and fifth segments, and none on the sixth or seventh. There are thus eight swimmerets in all, four in a row on each side. Each swimmeret is made up of two branches, an inner and an outer (Pl. XLIX, fig. 16). The hairs borne by the inner are much finer and longer than those on the outer, measuring in diameter from 1/200 of an inch at the base to 1/700 at the middle.[b] The eggs all find lodgment on and are carried entirely by these hairs of the inner branches of the swimmerets, but never by the outer. Microscopic examination of these hairs, when they are bearing eggs, shows that each hair is covered throughout almost its entire length with a thin coating of a semitransparent material of a faintly yellow color. Each egg is attached to this covering by a separate short tendril of the same material, the hair and its burden resembling a long thin stem, with a great number of berries attached to it by short tendrils (Pl. XLVIII, fig. 7, and Pl. LII, fig. 30). From this resemblance, the crab, when bearing eggs, is sometimes said to be "in berry" or "berried."

There are eight tufts, or clumps, of eggs, corresponding to the eight inner branches of the swimmerets. These tufts are so large, however, that they are all crowded together, so that there is formed a flattish mass about 3 inches wide by 2 long by 1¾ deep, and fairly smooth in contour (Pl. L, fig. 19, and Pl. LI, fig. 22). From its general appearance and color, this mass is known commonly as a sponge, orange, lemon, punk, or ball.

The egg color is yellow or orange when first laid, but, as already stated, it becomes almost black as hatching time approaches. The abdomen is pushed back by the sponge until it extends almost in a straight line with the body, except at the posterior end, where it curls downward behind the mass of eggs.

[a] The measurement given in this text was made by the author. The size is placed at 1/108 of an inch by F. H. Herrick in Natural History of the American Lobster. Bulletin, U. S. Bureau of Fisheries, Vol. XXIX, 1909, p. 310. Washington, 1911.

[b] Herrick's op. cit., p. 310.

The number of eggs contained in a sponge of average size is enormous. S. I. Smith places it at 4,500,000,[a] which number was quoted by Herrick.[b] Paulmier[c] estimates that between 2,000,000 and 3,000,000 eggs are borne in the sponge. The present author found that by actual count there are about 200 eggs upon each hair of the swimmeret. The hairs occur in fairly regular bundles of about 5 each, there being about 20 bundles in each of the 11 rows, arranged in a longitudinal manner, on the swimmerets. There are 8 swimmerets. Computing these figures gives the sum of 1,760,000. It must be borne in mind that this figure is not much more than an estimate, as it is next to impossible to determine accurately the number contained in such a large mass of objects as minute as the eggs in question. The most accurate statement that can be made is that there are from 1,750,000 to 2,000,000 eggs in a sponge of the usual size.

The eggs had been fertilized while in the body of the female. This process is described on page 117.

The eggs are carried upon the swimmerets while their development goes on, or during what might be termed the "period of incubation." About 15 days are required for the eggs to hatch. A female crab was kept under observation in a float (Pl. LI, fig. 20, and Pl. LV, fig. 37).[d] On June 15 this individual threw out a sponge. On June 29 it was found that some of the eggs had hatched, since there were many empty shells upon the swimmerets. By July 2 nearly all the young had hatched out and left the mother. In this case it will be seen that the period of incubation was from 14 to 17 days. Another crab was observed to spawn on August 15. The eggs hatched within 12 to 15 days. The temperature of the water, no doubt, has some effect upon the duration of the incubation period. During the last of June, when the first experiment was being carried on, the temperature of the water was about 79° F. During the August experiment the water was about 85° F. This may account for the fact that the eggs hatched somewhat more quickly in the latter than in the former case.

It has been thought by some that the young crabs cling to the swimmerets of the mother for a time after hatching. Binford,[e] however, observed the young as they hatched from two females and found that this was not the case. The present author, in the case of the two crabs used in the experiments just described, found that the shell of the egg split into two parts (Pl. XLVIII, fig. 5), the young crab emerged and, after freeing itself from a thin membrane which covered it, swam away. Numerous empty split shells (Pl. XLVIII, fig. 10, and Pl. LII, fig. 30) were found on the swimmerets of the adult, but no young crabs were observed clinging there. Several other crabs were observed as the eggs were hatching, but in no case were any young found clinging to the swimmerets.

It is thought by many that the young, immediately upon hatching, turn about and devour the mother crab. Needless to say, this idea is a mistaken one, although, of course, quite small crabs feed upon and may even consume any dead crab which they chance to find. In fact, this erroneous notion arose from the occasional observation of

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[a] Smith, S. I.: Report on the Decapod Crustacea of the Albatross Dredgings. Report of Commissioner of the Fish and Fisheries for 1885, pp. 618–619. Washington.

[b] Herrick; op. cit., p. 309.

[c] Paulmier, F. C.: The Edible Crab. 55th Annual Report, N. Y. State Museum, 1901, p. 134.

[d] Unless otherwise stated, all of the experiments discussed in this paper were carried on at Hampton, Va., between October, 1916, and October, 1917.

[e] Binford, R.: Notes on the Life History of *Callinectes sapidus*. Johns Hopkins University Press, February, 1911, p. 1.

a dead sponge-bearing crab being surrounded and devoured by a multitude of young crabs about the size of the fingernail and the assumption that these young had just hatched from her sponge and then turned about and were devouring her. From the description, given in the following paragraph, of the young immediately after hatching, it will be seen that it would be impossible for them to devour a hard-shelled adult crab, even though observation were lacking to disprove the notion.

The young of the blue crab, after hatching, pass through two stages before assuming the true crab shape.[a] In the first stage a young crab is known as a zoëa. The zoëa is virtually microscopic in size, measuring about 1/25 of an inch in length. From Plate LI, figure 21, it will be seen that in this stage the crab is much unlike the adult form. The body is somewhat cylindrical in shape, the eyes large and conspicuous, the spines at the sides short; there is a long curved spine on the back; the claws are lacking; and the abdomen is long and round, ending in a sort of forked tail. The zoëa has a long, sharp beak, two pairs of antennæ, and four pairs of leglike appendages. The true legs have not yet appeared. The zoëa swims backward by very rapidly jerking the abdomen up against the lower side of the body. The crab in this stage is free-swimming and does not crawl over the bottom, as it does in the later stages. The zoëa increases in size only when it molts. At the present time, however, it is not known how many moltings occur before the second stage is reached.[b] At each molting the new form resembles a little more closely the next stage.

The crab in the second stage is known as a megalops (Pl. LI, fig. 23). It is still very small, being less than 1/25 of an inch in width. The megalops more nearly resembles the adult, having a rather flattened body and an abdomen shorter and wider than that of the zoëa. The eyes, however, are as yet more prominent than in the adult, and the two posterior legs are not flat, but rounded, and each is provided with a sharp point. The abdomen is not curled against the under side of the body, as is the case in the adult. The megalops swims freely and, also, may walk on the bottom. It is as yet unknown how many times the megalops molts before taking on the true crab shape. Smith and Hyman (op. cit.) found that, in the case of the rock, the green, and the fiddler crabs, there is only one megalops stage, the first megalops molting directly into the first crab stage. It is quite probable that this is true also of the blue crab.

Whether or not this is the case, there does come a molting at which the megalops suddenly assumes a shape very similar to that of the adult, except that the width of the body is not much greater than the length, and the eyes are borne on larger and thicker stalks. This creature may be called the first crab. The crab, as well as the preceding forms, increases in size only at the time of molting. Up to the present time no one has observed a crab as it passes through all the different molts involved in its life history. Certain stages, however, of the lives of several different crabs have been observed, so that a fairly accurate estimate can be made of the number of moltings which occur and the time required for the crab to reach the adult stage.

[a] The description of the first two stages of the young crab is abridged from the Handbook of Invertebrate Zoology, W. K. Brooks, published by S. E. Cassino, Boston, 1882.

[b] Paulmier, op. cit., p. 135, estimates the number of moltings to be probably six, but gives no data upon which to support his claim.

Smith, S., in The Invertebrate Fauna of Vineyard Sound, U. S. Fish Commissioners' Report, 1873, found that there are four zoëal stages in the green crab of the Atlantic coast.

Hyman, O. W., in a yet unpublished paper found that the fiddler crab passes through five zoëal stages.

Dr. Binford observed a crab which was kept in an aquarium while it passed from the megalops stage to that of the sixth crab stage.[a] The following table sets forth the results:

TABLE A.

Date molted.	Stage.	Width after molting.	Increase.
		Inch.	*Inch.*
July 18	Megalops	0.04	.....
July 19	First crab	.128	0.088
July 27	Second crab	.196	.068
August 1	Third crab	.260	.064
August 6	Fourth crab	.348	.088
August 12	Fifth crab	.456	.108
August 25	Sixth crab	.516	.060

This crab was caught in its natural habitat while in the megalops stage and placed in the aquarium on July 18. It changed to the first crab on the next day. The zoëa and megalops stages, therefore, were completed by about the middle of July. In the region of Beaufort, N. C., where this experiment was carried out, the bulk of the young hatch during June; therefore, probably not more than one month had elapsed between the hatching of this specimen and the time of confinement in the aquarium. That is to say, not more than a month was required in which to complete the zoëa and the megalops stages.

The author succeeded in carrying several crabs through certain of the molting stages between the sixth crab and the adult. Some of the crabs were kept in floats, but most of them were confined in cages of quarter-inch mesh wire (Pl. LV, fig. 38). These were placed on the bottom, in the water of Hampton River, at a depth of 4 or 5 feet at low tide. Each cage was equipped with a strand of wire by which it was lowered and raised and which was attached at its upper end to a stake. Although it was impossible to carry a particular crab through its entire life cycle, by beginning the experiment with crabs of different sizes, the author was able to collect data, from which it is possible to estimate how many moltings occur as the crab develops from the sixth crab stage to the adult size. It must be kept in mind that at this time of life the successive stages of the crab are very similar, except in size. This last also varies with the individual, the temperature, etc., so that it can not be ascertained by examination in just which stage a particular crab is. The best that can be done is to try to form as accurate an estimate as possible of the number of times a crab usually molts while reaching adult size and the time required to attain maturity.

The results obtained by the author are presented in Table B.

[a] Binford, op. cit., p. 2.

TABLE B.

Individual and sex.	Width.		Increase.		Time between molts.
	Before.	After.			
	Inches.	*Inches.*	*Inches.*	*Per cent.*	*Days.*
No. 1, male	0.437	0.562	0.125	28	17
No. 2, male	.562	.812	.250	44	(a)
	.812	1.000	.187	23	13
No. 3, female	.750	(b)	.....	.....	(a)
	(b)	1.000	.....	.....	11
	1.000	1.250	.250	25	10
No. 4, female	1.062	1.375	.313	28	(a)
No. 5, female	1.375	1.687	.312	29	(a)
	1.687	2.250	.562	33	16
No. 6, male	1.750	1.937	.187	10	(a)
	1.937	2.500	.562	29	26
	2.500	3.125	.625	25	20
	3.125	4.312	1.187	38	21
No. 7, male	4.250	5.500	1.250	29	(a)
No. 8, male	5.500	7.000	1.500	27	(a)
No. 9, female	1.687	2.125	.437	25	(a)
	2.125	2.750	.625	29	14
	2.750	3.750	1.000	36	25
No. 10, female	2.500	3.062	.562	22	(a)
	3.062	4.062	1.000	32	23
No. 11 [c]	1.437	1.687	.250	17	(a)
	1.687	1.937	.250	14	27
No. 12 [c]	2.000	2.250	.250	12	(a)
	2.250	2.937	.687	30	24
No. 13, female	1.562	1.937	.375	24	26
No. 14, female	3.500	4.500	1.000	28	(a)
	4.500	5.750	1.250	36	42
No. 15, female	4.750	6.000	1.250	38	(a)

[a] The interval between molts is unknown, since this is the first molting in captivity.
[b] No record.
[c] Sex unknown.

From the data here given, combined with those furnished by Binford's results (Table A), it is possible to work out a table showing the number of moltings, the successive sizes of the stages, the percentages of increase, and the intervals elapsing between moltings of the crab while passing from the last megalops stage to the usual adult size. Such a table follows.

TABLE C.

Stage.	Width.	Increase.		Intervals between molts.
	Inches.	*Inches.*	*Per cent.*	*Days.*
Megalops	0.04	.....	.....	.....
First crab	.128	0.088	220	.....
Second crab	.196	.068	53	8
Third crab	.260	.064	32	5
Fourth crab	.348	.088	33	6
Fifth crab	.437	.089	25	6
Sixth crab	.562	.125	28	17
Seventh crab	.812	.250	44	11
Eighth crab	1.062	.250	30	13
Ninth crab	1.375	.313	29	10
Tenth crab	1.687	.312	22	[a] 15
Eleventh crab	2.250	.563	33	16
Twelfth crab	3.125	.875	38	20
Thirteenth crab	4.312	1.187	37	21
Fourteenth crab	5.500	1.188	27	[a] 25
Fifteenth crab	7.000	1.500	27	[a] 35
Average increase (first to fifteenth crab stages)	.....	.....	32.71	[b] 14.85

[a] Estimated. [b] Total time, 208 days, or 6.9 months.

It will be seen that, according to this table, 15 moltings occur. It is probable that the number is not absolutely fixed, but that it varies somewhat with the individual crab, usually being about 15. The size and rate of growth of individual crabs vary so that not all reach the width of 7 inches. No doubt, however, as many moltings occur, on the whole, in the smaller specimens as in the larger, the individual being smaller at the start and the actual increase in size at each molting being less. Various factors, such as temperature, food, etc., certainly affect the growth rate. Ninety-six adult female crabs were measured, and the average width was found to be 6.117 inches. No similar records are available for the male, but the average width is probably about 6.5 inches at least. Individual specimens of males are found which are much greater in width than this. Two exceptionally large specimens were measured, one of which proved to be 8 inches in width and 20 inches from tip to tip of the extended claws, and the other 8.5 inches in width and 1.25 pounds in weight. Specimens of females 7 inches in width are occasionally seen.

The average increase in width at each molting is 32.71 per cent, or about one-third. This does not include the change from the last megalops to the first crab stage, at which time the increase in width is over 200 per cent, owing to a material change in the form of the animal. The increase from the first crab stage to the second is over 50 per cent. At the subsequent moltings the increase varies from 22 to 44 per cent, usually being about 33⅓.

The time elapsing between molts is less in the early stages than in the later, averaging 6 days during the first 4 stages, 13 during the next 6, and 25 during the last 4. The average for all the stages is nearly 15 days.

The results above set forth are confirmed by data obtained from some unpublished notes which were kindly placed at the disposal of the author by Prof. Hay. Hay

observed the molting of 22 immature crabs which were confined in floats on the water at the United States Fisheries biological laboratory at Beaufort, N. C., during the summers of 1913, 1914, and 1915. These crabs ranged from 1.0625 to 6 inches in breadth. His results are summarized in the following table:

TABLE D.

Individual crab.	Width.	Gain.	Days between molts.
	Mm.	*Mm.*	
1	[a] 27 to 35	8	15
2	31 to 38	7	11
3	31 to 38	7	11
4	35 to 45	10	12
5	53 to 70	17	19
6	55 to 71	16	21
7	55 to 73	18	12
8	57 to 76	19	21
9	59 to 77	18	16
10	62 to 78	16	24
11	62 to 84	22	23
12	63 to 85	22	19
13	63 to 83	20	20
14	64 to 82	18	27
15	69 to 88	19	31
16	72 to 98	26	26
17	73 to 99	26	23
18	80 to 98	18	28
19	80 to 105	25	32
20	82 to 102	20	31
21	90 to 116	26	29
22	[b] 118 to 155	37	33

[a] 1.0625 to 1.375 inches. [b] 4.625 to 6 inches.

It will be seen from this table that the gain varies from 7 or 8 millimeters in the first stages to from 26 to 37 for the last. The gain is about one-third in 15 of the cases and one-fourth in the other 7. The interval between moltings varies from 11 days for the earlier to about 30 for the later stages. The average for the first 11 cases is 16 days and for the last 11 cases 28 days.

The total time required for the hypothetical crab of Table C to reach maturity from the megalops stage is 208 days, or nearly 7 months. Allowing a month (see Binford's results) for the completion of the zoëa and megalops stages, it will be seen that about 8 months would be required for the crab to reach adult size after hatching. All the evidence at hand, however, leads to the belief that the crab does not molt during the winter months. Perhaps the best evidence for this is the fact that, even before the close season was established in Maryland, the soft-crab industry ceased some time in October of each year until the middle or last of the following April. As this industry is dependent on the securing of molting crabs, they either do not molt during the winter or retire for the process to water of such a depth that access can not be had to them by the scrapes used in securing molting crabs nor by the oyster dredges.

Adult crabs which were kept in floats were found to become sluggish and to take no food after the temperature of the water fell to about 50° F. A juvenile crab, No. 6 of Table B, was secured on February 25 and kept until April 20 in the laboratory, where the temperature of the water in the aquarium varied from 44° to 55° F. No moltings occurred. Other experiments, carried out during the summer, proved that crabs will molt freely in aquaria in the laboratory. Binford's work also shows the same to be true. On April 20 this crab was placed in a float in the water of the bay, the temperature of the water being 60° to 65° F. On May 5 the crab molted. Very probably crabs do not molt during the season when the temperature of the water is less than 60° F. From temperature records of the water of Chesapeake Bay, kept throughout the year, it has been found that between about the last week of October and the middle of April the temperature of the water is below 60° F.

The bulk of the young crabs of Chesapeake Bay hatch during the last two weeks of June and the earlier part of July. From that time until the last part of October four months elapse. During this time the crabs pass the first two stages and reach probably about the ninth or tenth crab stage, attaining a width of about 1.25 to 1.50 inches. Then come the winter months, during which time the crabs most probably do not molt, but lie dormant on the bottom. Growth and molting are resumed about the middle of April or the first of May. During the next three and one-half or four months the crabs molt five or six times and reach maturity during the last part of July or in the month of August. This agrees with the fact that during the six weeks from the middle of July to the last of August most of the pairs of mating crabs are found. As is described more fully on page 104, this occurs in the female at the time of the last molting and is thus a sure index of her arrival at the adult stage.

The best evidence we have, then, points to the probability that the crab reaches the adult stage about 13 or 14 months after hatching. If, for example, a crab is hatched during June, it will reach the adult stage and mate during the latter part of July or the month of August of the following year.

After leaving the megalops stage the abdomen of the male assumes the characteristic ⊥ shape, which is found throughout the remaining term of his life. The abdomen is broad at the line of attachment with the body, but curves in shortly to a narrow portion (Pl. LIV, fig. 35), which lies in a groove in the middle of the lower side of the body. Plate LIV, figure 34, represents the adult male crab when viewed from above.

The abdomen of the female, after she leaves the megalops stage, is broad at the base of attachment and tapers to a point, each side forming almost a straight line (Pl. LIII, fig. 32). It lies in a depression on the lower side of the body and is held quite firmly in place by a pair of hooks which project from the body into cavities in the sides of the abdomen. This form of abdomen is found in each stage of the female until adult size is reached. At the molting from which the crab emerges as an apparent adult the abdomen changes to almost a semicircular shape, except for a small point at the tip (Pl. LIII, fig. 33). It no longer lies in a depression of the body, and there are no hooks. It is held against the body by the effort of the muscles alone. The swimmerets seen on the under side of the abdomen, when it is pulled away from the body, are large and conspicuous (Pl. XLIX, fig. 16). In the pointed form these are small and insignificant in appearance. Plate LIII, figure 31, gives a view of the adult female when seen from above. It will be noted that the body is relatively longer

from beak to abdomen than that of the male and that the claws are smaller. The adult male can usually be distinguished from the female by these characteristics without the necessity of examining the abdomen.

It is most probable that this molting, in which the change in the abdomen is involved, is the last one which the female undergoes. Adult females were kept under observation for several months in crates and floats. None was observed to molt during this time. Immature crabs molted when kept under similar circumstances. In the region of Crisfield, Md., the center of the soft-crab industry, hundreds of thousands of crabs are caught shortly before molting and kept until it occurs, in order to secure the soft crabs for the market. The author examined 2,624 cast shells obtained from various ones of the floats in which such crabs are confined. Not one of these shells bore the broad abdomen of the adult female. No crabber was found who could recall ever having seen a cast shell bearing the broad abdomen. Females with broad abdomen are virtually never found exhibiting the easily recognized marks that distinguish a crab which is preparing to molt. Three crabbers were found who said they had seen one or two adult females bearing such marks, but that they did not molt when kept in the floats. It is very doubtful if the marks observed on the crabs in question were really the same as those that characterize a crab in the premolting stage.

As no such change occurs in the abdomen of the male, we have no criterion other than that of size, general appearance, and the manifestation of sexual activity by which to judge its probable state of maturity or whether it molts again after reaching maturity. The average maximum size is, as stated above, about 6½ to 7 inches. It is probable that the males become sexually active somewhat before attaining the maximum size, although the evidence on this point is rather meager. Both male and female crabs are found, especially during the winter, whose shells are discolored and bear barnacles, oysters, etc., apparently giving evidence that the shell has not been cast for a considerable period of time. There is no especial reason to suppose that the male molts indefinitely, in contradistinction to the female, which most probably does not.

MOLTING.

As already stated, the crab increases in size only when it molts, or sheds its shell. It is not exactly true to state that the crab grows only when it molts or that it grows by molting. It molts because it has grown and the shell, being inelastic, is too small and is thrown off.[a] Thus there is a sudden abrupt increase in size due to the expansion of the organism which has previously been crowded and somewhat wrinkled up within the old, hard shell.

The actual molting process has been described by Hay.[b] His excellent photographs illustrating some of the stages of the process are included in the plates appended to this paper. The account given in this paragraph is modeled to some extent after his description, although an effort has been made to present the matter in more detail than he employed. As the crab approaches the molting period it begins to show its condition by various external markings, or signs. The first indication is the appearance of a narrow, black line just within the thin outer and back margins of the two

[a] Herrick, op. cit., p. 200.

[b] Hay, op. cit., p. 411.

outer segments of the swimming legs. In a day or two this line becomes white, and the crab is known as a green, fat, or snot crab. Within three or four days the line becomes pink or red. (See Frontispiece, upper small figure at left.) It is formed by the edge of the segment of the leg, which has become loose from the old shell about it and has produced a bright fresh one, which is visible through the thin, outer old shell. A crab bearing the pink or red line, sign, or ring will molt within two or three days and is known as a peeler or, more rarely, a sluffer. A set of fine wrinkles also makes its appearance on the blue skin between the wrist and upper arm of the claw. A reddish color begins to appear at the margins of the segments of the abdomen. The carapace, or black shell, and the top shell of the abdomen are naturally not continuous, and, when the moment of molting is at hand, the carapace begins to be lifted up slightly, so that a gap appears between it and the abdomen. Then, on the under surface of the carapace, a crack appears in the shell at each end of the gap just mentioned. As the carapace rises the crack on each side lengthens, passes below the spines, and extends nearly to the mouth. The posterior part of the body begins to protrude through the gap thus made. A crab in such a condition is known as a "buster" (Pl. LII, fig. 25). At this time it usually lies motionless, but can swim quite actively if disturbed. The remainder of the molting process requires only a few minutes, usually about 15. The carapace is lifted higher, the swimming legs begin to be withdrawn by rhythmic throbbing movements, and the body protrudes more and more from the shell (Pl. LII, fig. 26). The claws are the last to be withdrawn from the old shell, and, as they are large, some difficulty is involved in pulling them through the narrow arms of the claws. To obviate this, a roughly triangular portion of the shell of the large segment of the arm breaks along the outer side and rises up like a flap (Frontispiece, figure at lower left, and Pl. LII, figs. 26 and 27). The opening thus made extends along the arm to the body, and thus the natural opening for the connection of the muscles of the arm with the body is enlarged. Through this the large claw is drawn (Pl. LII, fig. 28). Immediately after molting is completed the skin is soft and wrinkled, and the spines are curved forward (Pl. LII, fig. 27). Although the crab is flabby and apparently helpless, it is capable of walking or swimming slowly if disturbed.

The spines soon become extended, and the shell fills out and begins to harden. A female crab was taken while in the buster condition and was placed in an aquarium in the laboratory, where it was allowed to complete the molting process. This crab measured 3.5 inches in width before molting. At 10.15 a. m., the instant after molting was completed, and at later intervals, the crab was measured. The results are summarized as follows:

Date.	Condition.	Hour.	Width.
			Inches.
July 12	Before molting	[a] 10 a. m.	3.500
Do	Just molted	10.15 a. m.	4.000
Do		11.15 a. m.	4.312
Do		2 p. m.	4.437
Do		2.30 p. m.	4.500
July 13	[b]	9.30 a. m.	4.500
July 14	[c]	9 a. m.	4.500

[a] Approximately. [b] Shell leathery, "buckram." [c] Shell nearly hard.

It will be seen that nearly all the increase in width, which amounted to 1 inch, was accomplished almost within the first hour after molting, and that, within 4¼ hours, the entire increase was completed. Within 24 hours the shell was too leathery to admit of the crab being used as a soft crab. A crab with such a leathery shell is usually called a buckram. Within 48 hours the new shell had almost reached the usual state of hardness.

Effect of the moon and tides.—It is a popular superstition that both the moon and the tides have a marked effect upon the molting of the crabs. It is supposed that at certain stages of the moon more soft crabs, or peelers, or whatnot, may be found than at certain other times. In the course of the experiments which were carried on in connection with the molting of crabs moltings occurred on the following dates in 1917: May 5; June 1, 12, 13, 19, 24, 26, 29, 30; July 2, 4, 9, 11, 12, 17, 21, 27, 31; and August 13, 20, and 23. In no case were there more than two moltings on any of the above dates, and usually only one. It would be difficult to establish any relation between the changes of the moon and the moltings observed in these cases. No evidence whatever exists for the belief that the moon has any effect upon the molting of the crab, and the matter may be dismissed as of a class with all folklore superstitions concerned with the supposed relation between the moon and mundane affairs, such as the weather, gardening, and the like.

In many places it is thought that there is a close relation between the rise and fall of the tides and the molting periods of crabs. Many persons claim that the young crabs molt at every tide or every two tides. This idea is shown at once to be erroneous, since at least 48 hours are required for the crab to reach the usual state of hardness after molting. The experiments with molting crabs, here described, were carried on where there was a tide of at least 4 feet. Some crabs were confined in floats which rose and fell with the water, others in wire cages resting on the bottom. No relation whatever was found to exist between the movements of the tide and the molting of the crabs.

The movements of the tides do affect the distribution of the crabs. Immature crabs especially tend to come in with the tide. Busters which thus come in with the water and soft crabs that have molted after coming in are rather inactive and slowly follow out the ebbing tide. For this reason the best time to find such crabs is on a "half tide," as it is falling. This, and other similar facts, have given rise to the notion that the movements of the tides actually hasten or delay or in some way regulate the molting act.

AUTOTOMY.

Closely connected with the process of molting is that known as autotomy, or the automatic throwing off of the appendages of the body. This phenomenon is common among crustaceans and has been the subject of considerable research. Little work, however, has been done in this line in connection with the blue crab.

If a crab is seized or held by a claw or leg, it often throws off the appendage and escapes. The break occurs across one of the segments near the body, there being an arrangement to prevent excessive bleeding. The crab is thus often enabled to escape with its life at the expense of an appendage. This latter loss is not always as serious as might appear as the power to regenerate the lost appendage is possessed by the crab, at least until the molting stages are completed. If the loss occurs shortly after a molting, the regeneration will be made at the next molting. If it occurs only a few days before a molting, the renewal takes place at the second subsequent molting.

In the process of regeneration a very small, white papilla, or protuberance, first forms in the end of the old stump. This papilla enlarges and becomes a sort of thin-walled sac in which the new appendage is formed. As the sac becomes larger the new appendage can be seen folded up within it. At molting the sac is thrown off with the old shell, and the new limb appears in its normal shape, but is smaller than the corresponding member of its pair. At subsequent moltings it increases in its relative proportions and eventually attains the normal size, unless the loss occurred only a molting or two preceding the acquisition of adult size. In that case the new appendage remains smaller than its fellow. Many adult crabs are found in which one claw is smaller than the other or both claws are below normal size. Such an undersized claw is termed by crabbers a "jew claw," i. e., reduced or "jewed down."

As an example of autotomy, the record of a crab which was kept under observation will be presented. A female crab, No. 9 of Table B, 1.687 inches in width and with the left claw missing, was placed in a small cage in the water on June 1. No papilla or limb bud had begun to form. This crab was kept under observation until July 21. The growth at the moltings which occurred during this time is recorded in the following table:

TABLE E.

Date of molting.	Width.	Length of claw, including entire arm.		Width of claw in widest place.	
		Right.	Left.	Right.	Left.
	Inches.	*Inches.*	*Inches.*	*Inch.*	*Inch.*
June 1 [a]	1.687	1.625	(b)	0.18	(b)
June 12	2.125	2.250	1.75	.25	0.18
June 26	2.750	2.930	1.87	.35	.31
July 21	3.750	3.500	3.50	.50	.43
Total gain [c]	2.063	1.875	3.50	.32	.43

[a] Placed in cage. [b] Claw missing. [c] Gain in 5 moltings or 51 days from time claw was lost.

It was necessary to close the experiment at this point. The left claw had practically reached the size of the right in three moltings, or in about 51 days from the time when it was lost. Plate LI, figure 24, represents the successive molts of the claws during the course of the experiment.

In the juvenile crab the completion of the process of regeneration never occurs except at the time of molting, although limb buds may be seen forming before this. The presence of a fairly large-sized limb bud is a sign that the crab is approaching or is already in the peeler state. If, as has been stated, molting does not occur after the crab has attained maturity and if regeneration does not occur except through molting, the adult crab can not renew cast-off appendages. Further research is necessary to clear up this point. Adult crabs cast off the appendages apparently as freely as do the juveniles. Whether they regenerate these or not, the author is not in a position to state. An adult female with limb buds has never been seen by the author or by

crabbers who were questioned. Various adult females, as well as large males, which were kept under observation lacked certain appendages at the initiation of the experiments. During periods of from one to three months, throughout which the experiments were continued, the appendages were not renewed, no signs of limb buds formed, nor did any moltings occur. Quite large males, 6 or more inches in length, have sometimes been observed to bear limb buds. As males, however, are found which are at least 8 inches in width, it could not be said that the individuals with the newly forming appendages had yet reached the adult stage. Large males with discolored shells, barnacles, and similar apparent evidences of age, have not been observed to have appendages in the process of formation. It can not yet be stated definitely whether the adult crab has the power of regenerating appendages removed voluntarily or involuntarily.

MIGRATION IN CHESAPEAKE BAY.

The migrations of the crabs found in Chesapeake Bay are of sufficient interest to merit special discussion. Nearly all the sponge-bearing crabs are found in the southern part of the Bay, in fact, far enough south so that very few occur in Maryland waters. The chief spawning grounds are in the waters of the lower part of the Bay.

Records kept by a leading crabbing firm of Hampton, Va., for the summers of 1906–1913, inclusive, show that the average number of male crabs was 11.8 per cent of the catch handled by this firm during those seasons. During the summer of 1917 the author kept records of the percentages of male and female and sponge-bearing crabs found in certain lots taken at random from the catches brought in to the crab dealers at Hampton, Va. The results are summarized in the following table:

TABLE F.

Date.	Males in catch.	Sponge-bearing crabs in entire catch.[a]	Date.	Males in catch.	Sponge-bearing crabs in entire catch.[a]
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
June 1	13	42	July 20	10	54
June 2	5	79	August 7	18	24
July 9	37	46	August 10	8	56
July 10	16	65	August 14	13	42
July 19	19	20	August 30	24	5-7

[a] From the early part of June until about the 20th, the sponge-bearing crabs comprised at least 75 per cent of the entire catch.

The average percentage of males will be seen from this table to be 16, a somewhat larger proportion than that indicated by the records of the firm at Hampton, Va. From all that could be learned from observations made at various points along the Bay, it is safe to say that at least 80 per cent of the hard crabs caught in the lower part of the Bay are females, while in regions around Crisfield, Md., an equally large percentage are males. From these data it would be predicated that relatively few sponge-bearing crabs would be found in Maryland waters. Observation substantiated this assumption. The number of sponge-bearing crabs occurring in Maryland waters is relatively

quite small. In the fall months some few are found about Crisfield and to the southward in Pocomoke Sound, but in general the number is insignificant.

Practically all the young, then, are hatched in the southern part of the Bay. Sponge-bearing crabs begin to be fairly numerous during the last week of May. As seen in Table F, they are most numerous during the first two or three weeks of June. About June 15 to 20 the eggs begin to hatch. The bulk of the young are hatched from the middle of June to the middle of July. From then on a gradually decreasing number are hatched until about the first of September, after which time very few sponge-bearing crabs are found.

The young at some time between hatching and reaching maturity migrate northward to such a distance that the majority of them are found from about the latitude of the Rappahannock River, Va., to Baltimore, Md. They are most numerous in Tangier and Pocomoke Sounds and the neighboring waters of the Eastern Shore of Chesapeake Bay, in Maryland. This is, no doubt, due to the fact that the bottoms underlying these waters are extensively covered with sea grass and afford a very favorable ground for the molting process.

The proof for the fact of the migration of the young lies in this point: Almost no sponge-bearing crabs occur in these northerly waters. Countless numbers of immature crabs do occur there and form the basis for an immense soft-crab industry, an industry which does not exist in the southern part of the Bay.

As the young are found in these northern regions in vast numbers, but do not hatch there, they must have been hatched elsewhere and migrated to this point. The migration must have been made from the lower part of the Bay, since practically all of the sponge-bearing crabs are found there.

At the opening of the season, from about April 15 to May 1, crabs measuring from 1 to 2 inches in width are quite abundant in the vicinity of Crisfield, Md. So numerous are they that it has been found advisable to legislate against the catching of crabs measuring less than 3 inches in breadth. It is not probable that all these small crabs make the entire journey from the southern part of the Bay in the spring, but no doubt they have moved at least a part of the distance up the Bay during the preceding summer and autumn. It is not known what stage the young crabs are in either at the beginning or close of the migration. It may be that it is entirely completed during the first summer, possibly before the crab has finished the megalops stage. Or, on the other hand, it may not be undertaken until the crab stages are reached, and yet be completed before the close of the first autumn. However that may be, it is evident that the migration is made. Wherever cold weather overtakes them the crabs lie on the bottoms until spring, when they again resume their activities. Moltings occur at intervals in the course of this migration. The crabs cease the northerly migration at latest by the time the maturity and mating periods are reached. The fact that the sponge-bearing crabs are distributed over a region extending from the Capes to nearly the northern boundary of Virginia results in some of the young reaching more northerly points than others before attaining maturity. Observations carried out at various points on the Bay showed that the crabbing season opened later in the year the farther north the investigations were carried.

The young crabs then reach maturity and mate in the waters just mentioned, which extend from about the latitude of the northern part of Virginia to Baltimore, Md.,

and they are rather more numerous than elsewhere in the waters of Somerset and Dorchester Counties, Md. Pairs of mating crabs are found in great abundance in these regions from the middle of July to the last of August. Mating is described on page 115.

During the spring and summer of 1917, 3,898 crabs were examined either by means of the cast shells, the peelers in the floats, or the soft crabs in the packing rooms. It was found that in the early part of the season males predominated in numbers among the crabs handled for the soft-crab market, i. e., crabs which are immature or just about to reach maturity. As the season progressed, the relative number of females increased until in August there were more females than males among the crabs caught for the soft-crab trade. The following data for Crisfield, Md., constitute a typical illustration of the results obtained at various points on the Bay:

Date.	Males.	Females.	Total.
	Per cent.	*Per cent.*	*Per cent.*
May 22–25	78	22	100
June 21–23	58	42	100
July 23–27	42	58	100
August 23	38	62	100

The data here cited might at first thought lead to the belief that the males preceded the females in the migration and were found in greater numbers upon the bottoms. It seems to the author, however, that the explanation is simply that the males outstrip the females in growth and are the first to reach a marketable size. As the adult size of the male is greater than that of the female, in order to complete development in the course of a year, a more rapid growth must be maintained by the male than is required for the female. This would result in there being during the spring months more male crabs of marketable size than females upon the bottoms. As the females developed, the relative numbers of the sexes would tend to become more nearly equal. The preponderance of females caught during August is doubtless due in a small part to the partial depletion of the supply of males during the spring crabbing season. It arises mostly, however, from the fact that during August a great number of female peelers, while being carried by the males preparatory to mating, are caught on the trot-lines. These females, together with those taken by the scrape and the dip net, would make the total number of immature females caught greater than that of the immature males, which are taken only by the scrape and dip net. As peeler crabs do not eat much, they do not bite readily on the trot-line.

After maturing and mating in the waters of the central and upper parts of the Bay, the female crabs migrate southward during the autumn and lie on the bottoms of the southern part of the Bay during the winter. While the males move southward to some extent, they do not go as far as the females. Not a great many remain as far north as Maryland waters, although a few are taken in that region while dregding for oysters during the winter. This southerly migration is proved by the following facts:

First. Very few sponge-bearing crabs are found in Maryland waters; therefore, the females that have mated there must have gone elsewhere before the eggs were thrown out upon the abdomen.

Second. During the month of October and the early part of November of each year large schools of crabs are found by the crabbers in the southern part of the Bay; in fact, the average daily catch per crabber is often higher during this time than at any other part of the summer season. A leading crabbing firm of Hampton, Va., has kept an exact record of the daily catch of each crabber selling to it since its inception in 1878. This firm very kindly placed these records at the disposal of the author. From the data thus obtained the average daily catch per crabber for each week of the summer

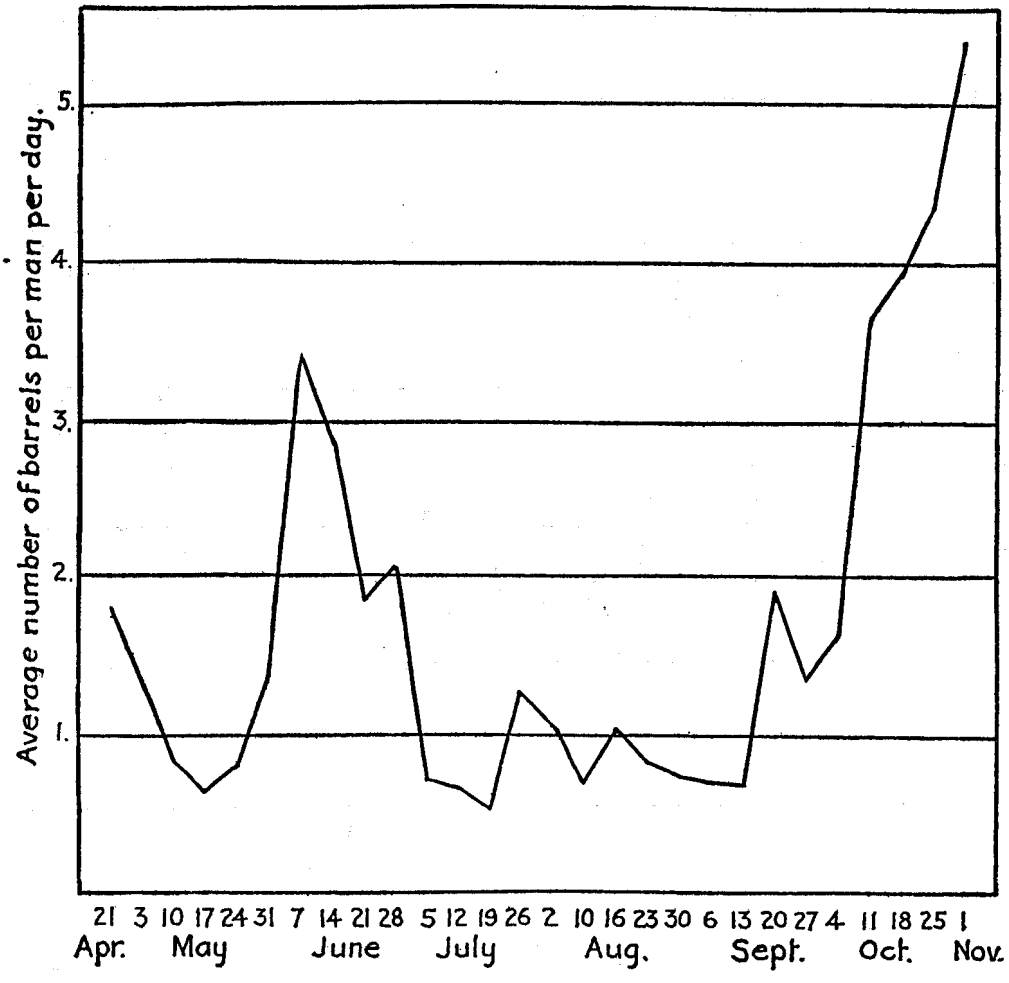


FIG. 1.—Curve showing average daily catch of crabs per crabber for each week during the summer season of 1917. The vertical line represents the number of barrels; the horizontal, the weeks.

season was worked out for the years 1900 to 1902 and 1907 to 1917, all years inclusive. The results were plotted in the form of curves. That for the year 1917 is shown in text figure No. 1. It will be seen that the highest point of the curve is at the close of the season in November. Owing to the close season on sponge-bearing crabs during July and August, the curve for 1917 falls lower during those months than do the curves for similar periods in the years before the close season was established. The curve shown in text figure No. 2, for the year 1910 is typical of the condition obtaining in the southern

part of the Bay before the establishing of this regulation. It shows that even before the institution of the close season there was a low period during the middle or last part of the summer. Nearly every curve for the 14 years which were analyzed exhibits the following characteristics: There are two high points, one occurring in the late spring, about May or June, and one in the fall, somewhere between the middle of September and the middle of November. In 7 of the 11 years for which complete records for the entire season were available the fall peak was higher than that for the spring. In 3

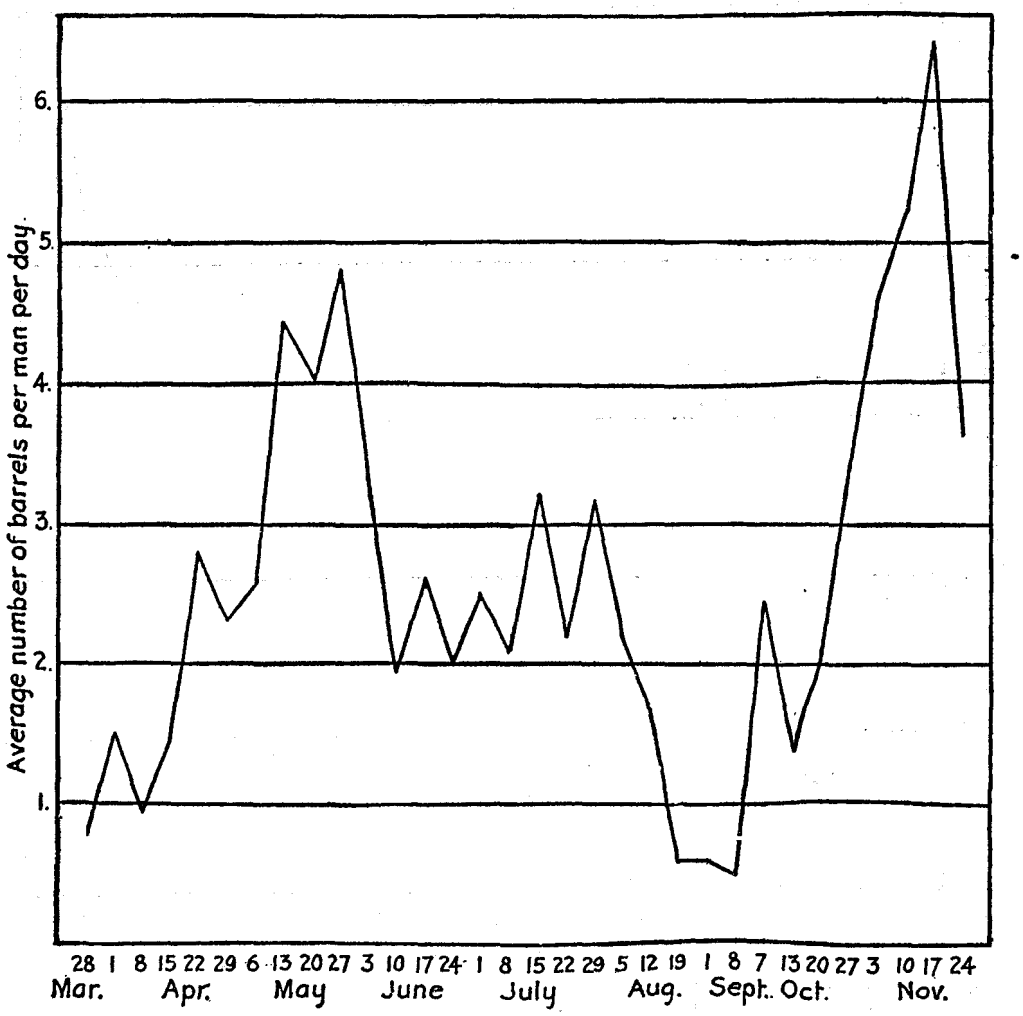


FIG. 2.—Curve showing average daily catch of crabs per crabber for each week during the summer season of 1910. The vertical line represents the number of barrels; the horizontal, the weeks.

years of the 14 the records are not complete, owing to the fact that the firm was closed during the fall months and that no crabs were purchased. During August or the first part of September there is a depression, often very marked. These curves would indicate that crabs are most abundant in the late spring and in the fall, and that a slack season ensues in August or the early part of September. This is amply borne out by observation of the activities of the crabbers in that region. By the month of June the

crabs have become active and have left the deeper waters, being abundant in the shallower waters. The peak of the spring catch is attained then. The falling off in the abundance of crabs during August is probably due to two factors; first, a great number have been caught by the crabbers; second, many of the females which spawn in June and July do so for the last time and die shortly thereafter. This matter is discussed more fully on page 123. The sudden abundance of crabs appearing in October and November is due to the migration to these waters of the crabs which have matured and mated in more northerly waters. These constitute the school crabs previously mentioned. About 80 per cent of the individuals of these schools are females, and nearly all are adults.

Third. During the first part of the summer great numbers of sponge-bearing crabs are found in the southern part of the Bay. So we have these conditions: A great number of maturing females in Maryland which mate and go somewhere else, since no sponge-bearing crabs are found there, a sudden appearance of large schools of female crabs in the southern part of the Bay in October, crabs in considerable numbers on the bottoms in the southern part of the Bay during the winter, and an abundance of sponge-bearing crabs in the southern waters the following June. Every evidence points to the fact that the mature female crabs which mated in Maryland waters migrate to the southern part of the Bay and spawn there the following summer.

Records were kept of various catches made by the dredge boats at intervals during the winter of 1916–17. Fourteen lots dredged in the lower part of the Bay gave an average percentage of 85 females to 15 males. Four lots dredged from points north of the city of Cape Charles, Va., gave 55 females to 45 males. It is safe to say that at least 80 per cent of the adult crabs found on the bottoms in the lower part of the Bay during the winter are females.

In brief, the migrations of a majority of the crabs of Chesapeake Bay are as follows: They hatch in the southern part, move northward as they develop and molt, lie on the bottoms where winter overtakes them, resume their northerly course in the spring, continue molting, reach maturity in the waters of upper Virginia and central Maryland, and mate there. The females return south in the autumn, lie on the bottoms of the southern part of the Bay, and spawn the following summer, the males remaining mostly in more northerly waters. A certain number do not migrate, but spend their entire life in the lower part of the Bay. Some small crabs may be found there during the entire summer. The great majority, however, of the young migrate as described above.

GENERAL HABITS.

Hay [a] presents an excellent description of the general habits of the blue crab. Certain portions will be quoted as affording the most convenient method of presenting these interesting features of the natural history of the blue crab.

Either in the water or on land the blue crab is an animal of great activity and has considerable power of endurance. Progression through the water is effected by means of a sculling motion of the broad, oar-like posterior legs, and under ordinary conditions is slow, the effort of the animal being apparently only to keep itself afloat while it is borne along by the current. Under these conditions the movement is either backward or sidewise. The shell is held with the posterior portion uppermost, the legs are brought together above the back and strike backward and downward at the rate of from

[a] Hay, op. cit., pp. 401–403.

20 to 40 strokes per minute. When alarmed, however, the animal strikes out with great vigor and rapidity, moving its paddles too swiftly for the eye to follow; it moves through the water almost as rapidly as a fish and quickly sinks below the surface. When on the bottom and undisturbed, the crab may be seen to walk slowly about on the tips of the second, third, and fourth pairs of legs, the large pincers being held either extended or folded close under the shell and the paddles either raised and resting against the back of the shell or assisting the movement by slow sculling strokes. In such cases the movement is in any direction—forward, backward, or sidewise—although the usual direction is sidewise. If the animal becomes alarmed, it moves away by a combination of the walking and swimming motions and often disappears like a flash. * * * All the legs are in motion except the large first pair. Of the latter, the one on the side toward which the animal is moving is held straight out sidewise, while the other is folded up under the shell.

The coloration of the crab is such as to harmonize very perfectly with the surroundings, and the animal attempts very little concealment if there are other objects on the bottom. Often, however, a clear, sandy bottom or some oozy pond will be found to be almost alive with crabs which have buried themselves until only their eyes and their antennæ are exposed.

The experience of the present author has been that it is only immature crabs which bury in this manner. No adults were found so hidden.

In thus hiding, the crab goes nearly vertically backward into the bottom and then, by a few movements, turns slightly, so that the shell rests at an angle of about 45 degrees. The material above settles down and effaces all traces of the entrance. It usually happens that the bottom affected by the crab is firm enough to render this operation somewhat slow and it rarely attempts to escape pursuit in such a way. It seems probable that concealment is usually adopted as an ambush from which a sudden attack can be made on some passing fish.

The author has often seen immature crabs dart away and burrow in the substratum, as described above, apparently in order to escape pursuit. It is probable that burrowing may be undertaken either for the purpose of escape or for lying in ambush. Hay describes an interesting habit of the crab which the author has never had the opportunity of witnessing:

In certain places, notably shallow ponds and streams which become nearly dry at low tide, the crab may be observed to dig rather large, conical holes, apparently as reservoirs, and to take up its position in the deepest part * * * and waits until the rising tide offers an opportunity to move about again.

The hole is described as about 1 foot across and 6 inches deep. The sand or mud is loosened by means of the tips of the walking legs and carried, clasped between the claw and the underside of the body, to the side of the excavation.

The color of the crab is more or less variable, and it is believed by the fishermen that the animal is able to change its hue slightly to approximate the color of its surroundings. Light grayish-green individuals are said to be taken on sandy bottoms, while the dark olive-green are said to be found among the grass. This theory, however, is not very well borne out by crabs held in captivity in the live boxes, for there they retain their original colors, and even after they have cast their shells exhibit quite as much variety as before.

The author agrees with the last statement of Hay and is of the opinion that there is no approximation of the color of the bottom by the crabs. In a catch, all the individuals of which were taken from the same area, he has seen specimens exhibiting all the varieties of colors which are found in crabs.

The blue crab's food is of a varied character, but the animal is preeminently a scavenger and a cannibal. In the shallow waters of ponds and small tidal streams it preys to a certain extent upon small fish, which it stalks with some cunning and seizes by a quick movement of its large claws. In such situations, too, I have sometimes observed it nibbling at the tender shoots of eel grass or other aquatic vegetation, or picking at the decayed wood of some sunken log. Its favorite food, however, is the flesh of some dead and putrid animal, * * * stale meat or a rotten fish.

An injured crab, if thrown into the water, will be speedily set upon by its associates and torn to pieces. Even one that is uninjured, if small or in the soft-shelled condition, is likely to be captured and eaten by stronger individuals.

In eating a bit of food the crab first grasps it in the large claws and pushes it back under the front of the shell, where it is seized between the tips of the second pair of legs and pushed forward and upward to a point where it can pass between the third maxillipeds to the jaws. These strong organs masticate the food, while the other mouth parts prevent the escape of the smaller particles. It is then swallowed and the complicated set of teeth in the stomach reduce it to a thin fluid mass before it is allowed to pass into the intestine.

REPRODUCTION.

MATING.

Among the crabs of Chesapeake Bay, mating occurs chiefly in Maryland waters and lasts from about the middle of July to the last of August, although mating crabs are seen earlier than this in the lower part of the Bay. The crab reproduces by means of eggs which are laid by the female and carried on the abdomen until hatched, as described on page 97. Previous to being laid the eggs are fertilized by spermatozoa which have been implanted in the body of the female crab by the male at the time of copulation. Mating and copulation occur, as far as is known, once only in the lifetime of the female crab. This takes place when she is yet soft at the time of the last molting, when the triangular-shaped abdomen changes to the rounded form. For a few days previous to copulation the female is carried about by the male, which clasps her, back uppermost, against the lower side of his body by means of his three pairs of walking legs. This leaves his claws and swimming legs free and he is enabled to feed or swim about. He at times frees a number of walking legs and moves over the bottom. Such pairs of mating crabs are called "doublers" and are often seen clinging to posts or pilings in the water. As already noted, the male's hold upon the female is quite tenacious, and both individuals are caught in great numbers on the trot-line, due to the male seizing the bait and both being drawn to the surface.

In all the numbers of pairs which have been observed by the author and by crabbers who were questioned, no male crab has ever been found, in nature, carrying any sort of female except one with a triangularly shaped abdomen and which bore all the marks of a peeler, or, more rarely, a soft-shelled female with a broad abdomen. If a female of the former sort is removed from the male and kept in a float, molting occurs, and the broad abdomen is acquired. Dissection shows that in such a case copulation has not yet occurred. If the male be carrying a soft-shelled female, it will be found that copulation is in progress or has just been accomplished.

Copulation.—If the female in the peeler state is left with the male, however, copulation ensues as soon as she has molted and while yet soft. The author observed one pair of copulating crabs which were found in a float. The female was lying on her back on the bottom of the float, with the abdomen extended backward, thus exposing the openings of the oviducts (Pl. XLIX, fig. 16). The male stood above her, with the walking legs partially clasped about her body and with the two intromittent organs (Pl. XLIX, figs. 14 and 15,) inserted in the openings of her oviducts. Opportunity was not given for observing the beginning or concluding stages of the copulatory act.

Hay [a] states that the male frees the female as she actually begins to molt, stands near by during the process, and seizes her again at its completion. A reliable crabber,

[a] Hay, op. cit., p. 405.

who stated that he had several times observed the process of copulation in the blue crab, told the author that the female crab voluntarily turns upon her back and spreads open the abdomen to expose the genital pores. Copulation lasts for a day or two, the female being carried about by the male, as before molting, except with the under side of her body uppermost. After copulation the female resumes her normal position and is usually carried by the male until her shell is hardened.

Male reproductive organs.—Plate XLIX, figure 14, shows a view of the male crab with the abdomen turned back to display the intromittent or copulatory organs. It will be seen that there are no appendages of moment other than these upon the abdomen. They correspond to the two anterior pairs of swimmerets upon the abdomen of the female and have been modified in the course of development to form copulatory organs. From Plate XLIX, figure 15, and Plate XLVIII, figure 2, it will be apparent that each organ consists of two parts, the one in front having a fairly broad base and being extended forward into a long, fine, slightly curved portion. The one in the rear is attached to the succeeding segment of the abdomen, is short, and has a sort of spur which fits into an opening in the base of the large anterior part of the organ. It evidently acts as a brace to strengthen the entire organ.

Plate XLVIII, figure 11, represents a dissection of a male crab, showing the testes, which lie upon the digestive glands or "fat;" the glands, which secrete a pink-colored, jellylike fluid for carrying the spermatozoa; and the long, thin, white, convoluted tube, or vas deferens, through which the spermatozoa pass to the copulatory organs. Each of these tubes (Pl. XLIX, fig. 15, and Pl. XLVIII, fig. 2), passes out through an opening on one of the segments, the coxopodite, of the swimming legs and into the base of the large part of the copulatory organ. The spermatozoa pass through a hollow in the center of these organs and into the sperm sacs of the female.

Female reproductive organs.—Plate XLIX, figure 16, shows the under side of an adult female crab. The broad abdomen is turned back, exposing the openings of the two oviducts and the large swimmerets, which are borne on the lower side of the abdomen. The copulatory organs of the male are inserted into the two openings during copulation. The eggs pass out through these openings when laid and become attached to the inner portion of each pair of swimmerets, thus forming the sponge (Pl. L, fig. 19, and Pl. LI, fig. 22).

Plate XLVIII, figure 3, represents the dissection of a female crab in the stage immediately preceding molting for the last time. The ovaries are very narrow and are white in color. After this molting and before copulation, the ovaries are very little larger, and the sperm receptacles are flat, empty sacs with a fairly tough, white wall. The ovaries are attached to the upper side of the sperm sacs, and at the point of attachment there is a passage leading from each ovary into the interior of the sperm sac. A tube or oviduct leads from each sperm sac and opens on the exterior, as shown in Plate XLIX, figure 16. At the time of copulation the pink, jellylike fluid carrying the spermatozoa is forced into the sperm sacs, which, as a consequence, become hard and distended and of a pink color (Pl. XLVIII, fig. 4, and Pl. L, fig. 17). The presence of sperm sacs of such a nature is always a sure indication that the female has mated within the preceding few days.

Within a few weeks the pink jelly will be found to have disappeared, leaving the sacs flat again, but with a white ridge along their lower side (Pl. XLVIII, fig. 6). The spermatozoa will be found stored in this ridge. They are carried from the male by the jelly in bundles of an oval shape slightly larger than the eggs of the female. Such bundles are called spermatophores, and one is shown in Plate XLVIII, figure 8. The spermatophores disintegrate as the jelly disappears from the sperm sacs and the spermatozoa are found to lie in a mass in the white ridge at the bottom of the sperm sacs. Drawings of the spermatozoa which have been mounted for microscopic study are shown in Plate XLVIII, figure 9.

Development of the ovaries.—The ovaries enlarge until they are about one-half inch in width (Pl. XLVIII, fig. 13), at the same time becoming a bright orange-red color. The color is due to yolk granules in the eggs, as described earlier. If examined microscopically, some of the eggs will be found to have reached the size at which they are when laid upon the abdomen (Pl. XLVIII, fig. 1). Smaller eggs, which will be laid in subsequent batches, will also be found.

The enlarging of the ovaries is not dependent, however, upon copulation. It has been found that they enlarge and the eggs likewise increase in size, even if copulation has not occurred. On June 19 a female crab with the triangularly shaped abdomen was placed in a float with no male present. On June 25 it molted, the abdomen changing to the rounded form. On July 21 this crab was killed and its ovaries examined. They were found to have attained, during this period of only 26 days, to about one-half the full width. The eggs were about one-half the mature size. The color was orange. The sperm sacs were thin and flat, as already described for the crab which was removed from the male immediately before copulation. There was no white ridge found along the lower side, such as is present in a crab which has copulated. It is possible that such a crab would lay the eggs when they had attained the full size, but they would, of course, be infertile, and therefore would not hatch.

It is thought by many crabbers that the abdomen of the female will not change to the broad form unless the male is carrying the female at the time of the last molting. This is shown to be an erroneous idea, both by the evidence of the experiment just cited and by the fact that at least four other female crabs were allowed to undergo the last molting while under observation, no male being present, and in each case the normal, broad abdomen appeared.

Probably very few female crabs, however, pass the last molting stage in nature without mating. Observations made at various times on at least 300 adult females revealed none which had failed to undergo copulation.

Fertilization.—The eggs are, in all probability, fertilized as they pass through the sperm sacs on the way from the ovaries to the exterior at the time of spawning. The spermatozoa are found in the sperm sacs, as before stated. The author was able to find no evidence that would lead to the belief that spermatozoa pass up into the ovaries and meet the eggs there. Eggs taken in May from the hollow in the middle of the fully developed ovary gave no appearance of having been fertilized and did not develop when kept in sea water. On the contrary, they always become swollen within the course of 10 or 15 minutes (Pl. XLVIII, fig. 12), apparently from having absorbed water. Eggs taken from the sponge of the female were found to be covered by a tough trans-

parent membrane, which is probably a means of protecting them from the action of the sea water, by which they are surrounded. It seems probable that the eggs lack this tough membrane until after they have passed through the sperm sacs and have been penetrated and fertilized by the spermatozoa which are found there.

Interval between copulation and spawning.—The length of time which elapses between copulation and the laying of the eggs depends on the season at which copulation occurs. Experiments which were performed in the endeavor to throw some light on this question follow.

On various dates between June 18 and 26, 15 adult female crabs were selected and confined in floats for observation. By the external appearance it had been ascertained that these crabs had molted for the last time within the previous few days. Such crabs can readily be distinguished after a little practice by their fresh, blue color, the weakness of the muscles holding the abdomen against the lower side of the body, and the bright, clean, slightly golden appearance of the swimmerets. At the same time several such females taken from the same catch were dissected and found to have copulated. It was assumed that those selected for the experiment had also copulated. During the course of the experiment the crabs were fed with fresh fish. On August 1 one female threw out a very few eggs. About August 15 two others each formed a sponge, the eggs of which hatched from the 27th to the 30th. In general, it was found in all experiments with female crabs confined in floats and crates that only a small percentage of such individuals spawned. The confinement was apparently prejudicial to the full exercise of their natural functions. In the case of the three individuals which did spawn it will be seen that the interval between copulation and spawning was about two months.

Further, on June 20, a female crab with the triangularly shaped abdomen was confined in a float with a male. On June 25 it was found that the female had molted and had the broad abdomen. Presumably she had mated, although the act had not been observed. The male was removed. On August 27 it was found that the female had thrown out a small sponge within the preceding two or three days. Upon microscopic examination the eggs were seen to have begun development, showing that mating had occurred and that they had been fertilized. In this case also about two months elapsed between copulation and spawning.

The facts just mentioned apply, however, to the fairly small percentage of female crabs which mature in June or the early part of July, and more especially to those of the southern part of Chesapeake Bay, since not many mature before the middle of July at points farther north in the Bay. Earlier in this paper it was shown that the most of the mating occurred from the middle of July to the last of August and that the female crabs migrated to the southern part of the Bay and spent the winter on the bottoms thereof. Later it is proved, page 119, that these crabs spawn the following June and July, thus accounting for the abundance of sponge-bearing crabs found in the late spring and summer in the southern part of the Bay. In this case the period elapsing between copulation and spawning is about 9 or 10 months. During the winter the crab is inactive, eating very little or nothing. Its natural functions are therefore practically suspended, for it remains in a state of semihibernation.

SPAWNING EXPERIMENTS WITH CRABS TAKEN DURING THE WINTER.

The fact that the female crabs mate during one summer and do not spawn until the next, as stated in the preceding paragraph, is proved by the following examinations and experiments: During the winter of 1916–17, 238 adult female crabs taken from the catches made by various dredge boats were examined. In each case specific records were kept of the condition of the ovaries, sperm sacs, eggs, etc. In 204 of these, the ovaries were found to be large and full, as shown in Plate XLVIII, figure 13, and Plate L, figure 18. In 30 cases the ovaries were small, but microscopic examination revealed the presence of small eggs within them. Four crabs taken early in the season had recently copulated, as was shown by the presence in the sperm sacs of the pink, jellylike fluid (Pl. L, fig. 17). The sperm sacs of the other 234 crabs had the small white ridge along the lower side (Pl. XLVIII, fig. 6). Spermatozoa were found within the mass which made up this ridge. Plate XLVIII, figure 9*B*, shows some of such spermatozoa after having been mounted for study. Every appearance was given that these crabs had mated during the preceding summer and would survive the winter and spawn the following summer.

To test this matter more fully, the following experiments were performed: Twenty-eight adult female crabs which had been taken on March 28 with the dredge were placed in a crate made of chicken wire fencing and measuring 2 by 2 by 4 feet. This crate was placed in water of such a depth that it was entirely covered at low tide. The crabs were fed nearly every day with pieces of fresh fish. On June 28, 8 crabs were living, one of which bore a sponge of normal size. On March 22, 19 crabs which had been taken with a dredge were confined in floats in the water of the Bay. These crabs were fed with fish. On June 15 one spawned, and on June 22 another spawned. The latter was kept under observation, and upon microscopic examination on June 25 the eggs showed marked cleavage, proving that they had been fertilized and were developing.

Through the courtesy of John S. Parsons, late commissioner of fisheries of Virginia, the author was enabled to utilize a small cove at Lynnhaven Bay, Va., in which to keep crabs under observation. Wire netting was placed across the mouth of the cove in such a way that the crabs were prevented from escaping, while allowing direct connection between the water of the cove and that of the Bay. The cove was divided by a close, wooden partition, so that two independent experiments could be maintained simultaneously.

On April 18 the author accompanied a dredge boat which secured 2½ barrels of crabs in Lynnhaven Roads, east of Norfolk, Va. On the same day these were put in one part of the cove by the author and Messrs. Owens and Woodhouse, crab inspectors of the the State of Virginia. During the first week in June several dozen crabs bearing sponges were removed from the cove by Mr. Woodhouse and sent to Commissioner Parsons. On June 7 the author and Mr. Woodhouse removed from the Cove six sponge-bearing crabs. Two of these are shown in Plate LI, figure 22, being the two at the right of the picture. Quite a number of others were seen in the water of the cove. Apparently they spawned there about as freely as in their natural habitat.

From the evidence of these examinations and experiments it is plain that the connecting link is perfect between the crabs that mate one summer and those that spawn the summer following. The great bulk of the crabs of Chesapeake Bay, after mating in Maryland waters where they matured, move to the lower part of the Bay, retain their eggs during the winter, and spawn the following June and July.

NUMBER OF BATCHES OF EGGS LAID.

The prevailing supposition among most crabbers is that the female crab lays but one batch of eggs and dies shortly thereafter. Binford,[a] however, in 1911, reported that he observed the eggs hatch from a sponge on a female crab, which he then dissected. The ovaries were examined and found to contain "nearly mature eggs, as was judged from their size and color." He concluded from this fact that the crab would have been capable of spawning again. Hay and Shore,[b] 1918, state that it is believed that the female crab molts but once, "although she may produce more than one lot of eggs." The following experiments and observations were made in an endeavor to test this matter more fully.

Two crates, measuring 2 by 2 by 4 feet, were constructed from chicken wire fencing. About 30 female crabs, which were known to have spawned, were confined in each crate during September, 1916 (Pl. LIV, fig. 36). The crates were partially sunk in the mud and water to a depth of about 6 feet at low tide. The crabs were fed two or three times a week with bits of fish which were pushed by a stiff wire down a galvanized-iron sheeting tube into the crates. Feeding was discontinued about December 1, as it was found from other experiments that the temperature of the water was below 50° F. and that crabs eat little or nothing at such low temperatures. It was hoped that some of the crabs might survive until the following spring, when the question of spawning could be tested. The effort was a failure, however, for it was found on lifting the crates in the spring that the crabs were all dead.

Effort was also made to keep some adult female crabs through the winter in the United States Fisheries biological laboratory at Beaufort, N. C. Although two crabs survived until the following June, and were placed in floats, neither spawned. Judging from their appearance at the time when placed in the floats, they were not in a very vigorous or healthy condition.

During the winter of 1916–17 a method was found by which this problem was successfully met and it was shown that at least a second batch of eggs may be laid by the female crab. The procedure followed and the results attained are here discussed.

It was found that it was possible to determine, in the case of many of the female crabs which were examined during that winter and the subsequent spring, whether they had ever produced a sponge. Microscopic examination of the hairs on the swimmerets of these females revealed, in many cases, occasional hairs which still bore the tendrils that had served to hold the eggs of a sponge produced at some previous time, most probably the season immediately preceding. Often, the fragments of the shells which had incased the eggs were yet attached to the tendrils. Plate XLVIII, figure 10, represents a hair from the swimmerets of such a crab. Numerous tendrils and shells are to be seen still adhering to it.

The method of examination was as follows: A cursory examination with the unaided eye or a hand lens was first made. After some experience had been gained, it was found that remnants of a sponge were not found in case the swimmerets were bright and clean in appearance. In case they were blackened or débris of any sort was apparent, a small portion of the tips of the hairs on the anterior swimmerets was

[a] Binford, op. cit., p. 1.

[b] Hay, W. P. and Shore, C. A.: The Decapod Crustaceans of Beaufort, N. C., and the Surrounding Region. Bulletin, U. S. Bureau of Fisheries for 1915–16, Vol. XXXV, p. 433. Washington, 1918.

clipped off with the scissors and examined with the dissecting misroscope. It was found that very little or no bleeding resulted and that the crab very seldom, if ever, died as a result of the removal of the tips of the hairs in this manner. Such individuals could, therefore, be kept under observation to await subsequent spawnings.

The presence of such remnants of a sponge upon the swimmerets of a female crab is conclusive proof that she has at one time laid a batch of eggs, presumably during the summer immediately preceding. The absence of any such remnants is not proof that the individual in question has never spawned, since all the hairs may have become entirely cleared of any portions of the sponge. It was seldom found that many hairs bore remnants; in many cases they would be found upon only one or two located at the tips of the anterior swimmerets.

During the winter and spring, in almost any barrel of crabs which was examined, it was possible to find without difficulty females bearing such remnants of a sponge. On April 18 the author accompanied a dredge boat which was working in Lynnhaven Roads, Va. Three barrels of crabs were dredged in about five hours' time. During this time, with the aid of a dissecting microscope, one-half barrel of crabs which bore remnants of sponges was selected from those dredged. This means that at least 16⅔ per cent of those dredged up on this occasion had spawned during the preceding summer. As not nearly all those obtained were examined, owing to lack of time, the actual proportion bearing remnants was no doubt greater than this. Most of those which bore remnants appeared to be vigorous and capable of living the remaining weeks until June.

On May 15 seven females were removed from a barrel of crabs that had been caught by the trot-line. All were living. Upon examination it was found that three had spawned during the preceding summer. Crabs bearing remnants of an old sponge usually have a peculiar rusty-brown color which is not possessed by the other females. This is probably due to the fact that the former are older and have usually survived two winters. In searching for remnant-bearing crabs this color characteristic proved to be a useful guide. The proportion of three to four, apparently, as just shown, would not hold for the entire barrel, since the seven crabs were not selected at random, but with reference to the brown color.

As late as June 1 it was possible to find individuals bearing remnants of the sponge of a previous season. Thus it is plain that the crabs which have spawned during one summer may survive throughout the winter until the following spawning season.

Crabs which carried remnants of a sponge were dissected during the winter and spring of 1916–17. This examination led to the belief that such crabs were capable of spawning the ensuing summer. The ovaries were large and full; in fact, they appeared in every way similar to those of the individuals which had mated the previous summer and had not yet laid any eggs. (Compare Pl. XLVIII, fig. 13, and Pl. L, fig. 18.) The sperm sacs were found to contain the white ridge or mass (Pl. XLVIII, fig. 6), in which spermatozoa (Pl. XLVIII, fig. 9*B*), were found, as in the case of the other crabs. Apparently enough spermatozoa were provided by the male at the time of the one copulation which the female underwent to fertilize successive batches of eggs. What was not utilized at the passage of the first lot of eggs through the sperm sacs remained there in a

living condition and would fertilize later lots. Such a phenomenon is known to be true for the stone crab of our Atlantic coast,[a] and probably for the edible crab of England.[b]

Crabs bearing remnants of a sponge which had been produced during a preceding summer were selected during the spring of 1917 and kept under observation until June in order to ascertain whether or not they would spawn again. The half a barrel of such crabs which was selected on April 18, as already stated, was placed the same day in one part of the cove at Lynnhaven Bay, at the time of the initiation of the experiment with the other dredged crabs, previously described. During the first week of June several sponge-bearing crabs were removed from this part of the cove by the crab inspector, Mr. Woodhouse, and sent to Commissioner Parsons. On June 7 the author and Mr. Woodhouse removed one sponge-bearing crab from this part of the cove. This individual is shown in Plate LI, figure 22, being the one on the lower left.

On March 22, 19 crabs which bore remnants of a sponge were selected from a lot that had been caught with the dredge. These were confined in floats and fed with fish during the course of the experiment. On June 4 two spawned and on June 15 another. On June 22 a fourth spawned. The last was kept under observation, and on June 25 the eggs were examined and found to show marked cleavage, proving that they had been fertilized and were developing. The individual which spawned on June 15 was also kept under observation. On June 29 it was found that part of the eggs had hatched. By July 2 nearly all the young had hatched and left the mother. The crab was killed and dissected. The ovaries were found to contain eggs of about one-third full size. Indications were thus given that still another lot of eggs would be laid.

On April 24 a female crab bearing remnants of a sponge was placed under observation. On May 30 this individual spawned. This crab is shown in Plate L, figure 19.

On June 1, in a lot brought in by a trot-line boat, a female crab was found which bore remnants of an old sponge and also some eggs, which were recognized by their color and appearance to have just been laid. Many full-sized eggs were found in the ovaries. This individual had evidently been caught shortly after having begun to throw out what was at least the second lot of eggs. The spawning process was thus interrupted before completion.

Further experimentation showed that some of the female crabs lay two batches of eggs during the same summer. After about June 20 it was observed that the eggs of the majority of the sponge-bearing crabs were beginning to hatch. By July 1 probably half the young for the season had been hatched. (See table F.) It was thought possible that some of the females which had thrown off a sponge in June would produce another lot of eggs that same summer.

On June 27 a dozen such females were confined in a float. On July 6 one was found to have spawned during the preceding 24 hours. Upon examination the eggs were found to show faint cleavage lines, indicating that they had been fertilized and were beginning to develop. This also shows that cleavage had probably not begun until the eggs had been deposited upon the abdomen, otherwise it would have reached a

[a] Binford, R.: The Germ-Cells and the Process of Fertilization in the Crab, *Menippe mercenaria*. Journal of Morphology, vol. 24. June, 1913, p. 161. Philadelphia.

[b] Pearson, J.: Cancer (the Edible Crab). Trans., Liverpool Biological Society,, Vol. XXII, 1908, p. 468. Liverpool.

more advanced stage. On July 9 another crab threw out a few eggs and on July 28 another spawned. In another similar experiment, two crabs were found to spawn.

These experiments show that the female crabs spawn twice or more times during the course of their lives. The successive lots of eggs are fertile and will hatch. Enough spermatozoa are stored in the sperm sacs of the female at the time of the one copulation which she undergoes to fertilize all the eggs which she lays.

It is evident, also, that the adult female crabs found on the bottoms in the southern part of Chesapeake Bay during the winter are not spawned-out or barren crabs. On the contrary, part of them are individuals which have mated the previous summer and will lay their first lot of eggs the next season, and part are crabs which have produced one or more sponges the preceding summer and will survive the winter and lay again the succeeding season. Most of the females lay one or sometimes two lots of eggs the first season, one toward the early part and the other (when this occurs) later on, survive the winter, and lay again the next season. Some lay the first lot late in the summer and one or two batches the succeeding season.

Of course a crab will not spawn indefinitely and just as surely it must finally die. The ovaries of some of the crabs which spawned in captivity were found to contain no more eggs, however small. Evidently such crabs had spawned out and would produce no more sponges. Crabs whose ovaries are in this exhausted condition are found during the summer among those taken for market. As the ovaries of none of the 238 individuals examined during the winter were in this condition, it seems probable that the female crab dies shortly after having produced her last lot of eggs. This probably occurs during the late summer or early fall. As mentioned earlier, this is, no doubt, one of the causes for the falling off in the available supply of crabs in the southern part of Chesapeake Bay during August of each year. This decrease is manifested in the curves of the averages of the daily catches of the 14 years for which the data were worked out. A typical curve is shown in text figure No. 2.

WINTER HABITS.

It has usually been thought that during the winter the crabs retire to fairly deep water and bury in the mud or sand. It is very apparent that this view is in part correct. Most of the crabs proceed to the deeper water to pass the winter. The author is reasonably sure, however, that the majority of the crabs do not bury in the substratum. This, at least, is true of those found in the waters where dredging is carried on. The author has been told of cases in which crabs were found buried during the winter in the mud of a shallow cove or creek, but has never had the opportunity of verifying such statements by personal observations.

If one judges from the appearance of the hauls made while dredging, the crabs brought up have not been buried. This is especially true in cases where the dredging was being carried on over fairly hard, sandy bottoms. Many observations were made when the teeth of the dredges were so clogged with seaweed that they could not possibly be sinking into the comparatively hard sand; even if it is supposed that the crabs could have buried in it. Crabs were being brought up in average quantities. Many dredgers

have given instances in which buoys were left to mark an area on which crabs were abundant, and on the next day it was found that the crabs had moved away. Other instances have been given in which dredgers systematically followed a school of crabs from one point to another. These facts show that the crabs may move about to a considerable extent during the winter months.

From observations which were made on crabs being kept in floats, it was found that, as the temperature lowered, the crabs became more and more sluggish and at about 50° F. moved very little and practically ceased to eat. On warmer days they became more active. Crabs were also kept in wire crates partly sunk in the mud. At various times during the winter examination was made and it was found that the crabs had not buried in the mud.

It seems most probable that the crabs, instead of burying, merely move toward deeper, and consequently warmer, water as winter approaches and as the temperature falls become more and more inactive and finally lie motionless on the bottom. On milder days they move about to some extent, especially if disturbed.

LENGTH OF LIFE.

The only original statement concerning the length of life of the blue crab which is found in the literature is that of a correspondent quoted by Dr. Mary J. Rathbun.[a] The probable duration of the life of both the male and the female is there estimated to be seven years. The correspondent bases his conclusion partly on certain wholly casual observations made during his boyhood and partly upon assumption. The period before the crab attains maturity is stated to be three years, and it is thought to molt twice each year during this time. As the correspondent is dealing with the blue crab found near Victoria, Tex., it is possible that the life history of that form is widely different from that of the crab of the Chesapeake Bay, although both belong to the same species. On the whole, however, it does not seem that a great deal of weight can be attached to the opinions set forth on this subject by the correspondent.

In connection with the blue crab of the Atlantic coast, and of Chesapeake Bay, in particular, experiments and observations led to a very different conclusion from that arrived at by the person mentioned by Dr. Rathbun. It was found that a crab which is hatched during one summer will reach maturity the next, molting from 15 to 20 times during this interval. It then mates and, in the case of the female, spawns at the age of 2 years, during the summer following the one in which mating occurs. The female was also found to be able to survive the winter following the first spawning and to spawn again at the age of 3 years. It is probable that this is the usual length of life of the female, although some may survive until yet another season. In the case of the male, there are no spawning periods by which to judge its term of life. The best evidence available shows that the males mature in one year, as do the females. During the spring and early summer full-sized males are found which, judging from their brownish color and the presence of barnacles, etc., upon their shells, have survived at least one winter after reaching maturity. It is very probable that the usual term of life of both the male and female crab is 3 years.

[a] Rathbun, op. cit., p. 370.

SUMMARY.

The following is a list of the main points brought out in this report:

1. The blue crab, *Callinectes sapidus*, is found in the salt and brackish waters of the Atlantic coast from Massachusetts to South America.

2. The young hatch from eggs borne for about 15 days upon the swimmerets of the abdomen of the female in a mass called a sponge. There are about 1,750,000 eggs in one sponge.

3. The young do not cling to the swimmerets of the mother after hatching. They do not devour the mother as they are hatched, as supposed by some.

4. The young, after hatching, increase in size only when they molt. They pass through two stages before reaching the true crab shape. In the first, or zoëa stage, molting occurs four or five times; in the second, or megalops stage, probably only once. About one month is required to complete these two stages.

5. In passing from the megalops stage to that of the adult-crab stage about 15 moltings occur. The average time between molts is 15 days, ranging from 6 days for the early stages to about 25 for the last. The average increase in width at each molt is one-third.

6. The crabs mature and mate during the second summer, at the age of 12 to 14 months.

7. The female reaches a molting at which the abdomen changes from a triangular to a broad, rounded form. This is most probably the last molting. The male, also, probably does not molt after reaching maturity.

8. Molting is described. The crabs become hard again within two or three days after molting. Neither the tides nor the moon have any effect upon the molting process, although the tides do affect the distribution of the crabs.

9. Juvenile crabs possess the power of regenerating an appendage which has been lost or voluntarily thrown off. Regeneration is completed at molting, but it is not yet known whether it occurs in the adult crab, which most probably does not molt.

10. The young of the crabs of Chesapeake Bay hatch in the lower part of the Bay during June and July, migrate northward, mature in Maryland waters the next summer, mate there during July and August, then the females move southward in the fall, and pass the winter on the bottoms in the southern part of the Bay. They spawn the following spring and summer. The males remain for the most part in more northerly waters.

11. Mating occurs in the female at the time of the last molting, while she is yet soft. She is carried by the male for a few days prior to such molting, after which copulation is effected. At this time sufficient spermatozoa are implanted in the sperm sacs of the female to fertilize all the eggs which she lays during her lifetime. Fertilization is effected in the sperm sacs of the female. The ovaries of the female are very small at the time of the last molting, but begin to develop then, whether or not copulation occurs. If mating occurs quite early in the season, the eggs are laid within about two months. In the great majority of cases, however, mating occurs in July or August and the eggs are not laid until the following spring or summer.

12. Practically all the female crabs found on the bottom of the southern part of the Bay are filled with eggs and will spawn the following season. This was amply

proved by keeping some of such crabs until spawning season and finding that spawning ensued.

13. A female crab may lay two and probably more batches of eggs during the course of her life, the spermatozoa from the one copulation sufficing to fertilize successive lots of eggs. This was proved both by microscopic examination and by experimentation upon crabs which were known to have laid at least one previous batch of eggs. The female crab dies shortly after having laid the last lot of eggs. Death usually occurs in the late summer or autumn.

14. The general habits are discussed, including walking, swimming, methods of concealment, feeding, etc. The majority of the crabs do not bury in the substratum during the winter but lie on the bottom in the deeper water in a more or less dormant state.

15. The usual term of life of the crabs is probably about three years.

EXPLANATION OF PLATES.

PLATE XLVII (Frontispiece).

(Drawn by Mrs. W. P. Hay.)

Above.—Female crab immediately after having molted and acquired the broad abdomen. The coloring of the crab is most marked while the individual is yet soft.

Below.—At the left (upper) two outer segments of swimming leg of immature peeler crab, showing the pink line which is the "sign" most commonly used to distinguish peeler crabs; (below) portions of arm of claw showing distinctive markings of the peeler; at the right, abdomen of immature female crab in peeler stage showing the reddish hue assumed at that stage.

PLATE XLVIII.

Fig. 1. Mature egg taken from ovary of blue crab. Stained to show nucleus. *A*, nucleus; *B*, yolk cells. ×280.

Fig. 2*A*. Outer view of basal portion of left intromittent organ. *B*, coxopodite of leg; *C*, vas deferens, continued by dotted lines *behind* upright portion of organ and entering as shown in 2*B*; *D*, basal portion of anterior section of organ; *E*, posterior section of organ, attached to succeeding abdominal segment; *F*, spur on posterior section, fitting into socket in anterior. Natural size.

Fig. 2*B*. Inner view of anterior section of intromittent organ, showing manner of vas deferens and continuation of the organ into the long copulatory portion. Natural size.

Fig. 3. Reproductive organs of immature female, with triangular abdomen. *A*, sperm sacs; *B*, ovaries; *C*, digestive gland; *D*, stomach.

Fig. 4. Reproductive organs of adult female shortly after copulation, showing enlarged size of sperm sacs. Lettering as in figure 3.

Fig. 5. Empty shell from which egg has hatched. ×280.

Fig. 6. Sperm sac of female after jelly which carried spermatophores from the male into it has disappeared, leaving the spermatozoa in the white ridge, *A*. *B*, anteriodorsal opening to ovary; *C*, opening to oviduct. Natural size.

Fig. 7. Small portion of sponge, showing manner of attachment of eggs. *A*, hair; *B*, covering of hair and tendril. Unstained. ×280.

Fig. 8. Spermatophore in which the spermatozoa are carried from the male to the sperm sacs of the female. ×280.

Fig. 9*A*. Spermatozoa from vas deferens of male, after treatment with Bouin's fixing fluid and mounting on slide.

Fig. 9*B*. Spermatozoa from the sperm sacs of females, some of which had previously spawned one batch of eggs.

Fig. 10. Hair from swimmeret of blue crab, bearing empty shells of the eggs from which the young have hatched. The presence of such fragments of a sponge upon the swimmerets of a female crab is proof that she has spawned at some time. Individuals may be found in considerable numbers with such remnants during the winter and spring months. ×25.

Fig. 11. Reproductive organs of male crab. *A*, testis; *B*, gland secreting medium for transporting spermatophores; *C*, vas deferens; *D*, stomach; *E*, digestive gland. ×½.

Fig. 12. Egg taken from ovary and kept for 15 minutes in sea water; note swelling, manifested by distension of egg membrane; *A*, egg membrane.

Fig. 13. Reproductive organs of adult female crab taken with the dredge on January 5, 1917, in Chesapeake Bay. *A*, ovaries, large, and filled with mature eggs. The sperm sacs are covered by the ovaries at this stage. ×½.

PLATE XLIX.

Fig. 14. Ventral view of adult male crab showing copulatory organs.

Fig. 15. Copulatory organs of male crab. Black paper has been placed behind the ducts leading from the reproductive organs. *A*, vas deferens, duct leading from the testis out through the inner joint (coxopodite) of the leg to the intromittent organs; *B*, intromittent organs.

Fig. 16. Ventral view of adult female crab showing swimmerets. *A*, inner swimmerets to which the eggs are attached; *B*, external openings of oviducts. × ½.

PLATE L.

Fig. 17. Photograph of reproductive organs of female crab shortly after copulation, showing sperm sacs large and distended by the jelly carrying the spermatozoa from the male. *O*, ovary; *S*, sperm sacs; *L*, digestive gland.

Fig. 18. Photograph of female crab upon whose swimmerets remnants of an old sponge were found, thus showing that the individual had spawned. This crab was taken with the dredge on February 28, 1917, in Chesapeake Bay. Note large, full appearance of ovaries, *O*, which are filled with mature eggs; *L*, digestive gland.

Fig. 19. Female crab bearing what is known to be at least the second sponge. Remnants of an old sponge were found upon the swimmerets when she was taken on April 24. This individual was kept under observation in a wire cage in the water of Hampton River. On May 30 this sponge was formed. Microscopic examination during the next few days showed that the eggs were fertile and beginning to develop. × ⅔.

PLATE LI.

Fig. 20. Floats secured within an inclosure of wire supported on posts to prevent disturbance by boats.

Fig. 21. Zoëa, form possessed by the blue crab when first hatched. (After Brooks.) × 80.

Fig. 22. Four crabs which were taken with the dredge during the spring of 1917 and which spawned in June of that year. The three without claws were kept under observation in a cove at Lynnhaven Bay, Va. The one with the claws was kept in a wire cage in the water of Hampton River, Va. The two at the left are known to have spawned the preceding season as remnants of an old sponge were found upon the swimmerets of each of them when caught.

Fig. 23. Megalops, second form of the blue crab, attained after molting from the zoëal stage. (After Brooks.) × 80.

Fig. 24. Regeneration of the claws. When this individual was caught the left claw was lacking. At the first molt while in captivity the claw was regenerated, upper row; in the two succeeding molts the left claw practically overtook its fellow in size, middle and lower rows.

PLATE LII (After Hay).

Fig. 25. "Buster" crab, first molting stage.

Figs. 26, 27, 28, and 29. Successive molting stages.

Fig. 30. Photomicrograph of eggs attached to hairs of swimmerets. A few empty shells from which the young have been hatched are shown. In many of the eggs, the eyes of the developing zoëas may be seen. × 120.

PLATE LIII.

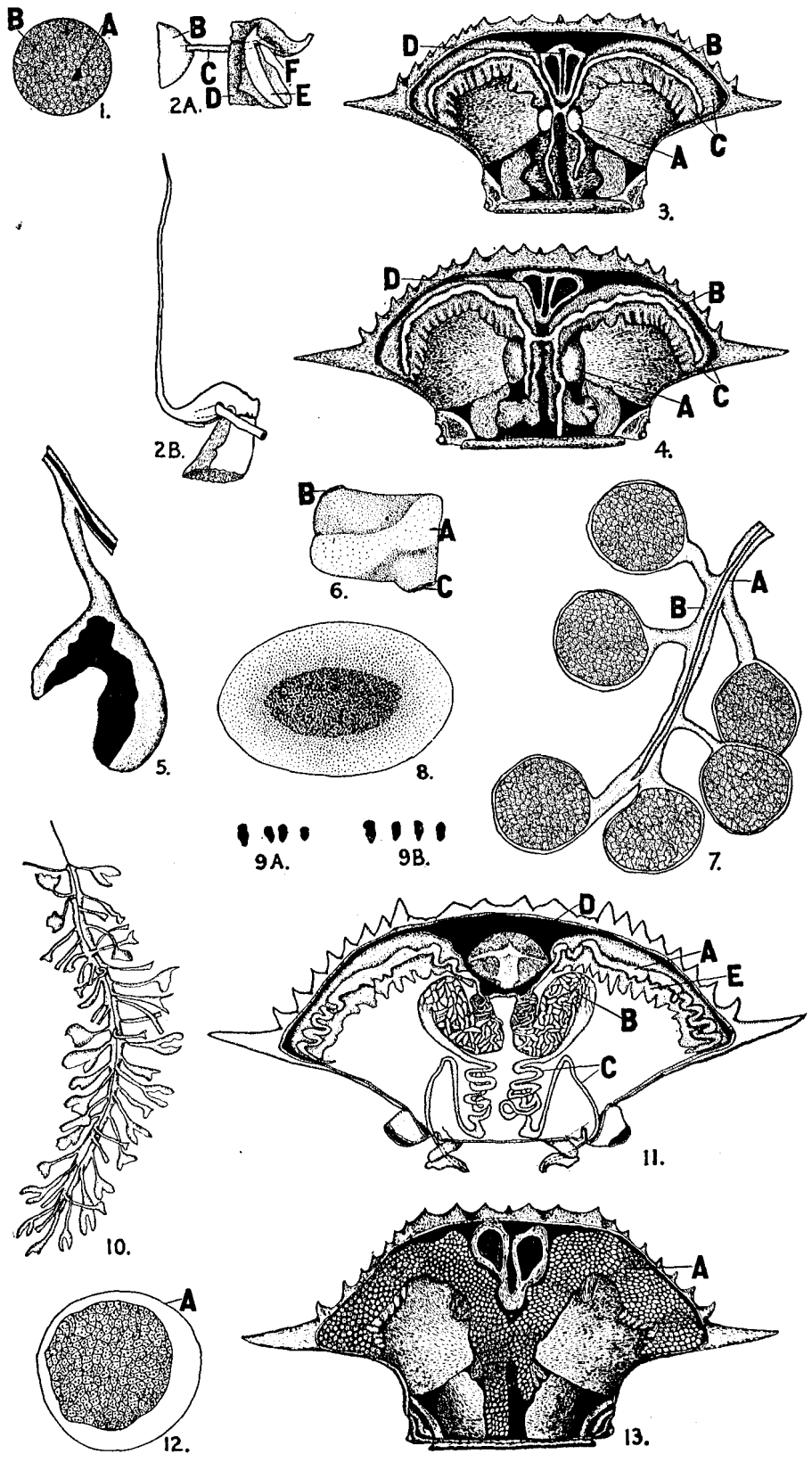
Fig. 31. Dorsal view of adult female crab.
Fig. 32. Ventral view of immature female crab, with triangular abdomen.
Fig. 33. Ventral view of adult female crab, with broad abdomen.

PLATE LIV.

Fig. 34. Dorsal view of adult male crab.
Fig. 35. Ventral view of adult male crab.
Fig. 36. Crate containing adult crabs for observation. It measured 2 by 2 by 4 feet and consisted of an iron frame covered with chicken wire fencing with a 1-inch mesh. It was divided into four vertical compartments to prevent the crabs crowding together and to prevent the escape of all the crabs in case the wire was torn at any point. A wire bail was attached at each end and brought together over the top in the middle. To their point of union a wire was secured by which the crate was lowered and raised.

PLATE LV.

Fig. 37. Type of float which was used in the experiments with adult crabs.
Fig. 38. Wire cages in which molting crabs were confined for observation. The cages rested on the bottom within the inclosure shown in figure 20, each being raised and lowered by means of an individual wire, the upper end of which was attached to a post at a point above high-water mark.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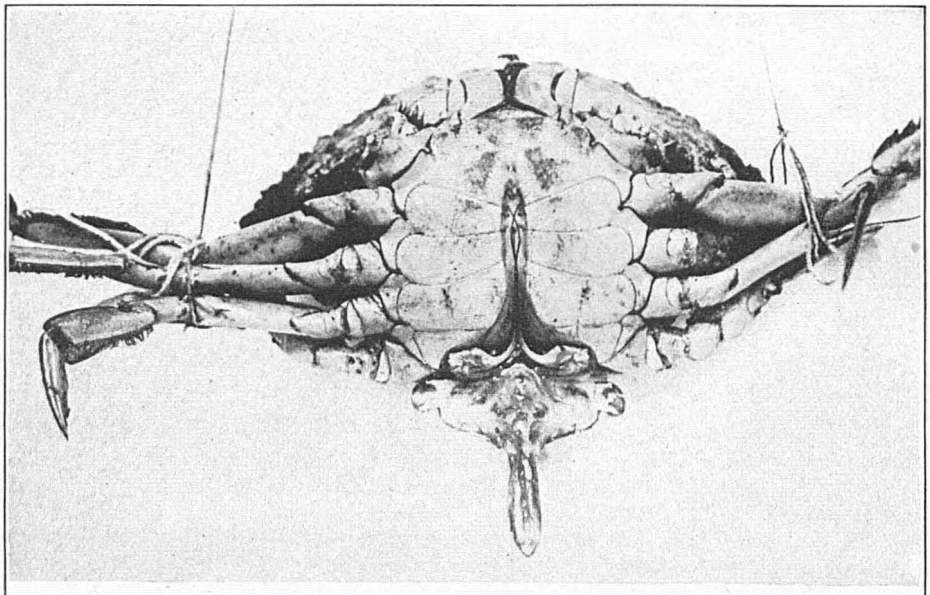

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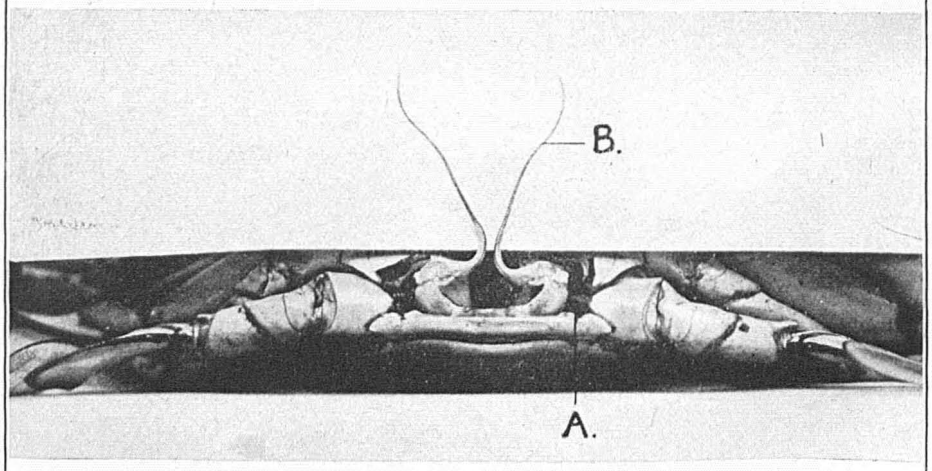

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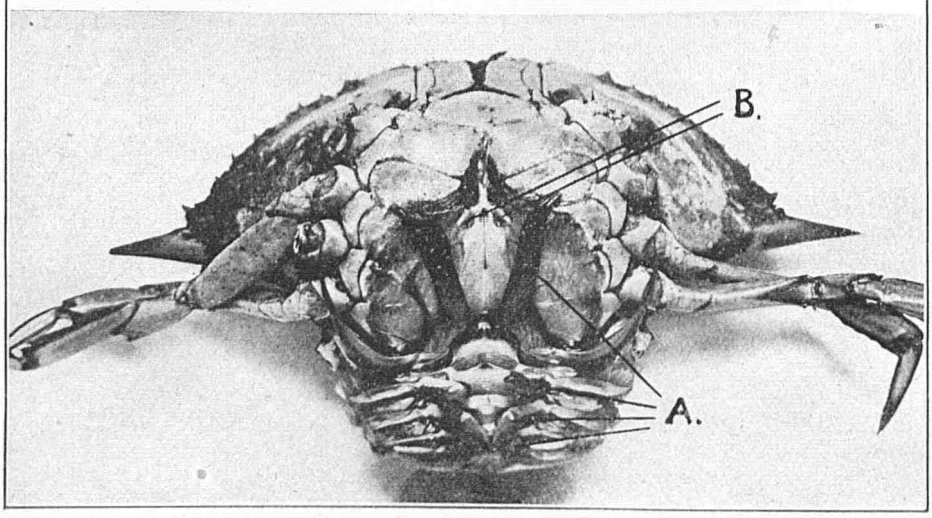

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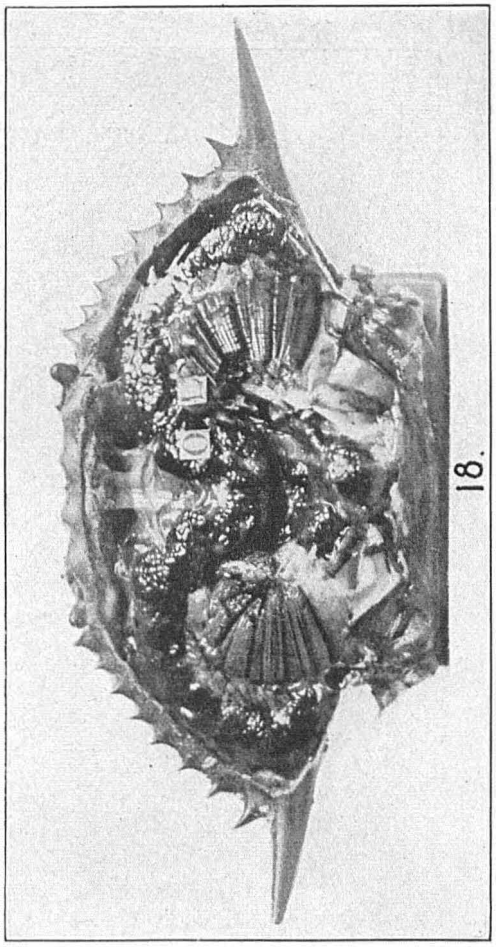

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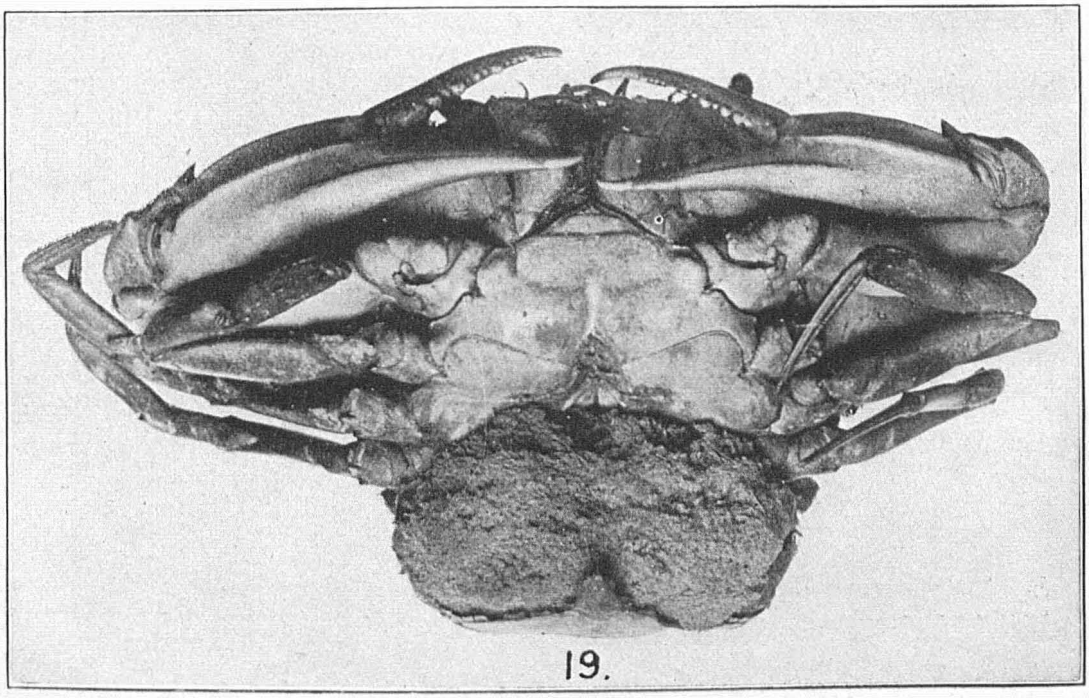

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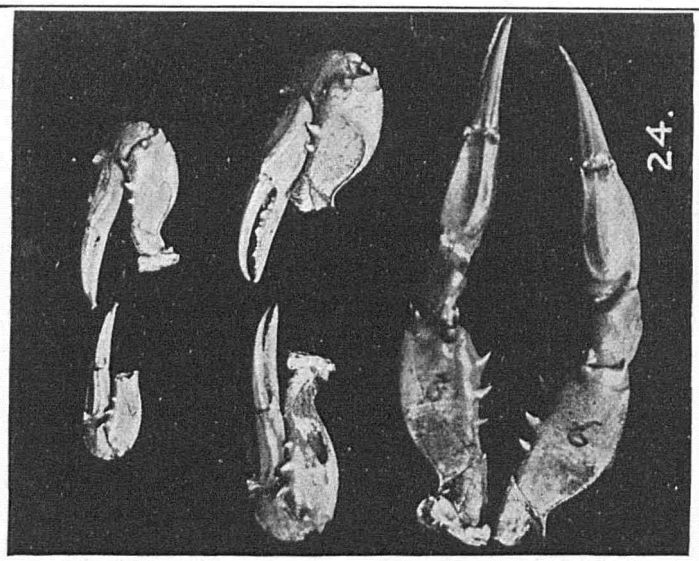
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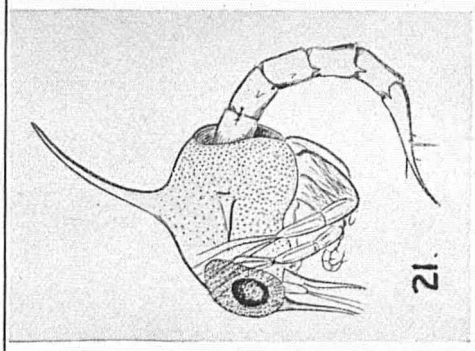
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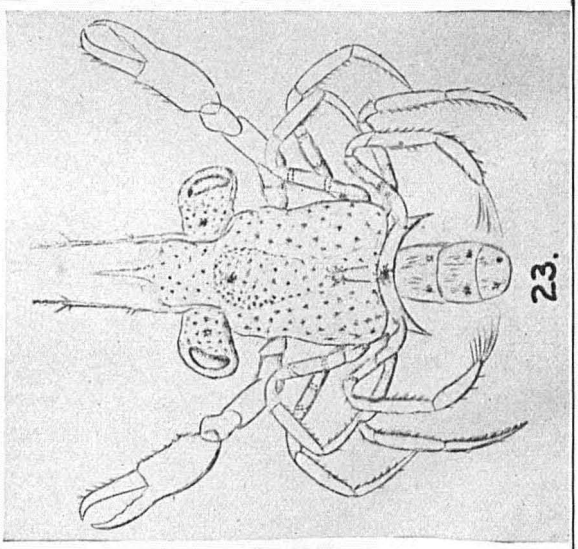
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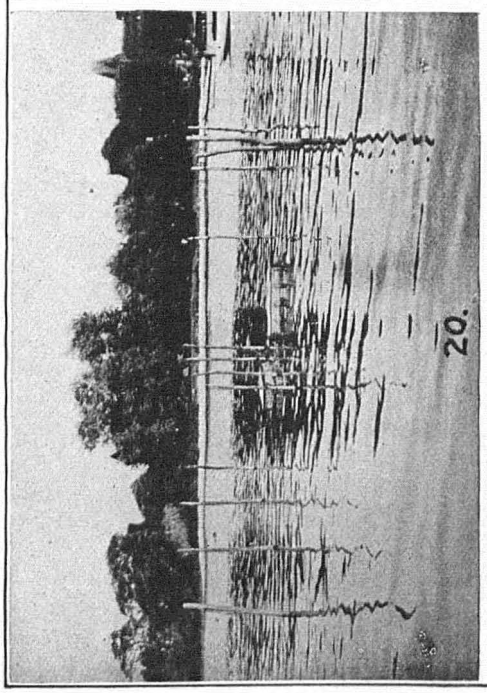
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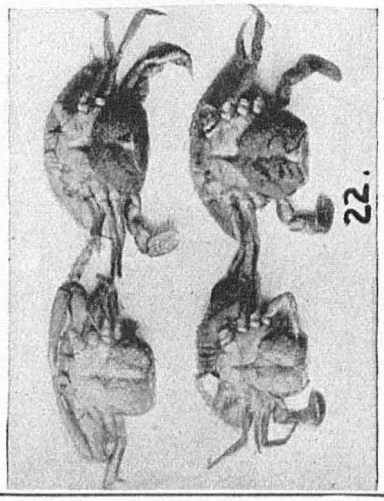
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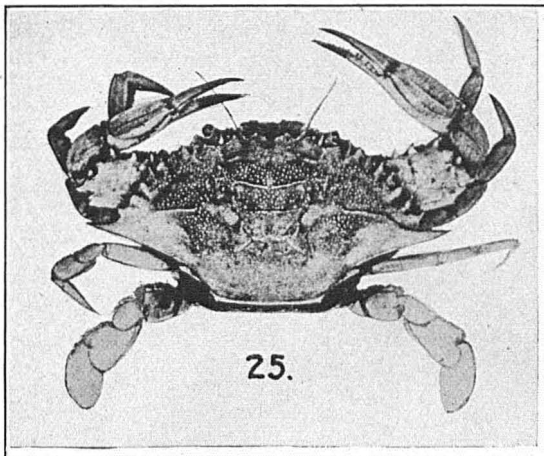

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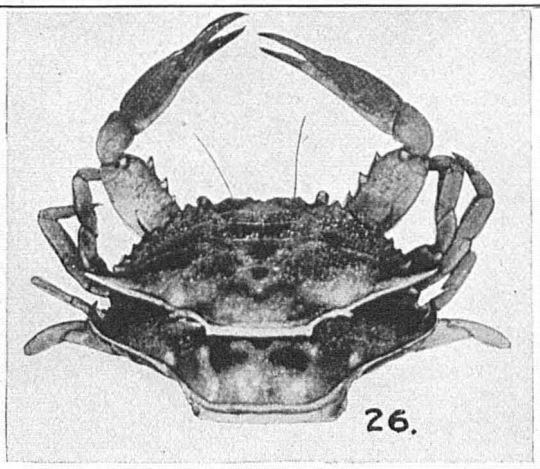

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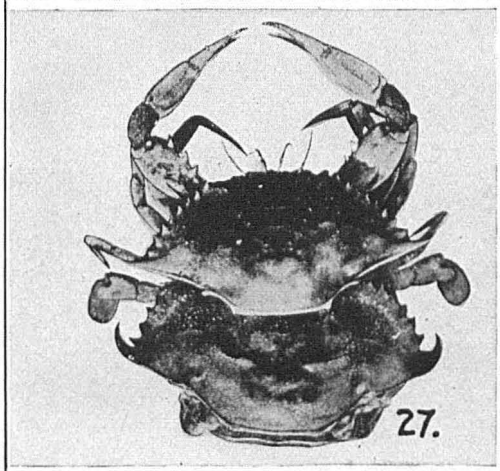

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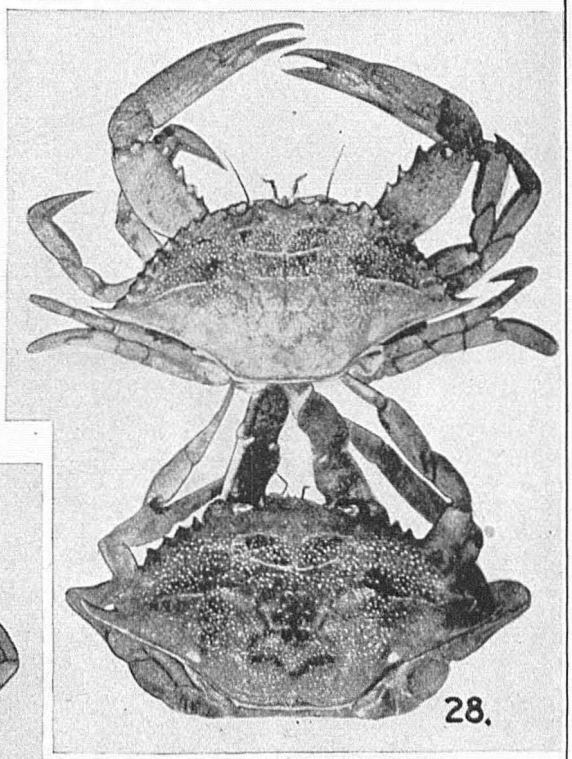

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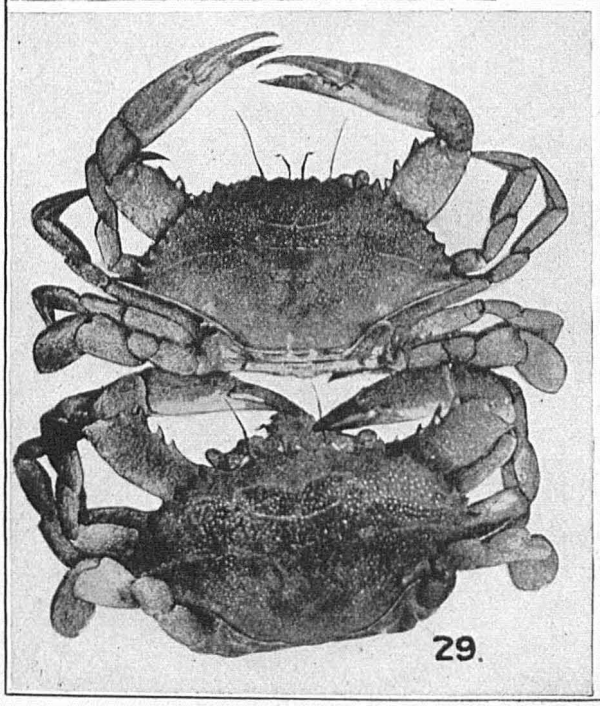

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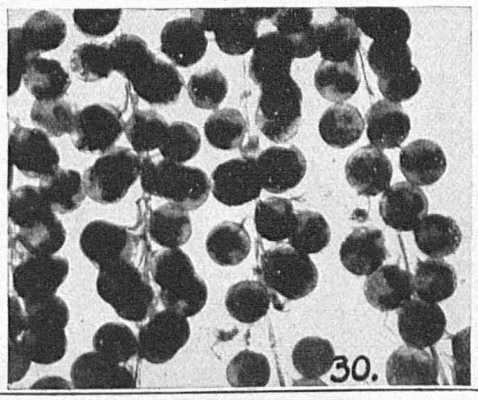

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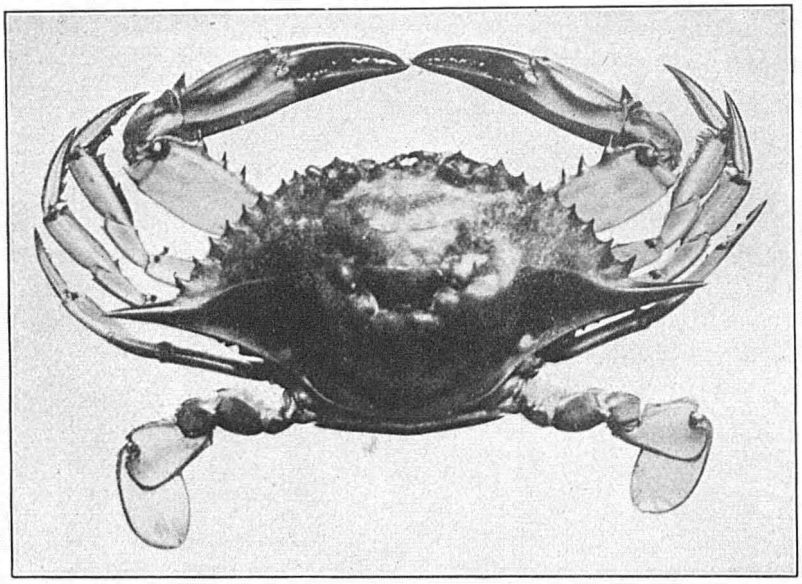

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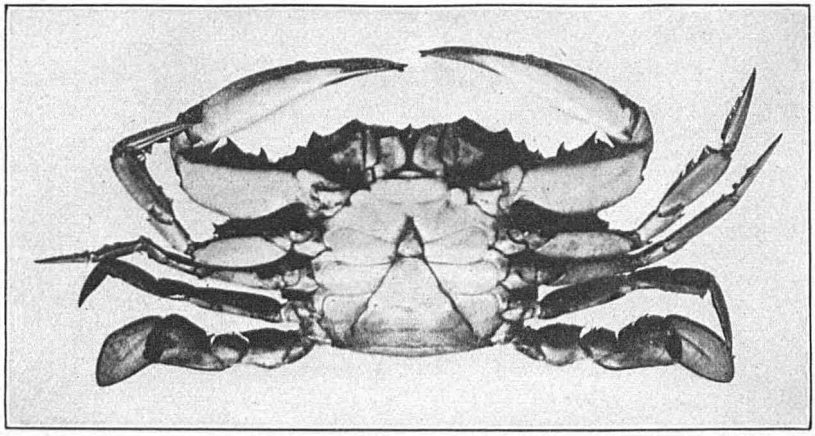

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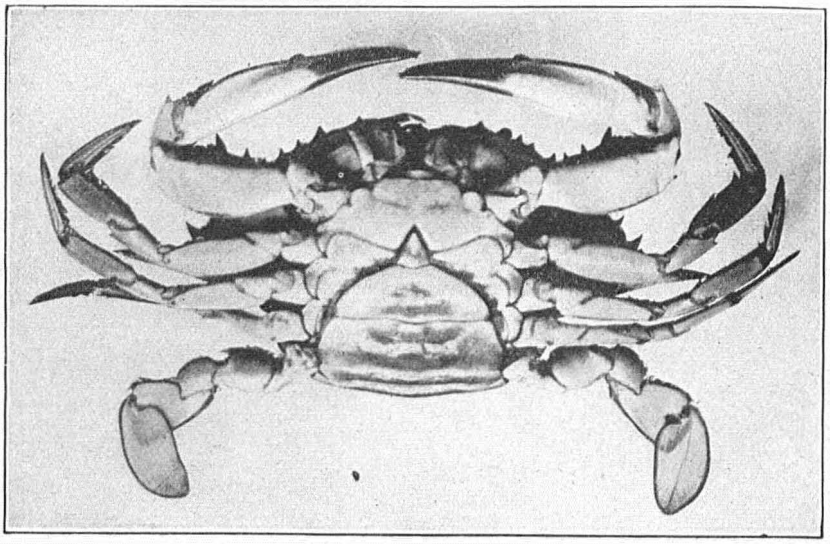

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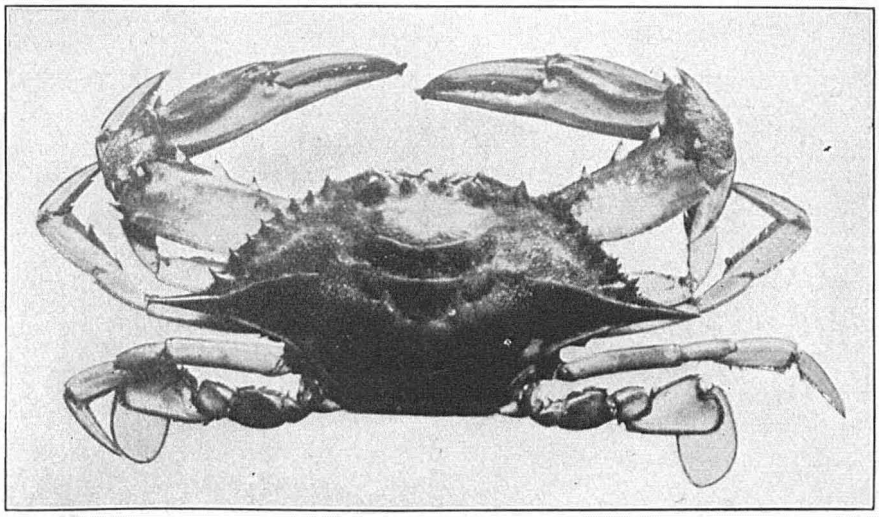

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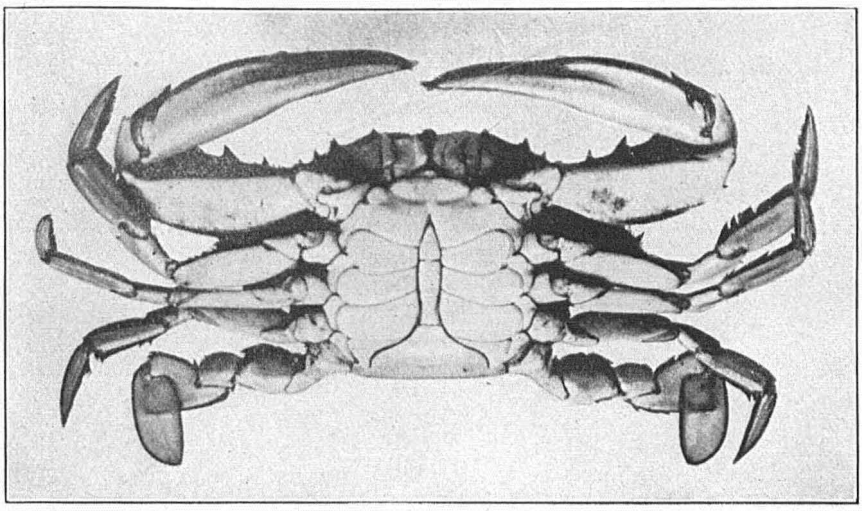

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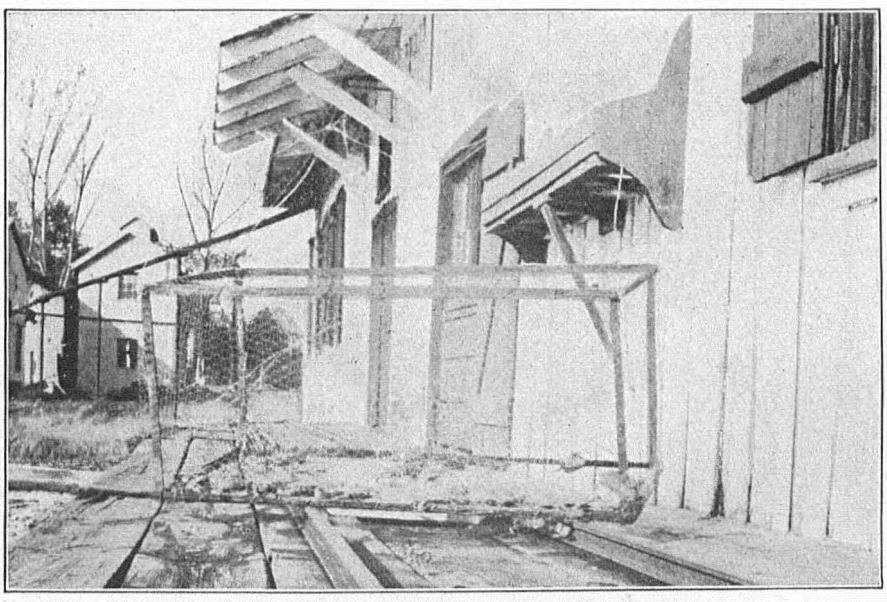

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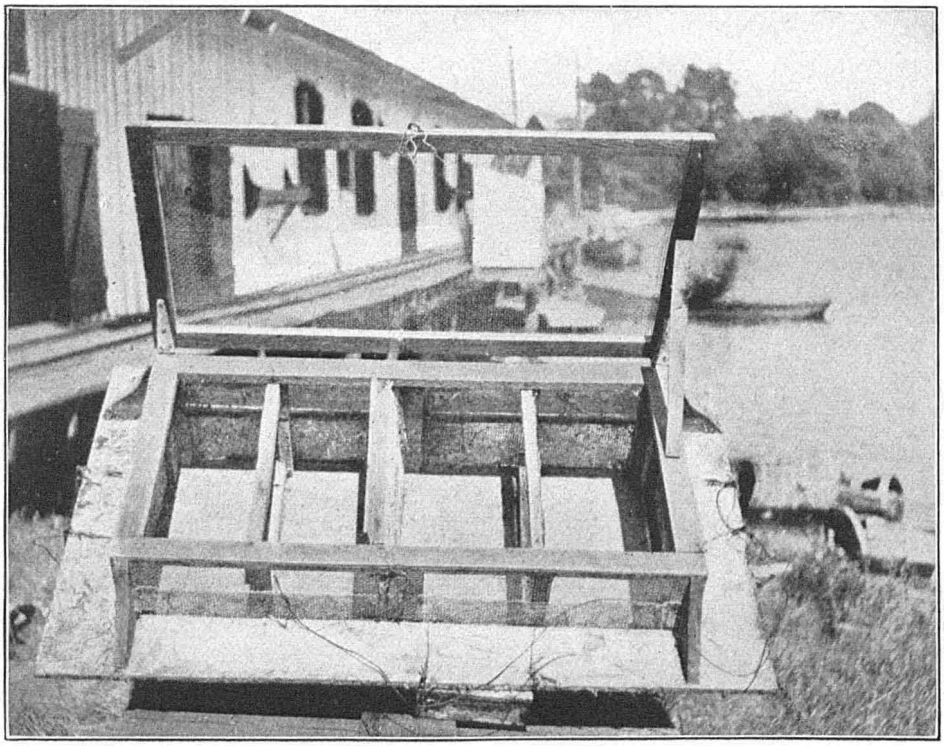

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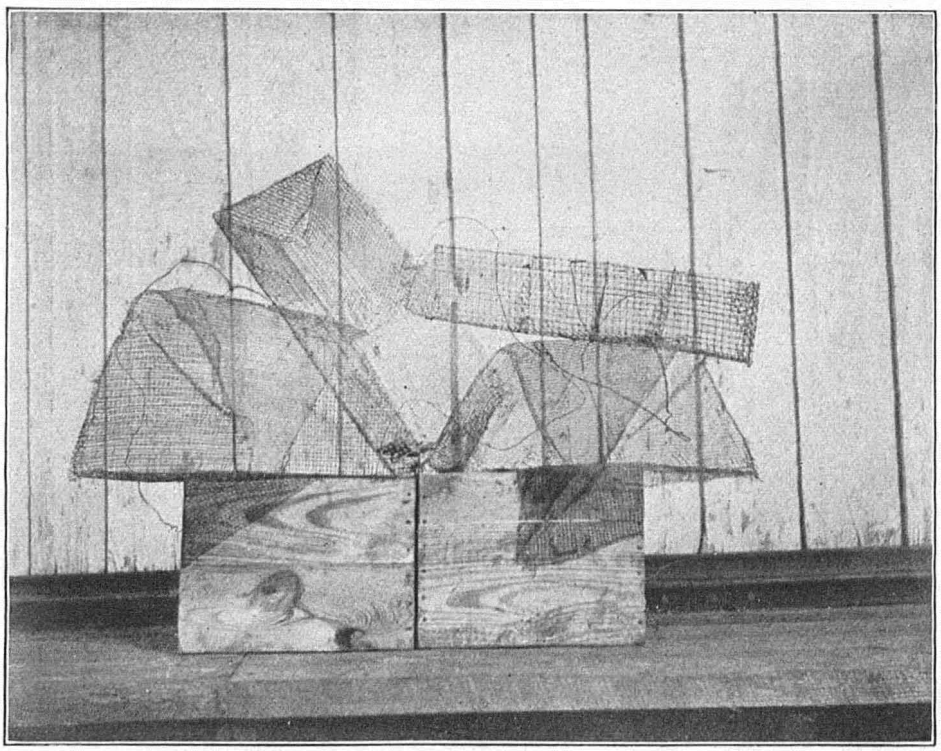

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