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Robert E. Harris
Virginia Institute of Marine Science

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LIFE HISTORY, ECOLOGY, AND STOCK ASSESSMENT OF THE BLUE CRAB *CALLINECTES SAPIDUS* OF THE UNITED STATES ATLANTIC COAST– A REVIEW*

ROBERT E. HARRIS, JR.
Virginia Institute of Marine Science
School of Marine Science
College of William and Mary
Gloucester Point, VA 23062

INTRODUCTION

The blue crab is found along the Atlantic coast of the United States from Maine to southern Florida. It is uncommon north of Cape Cod and is most abundant in the Chesapeake Bay where almost half of the United States commercial blue crab landings occur.

The Chesapeake Bay has the largest semi-confined area for blue crab spawning, more nursery area and probably the best mix of environmental conditions for blue crab along the United States eastern coast. In addition, an intensive commercial fishery enables the Chesapeake Bay region to be the area of highest blue crab production.

There are many basic similarities in the life history of the blue crab all along the Atlantic coast. Some differences do occur, however, in timing of some of the life processes, probably due to the different temperature regimes that exist along the coast.

The biology of the blue crab in the Chesapeake Bay has been described by several authors: Churchill (1919, 1942), Robertson (1938), Truitt (1939), and Van Engel (1958). Summarization of their studies leads to a model of the life history and ecology of the blue crab along the eastern coast. Geographic variations on this general life history and ecological pattern for blue crab stocks north and south of Chesapeake Bay are considered in this review.

LIFE HISTORY AND ECOLOGY

Blue crabs inhabit the entire salinity regime in our model estuary, the Chesapeake Bay. They are found from the fresh waters of the northern section of the bay to the high salinity waters in the southern part of the bay and the adjacent Atlantic Ocean.

Mating in blue crabs occurs in the moderate-to-low-salinity waters of the bay between early spring and fall. Males, also known as jimmy crabs, are in the hard-shelled condition when mating, while females are in the soft-shelled condition. Females do not molt again, but males may molt several times more after mating.

Several days prior to her terminal molt, the female is attracted to the male by a pheromone, a sex hormone that the male releases (Gleeson 1977). The interest of the male in the female is sustained by a pheromone which is released by her near the time of her molt. He cradle-carries his prospective mate under his body for several days before she molts (Williams 1965). These pairs of crabs are called "buck and rider" or "doublers."

After the female molts, copulation occurs, which may last for several hours, and the male again cradle-carries his mate until her shell hardens. All the eggs that the female later produces will be fertilized by sperm transferred in this single mating.

Ovarian development in female blue crabs may take from as little as 2 months to as much as 9 months after mating. Environmental conditions, especially temperature, play a role in determining the length of time it takes for the ovary to develop. Warmer temperatures speed development. Time of mating is another factor in determining the length of time it takes the ovary to develop. If mating occurs in late spring or early summer, the ovary should be well developed and ready for egg extrusion by late summer. If mating occurs late in the summer or early in the fall, the ovary develops during the winter and egg extrusion does not occur until late spring to mid-summer of the following year.

Females spawn in moderate to higher salinity portions of the bay and just outside the mouth of the bay from early May through September, although most spawn between June and August. The ovary may regenerate very quickly. Females that spawn in late spring may spawn again later in that same year and may spawn once again late the following spring.

Spawning consists of two distinct phases. The first, egg extrusion, is the process in which eggs pass from the ovaries, are fertilized as they go through the seminal receptacles, and are attached to the pleopods of the abdomen. The second spawning phase is egg carrying. Eggs are attached on the abdomen of the female for approximately 7 to 10 days before hatching. Females with external eggs are known as berried females, busted sooks or sponge crabs. The egg mass contains from three-quarters of a million to 2 million eggs each time the female spawns.

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Four distinct stages occur in the life history of the blue crab, the egg, zoea, megalopa, and true crab forms. The embryos change in color from orange to black as they develop on the abdomen of the female. Eggs are initially orange because of their high yolk content. As the yolk is absorbed by the developing embryo and as the eye spots appear, the egg mass appears almost black prior to hatching. Optimum conditions for the development and survival of blue crab eggs are 20 to 30 ppt salinity and from 20 to 30°C temperature.

Upon hatching from the egg, the crab reaches the zoeal stage. Prezoeae are nonviable forms from eggs that have hatched prematurely, usually because development has occurred in unfavorable environmental conditions, particularly in low salinity. For instance, if eggs hatch in the middle portion of the bay where salinity is 15 to 20 ppt, this premature stage will predominate, and survival is likely to be low.

Normal egg development and hatching produces zoeae which have seven or eight stages. Zoeae are initially found in the surface layers; as they advance through the various stages, they generally move lower in the water column. Optimum salinity and temperature for zoeal development and survival are, as for the egg, 20 to 30 ppt and 20 to 30°C. Development through the shrimp-like zoeal stages until transformation to the megalopal stage occurs takes about 1 month. Megalopae are usually found in the bottom waters in the high salinity areas. Peak occurrence of megalopae is usually in August about 1 to 2 months after peak spawning time. During their approximately 1 week of existence in this stage of development, megalopae generally feed on larval molluscs or other larvae. Again, 20 to 30 ppt salinity and 20 to 30°C temperature are optimum for blue crab megalopae as well as eggs and zoeae.

About 1 to 2 months after hatching from the egg, the true crab form is attained. Immature (juvenile) crabs migrate with flood currents to their "nursery grounds" into the tributaries and up the bay in search of food, protection from predation, and optimum hydrographic conditions for their growth and survival.

Nursery grounds are usually tidal marshlands and areas of muddy substrate. Prime nursery areas in the Chesapeake Bay occur where there are concentrations of submerged aquatic vegetation, most notably *Zostera marina,* the eelgrass. Eelgrass beds presently occur in the southwestern portions of the bay, around the mouths of the major rivers, and in the middle portions of the bay in the Tangier and Smith Island areas (Rooney-Char and Ayers 1978). The locations are the beds that survived a massive reduction in acreage that began in the early 1970's. With the reduction in eelgrass acreage in the Chesapeake Bay in the early 1930's and early 1970's, there was a decline in crab abundance. Other factors may have been involved, but we at least have circumstantial evidence that the quality of the nursery areas is very important in determining the level of crab abundance.

Growth of a crab is usually initiated when water temperature is about 15°C; molting occurs at varying time intervals depending on the size of the crab. Molting in the smallest crabs, those 1/10 to 1/2-inch carapace width, occurs every 3 to 5 days. As the crabs get larger, the frequency of molting decreases; with crabs of from 1/2 to 1 inch in width, molting occurs every 1 to 2 weeks, and larger crabs molt at intervals of 3 to 7 weeks until low water temperatures cause cessation of shedding.

Growth increment in width at each molt varies from 1/4 to 1/3 of the original size. Both sexes shed from 18 to 20 times after the megalopal stage to reach their largest size. Females reach sexual maturity at their terminal molt while males may continue to shed another three to four times after reaching maturity. Jimmy crabs generally remain in brackish waters throughout their adult life while females, after reaching sexual maturity and mating, migrate toward the "spawning grounds."

Variations from this life history model occur in blue crab stocks north and south of the Chesapeake Bay.

North of Cape Cod, blue crabs are so rare that distribution and migration patterns cannot be recognized. Blue crabs were, however, numerous along the southwestern coast of Maine in the abnormally warm years of 1948–1956. Scattergood (1960) suggested that these crabs could have migrated from the Cape Cod region to the southwestern coast of Maine during the summer, possibly wintering in Maine waters and becoming active again as the water temperatures increased in summer and fall. All blue crabs reported by Scattergood (1960) and those reported by Krouse (1979) as recently as 1977 were adult crabs caught incidental to the inshore lobster trap fishery in Maine.

Blue crabs are commonly found along the southern New England coast where their mating, spawning, and growth seasons are contracted in comparison to those in the Chesapeake Bay: mating of blue crabs occurs only in the summer months; spawning in eastern Long Island Sound and Narragansett Bay occurs primarily in August and early September; and molting occurs from the last of April through the summer months. Blue crab larval distribution patterns in this area are virtually unknown.

Nursery grounds and migration patterns of blue crabs along the southern New England coast are similar to those in Chesapeake Bay (Michael Fogarty, Northeast Fisheries Center, Woods Hole, MA; David Chadwick, Massachusetts Division of Marine Fisheries; Philip Briggs, New York State Department of Environmental Conservation; and Eric Smith, Connecticut Department of Environmental Protection; personal communications).

The Delaware Bay has almost the same characteristics as the Chesapeake except that it is not vegetated as heavily with *Zostera*, and extremely low winter temperatures lead to more frequent crab kills (Richard Cole, Delaware Department of Natural Resources and Environmental Control, personal communication).

Blue crab stocks south of the Chesapeake tend to have protracted times of mating, spawning, and growth. In the St. Johns River, Florida, blue crabs mate from March to July, and from October to December, mating not being common in August and September. Crabs spawn from February until October. Molting occurs throughout the year but the time interval between molts increases during the winter months (Tagatz 1968).

Along the South Atlantic coast, blue crab spawning areas are not as confined as those of the Chesapeake Bay. Apparently, larvae become more at the mercy of currents in this area than in the Chesapeake. According to Nichols and Keney (1963) in their analysis of plankton from cruises of the M/V THEODORE N. GILL, *Callinectes* zoeae and megalopae, not identified to species, were found as far as 40 miles offshore. Early stage zoeae were more abundant near the shore, while more advanced zoeal stages and megalopae were more abundant offshore. The greatest concentrations of all stages of zoeae and megalopae were at stations 20 miles off the coast. There are several species of the genus *Callinectes* found in this area and their larvae cannot be distinguished, so the percentage of larvae which were *Callinectes sapidus* could not be determined.

In the southeast, nursery areas are similar to those in the Chesapeake in that bottom types are muddy. *Zostera* is found in North Carolina, but the St. Johns River, Florida, is vegetated with *Ceratophyllum,* commonly known as coontail, and *Vallisneria,* known as eelgrass or tapegrass (Terry Sholar, North Carolina Division of Marine Fisheries, personal communication; Tagatz 1968).

The same migration patterns exist along the South Atlantic coast as have been described for the Chesapeake Bay area.

ASSESSMENT

Currently along the east coast, blue crab assessment work is being done from Delaware through Georgia, and there is interest in getting programs started in New Jersey and Florida. Nursery and spawning grounds are being identified so that anticipated encroachment on those areas by industrial, agricultural, residential, or other developments can be evaluated. Abundance estimates are being made to determine current year-class strength and its relation to that of prior years. Commercial catch predictions are being made, using knowledge of year-class strength and environmental conditions which affect survival at various growth stages. These predictions are a service to industry to assist them in planning their fishing and marketing activities.

Knowledge of the life history stages and ecology of blue crabs in relation to research and commercial gear is essential for the crab assessment surveys. A generalized time schedule for this relationship has been developed for the Chesapeake Bay area, showing the assumed relationship between the 1978 year-class (hatch) of crabs, juvenile crab abundance surveys made by the Virginia Institute of Marine Science (VIMS), and the Chesapeake Bay crab fisheries (Figure 1).

1. The peak of egg extrusion and egg carrying occurs from June through August (1978).
2. Eggs hatch in about 2 weeks so peak larval abundance is in July and August (1978).
3. Juvenile crabs of the new (1978) year-class first become available to our research trawl survey gear in September. Throughout the fall, September–November, we catch the new (1978) year-class of crabs which are 1/2 to 2 inches carapace width, and some older and larger crabs of the 1977 year-class.
4. Preliminary abundance estimates are made after our fall survey work.
5. During the winter, crabs are not vulnerable to our survey gear because low temperatures inhibit crab movement.
6. The 1978 year-class of crabs is available to our trawls from May through August of 1979. At this time the crabs are being caught in the peeler fishery.
7. Examination of the size composition and numbers of crabs in the fall, spring, and summer survey work leads to an update of abundance estimates.
8. The 1978 year-class of crabs is available to the pot fishery in late August or September 1979, when the crabs are about 15 months old.
9. Many of the females, recently mated, will migrate toward the higher salinity areas in late fall to become the bulk of the winter dredge fishery in December 1979 through March 1980.
10. In the spring of 1980, there should be a continued migration to higher salinity waters of those females which did not make the trip to the southern portion of the Bay the previous fall.

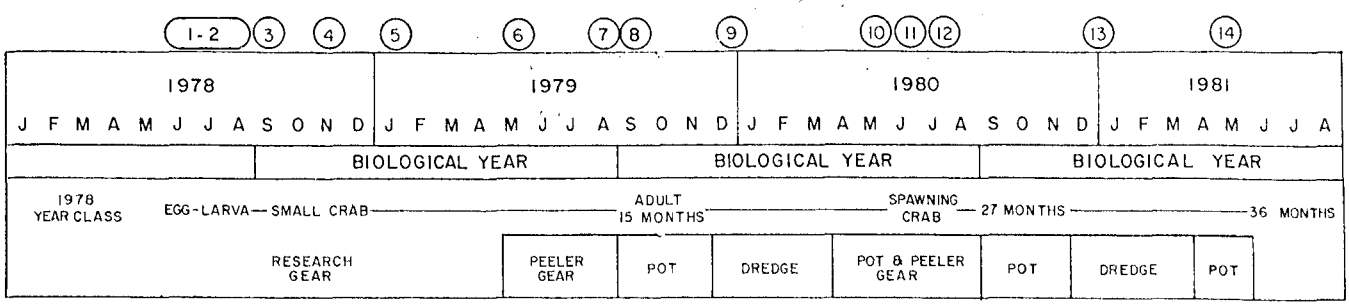

Figure 1. Generalized time relationship between blue crab life history stages and vulnerability to research and commercial fishing gears.

11. Both sexes of crabs of the 1978 year-class will comprise a small portion of the summer and fall crab pot fishery of 1980.
12. Each female may spawn once or twice during the summer when they are about 2 years old.
13. The females, about 2 1/2 years old, will be a very small percentage of the 1980–1981 winter dredge fishery.
14. The remaining crabs of both sexes of the 1978 year-class will contribute very little to the 1981 pot fishery in their third and final year of life.

I suggest that we, whether as scientists, administrators, or industry representatives, consider several things to get a better handle on variations in crab catches and to protect as well as we can this valuable resource.

There should be better coordination among the various blue crab assessment agencies. Improvements in crab survey gear and sampling techniques should be made along with comparison of indexes of abundance.

To improve our catch prediction capabilities, we should concentrate research in several areas. Density-independent environmental factors, such as temperature, salinity, and water-transport mechanisms, and density-dependent factors, such as food availability and predation, should be investigated more completely as to what affect they may have on various stages in the life history of the blue crab. Particular emphasis should be put on studying those factors which most affect the survival of egg, larval, and juvenile forms.

SUMMARY

Blue crabs inhabit various portions of an estuary at different stages in their life cycle. Mating occurs in the lower salinity areas. Females move to the high salinity portions of the estuary and adjacent ocean to spawn. Early zoeal stages are found in surface layers gradually moving deeper in the water column as they develop and become demersal when reaching the megalopal stage. Juvenile crabs move toward the lower salinity nursery areas as they grow. Adult males tend to remain in the brackish waters, while the adult females move to the spawning grounds. Migration between estuaries appears to be infrequent.

A prediction and management strategy for the blue crab should be developed in which consideration is given to the discreteness of the crab stocks at the various life-history stages, the short-lived nature of the species, and the fluctuations in abundance due to climatological factors and environmental alteration.

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DISCUSSION

Comment–Elliott Norse: I have worked on hatching out a number of species of *Callinectes.* I hatched out nine of the American species to get the first larvae. One of the things I found was that prezoeae were indicative of something wrong, but not necessarily just salinity. It could also be pollution. I found this out by pure dumb luck, the way I find out most things. If I kept ovigerous blue crabs with eggs ready to hatch in a vessel with circulating sea water, an open seawater system, I virtually never got hatching as prezoeae unless I greatly disturbed the females. If, however, I kept the female in a bucket of water overnight and the eggs hatched, they almost always hatched as prezoeae. This is something that was not generally realized in many of the crab-hatching studies in the past 10 years or so. In some cases, a prezoea may be a normal larva for other kinds of crabs; however, in the case of blue crabs, I strongly suspect that it is not.

Q. Kimball Brown: Is it true, in the fall as the Bay water temperature declines, if the watermen start dredging for crabs before the crabs have gone into hibernation, that it will cause them to disperse and will cause it to be a poor dredging season?

A. Robert (Bob) Harris: I would ask Van to comment on that.

Comment–Willard Van Engel: So called hibernation in which the crab is fairly immobile occurs when the water temperature is about 47°F. But temperatures in the Chesapeake region do not reach that low level until sometime after the end of December. Therefore, hibernation, as we might call it, or the slowing down of activity, or the "bedding in," of crabs in the lower Chesapeake cannot occur in December if that kind of temperature control mechanism is the thing that makes them stay where they are. If the fishery wanted to have a situation where no crabs would get up and move when the dredges pass over them, then the fishery would have to wait until after the first of January to start its operation. Economically this would be disastrous to the fishery, but temperature data for the Bay are not very large in number. We have been getting, as Bob said, some data from selected stations; we will be getting additional information out later.

Q. (Unidentified): Bob, what sort of effect does the crab dredging during the winter have on the spring spawning?

A. Harris: This has been a big controversy in Maryland and Virginia for quite sometime. Maybe Van would like to comment on that, too.

Comment–Van Engel: About 85 to 95% of the winter dredge catch consists of the adult females, which have not yet spawned. They have mated in the previous fall and will spawn next summer. The commercial fishery, the dredge fishery, takes an average of 10 million pounds of crabs. If we assume that all of these are adult females which have not spawned before, then about 2½ million pounds of adult female crabs are taken each month during the 4-month winter fishery. Of course, this is not spread out evenly that way; December taking almost half or 40% of the 4-month catch. During the remaining 8 months, the total landings in the Chesapeake average about 60,000 million pounds. If you say, one half of them are males, that means 30,000 million pounds of females are taken out of the Chesapeake in a year. Take 10 million off of that for the winter dredge fishery and you have 20,000 million pounds less spread over 8 months. So really there is no great threat; in fact a lesser threat by the winter dredge fishery in taking adult females than by the pot and trotline fisheries of Maryland and Virginia. I think the sentiment is misplaced; if you look at the statistics, the dredge fishery is taking crabs prior to a time when they could be spawning. Now the question might be . . . these females have not yet spawned. True, but in the fall fishery (September, October, November), there are heavy catches in the Chesapeake of females that have not yet spawned, and in May and June, there are many females taken that have not yet spawned. When you take them in the middle of their adult life or early in adult life, it makes no difference. Just based on figures, I don't think there is any basis for an argument that the winter dredge fishery is harmful.