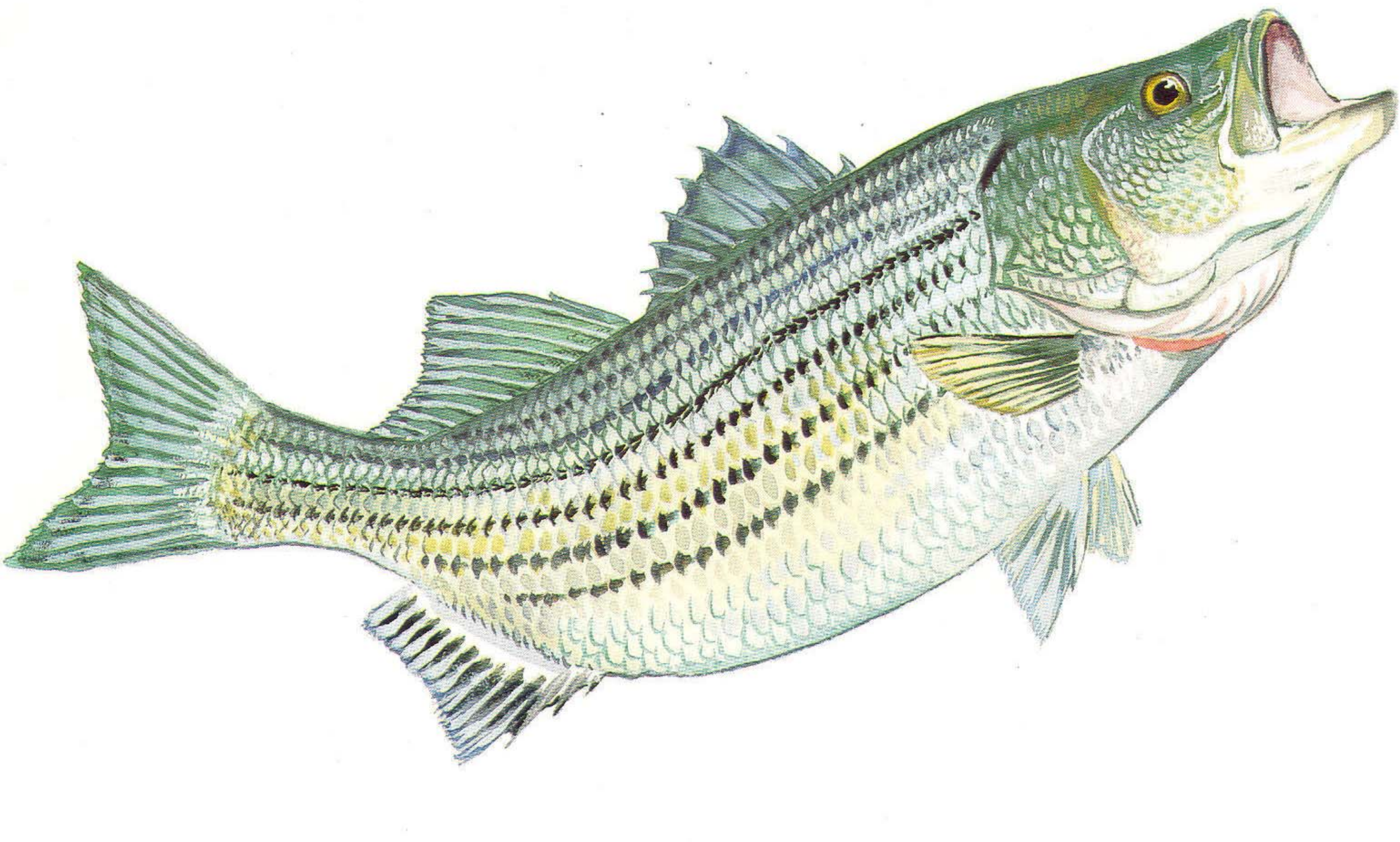
Virginia MARINE RESOURCE BULLETIN



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Dean and Director
Virginia Institute of Marine Science

DR. WILLIAM RICKARDS
Director
Virginia Sea Grant College Program

DR. WILLIAM D. DUPAUL
Director
Marine Advisory Program

MARINE RESOURCE BULLETIN

Spring & Summer 1993 **Vol. 25, No. 1 & 2**

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Susan C. Waters, Editor, Writer and Designer
Susan R. Stein, Typography
Kay Stubblefield, Mechanicals

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Frances Lee Larkin.

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The BULLETIN is intended as an open forum for ideas. The views expressed do not imply endorsement, nor do they necessarily reflect the official position of Sea Grant or the Virginia Institute of Marine Science.

Sea Grant is a partnership of university, government and industry focusing on marine research, education and advisory service. Nationally, Sea Grant began in 1966 with passage of the Sea Grant Program and College Act.

Controversy seems to follow striped bass (*Morone saxatilis*) wherever they travel. They have been the focus of a truly voluminous amount of research in recent years, and the source of great debates between states—debates where stock assessment methodologies were scrutinized, questioned and sometimes denounced. Restrictions and moratoriums have been enacted to protect this anadromous species which spends most of its adult life in salt water, but migrates up into fresh water tributaries to spawn.*

Of late, striped bass have been central to another debate: some contend that this voracious feeder—numerically on the rebound after fishing restrictions were enacted—is to blame for the poor commercial catches of the blue crab (*Callinectes sapidus*). Scientifically, at least, the jury is still out. . . Easy solutions, such as lifting all striped bass fishing restrictions, could have calamitous results. First, scientists need to determine if a correlation exists between the increased striped bass population and the diminished blue crab harvest. In itself, that sounds simple. However, a facile answer is not possible. Striped bass are opportunistic omnivores which will prey on certain species when that species is abundant. When a striped bass is found with many blue crabs in its stomach, scientists assume that the fish found a dense aggregation of blue crabs—not that the striped bass is specifically feeding on blue crabs in various locations. If another species is abundant where striped bass are feeding—and if blue crabs are not abundant—striped bass will feed on the abundant prey species, not the blue crabs.

Other considerations, too, are part of this debate about the cause of a diminished blue crab population, factors which will take an enormous amount of time through which to sort: the natural fluctuations in the population; environmental conditions, such as temperature, salinity and how they relate to recruitment or harvest; and fishing pressure.

This issue of the *Bulletin* provides a few views on the striped bass versus blue crab debate in hopes of providing an open forum for ideas, and for the research performed in the past and present. ✣ ✣

*Atlantic striped bass are coastal fish; however, the species has been introduced to landlocked lakes where they thrive.

Fisheries Management

As world fishery upon world fishery collapses, or is threatened, solutions are quickly sought—answers which will rapidly and efficiently *solve* today's marine resource problems. The difficulty inherent in this can be found in the word solve, which connotes finality; once a crisis is solved it need not be thought about again. Unfortunately, the complexity of the marine environment precludes final answers. Any action taken to manage a species is bound to have ramifications on other species, the ecosystem itself and the individuals economically linked to the overall system.

The problems associated with species management are complicated by a very human dimension. Politics intervene and sometimes impede; unrealistic expectations are placed upon science and scientists; and the seemingly dialectic nature of scientific inquiry is not understood by the general public.

The political process and how it can impede almost does not need explanation, though an example from the remote past might be fitting. More than a hundred years ago some scientists predicted that if the Chesapeake Bay oyster harvest were not restricted, stocks would plummet and the Bay system could be irrevocably changed. Politics intervened, timely and meaningful management was not enacted in full measure, and those scientists from a century ago foretold today's conditions.

The almost superhuman expectations placed upon science and scientists come in a variety of forms, the most obvious in society's belief that an *answer* can readily be found and is applicable in many circumstances. The difficulty in this concept was readily distilled by scientists Donald Ludwig, Ray Hilborn, and Carl Walters in an April 1993 *Science* article as they wrote about resource exploitation and conservation. Outside-of-

Historical photos of plenty by Aubrey Bodine. The photos depict scenes in coastal waters and the Chesapeake Bay.

lab, "scientific understanding and consensus is hampered by the lack of controls and replicates, so that each new problem involves learning about a new system. The complexity of the underlying biological and physical systems precludes a reductionist approach to management."

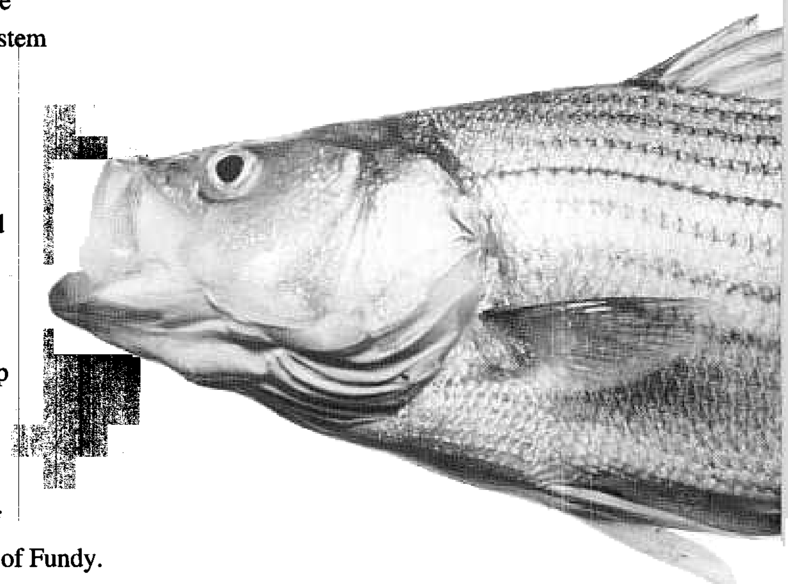
The seemingly dialectic nature of scientific inquiry (throughout all the sciences) must seem confounding to many. A lack of consensus may seem jarring, perhaps even at odds with what science is perceived to be; however, a legitimate basis does exist for apparently disparate ideas. Again, Ludwig, Hilborn, and Walters succinctly explain this resource management problem in light of the impossibility of controlled/replicated experiments in a large-scale system. Given that difficulty, it is no wonder that differing interpretations exist, they said, adding that differing views can create difficulties for resource managers since, ". . .experiments involve reduction in yield (at least for the short term) without any guarantee of increased yields in the future."

A Limited Window Of Opportunity

When the twain meet, striped bass will feed on blue crabs. However, that window of opportunity appears limited and probably should not be too closely linked to the current decline of blue crabs in the Chesapeake Bay system, according to Joseph Loesch, head of the anadromous fish* program at the Virginia Institute of Marine Science.

The best opportunity for striped bass to significantly feed on blue crabs is when numerous blue crabs have migrated down to the Bay mouth and when striped bass pause along their coastal journey, generally in October and November. However, a number of feeding studies** of striped bass in the Bay system indicate that blue crabs rank low in the striped bass's normal diet. Striped bass are opportunistic feeders, meaning that they feed on whatever is plentiful and readily available. Nevertheless, the studies show that large stripers in the Bay feed primarily on fish, while young rockfish tend to prefer invertebrates.

The mature striped bass which participate in the spawning runs arrive in the Chesapeake Bay system generally in April, make a fast trek up to presumably "parental" freshwater streams, spawn, and then quickly travel back out of the Bay to begin a northern coastal migration up the Atlantic coast. Some striped bass will migrate as far north as the Gulf of Maine and the Bay of Fundy.



The amount of time the newly spawned striped bass stay in the Chesapeake Bay and its tributaries varies, and is influenced by population density. Young males normally stay in the system approximately five years; young females usually depart for their first oceanic migration at an earlier age, at about three years or older. Some studies have found that more two-year-old striped bass leave the Bay when that year class population is dense. During winter, the resident immature striped bass remain relatively inactive, reducing their food consumption as they congregate in deeper water

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* Anadromous fish spend most of their life in salt water but migrate into freshwater to spawn.

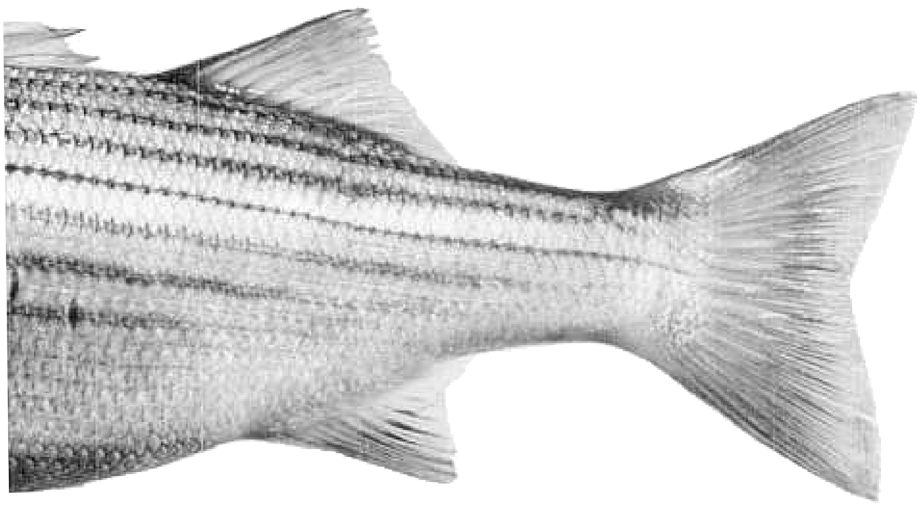
**Feeding studies which shed light on the current striped bass/blue crab debate include: "An Investigation into Striped Bass Predation on Blue Crabs in the Chesapeake Bay," by Thomas Mosca and Paul Rudershausen, Virginia Institute of Marine Science; "Striped Bass Feeding Behavior and the Potential Effect on the Blue Crab Population in the Chesapeake Bay," by Kenneth Booth and Martin Gary, Maryland Department of Natural Resources; and "An examination of the Relationship between Striped Bass and Blue Crabs," by Dave Goshorn and Jim Casey, Maryland Department of Natural Resources. ✣

portions of river mouths and the Bay.

Large striped bass in the Bay system subsist mainly on forage fishes such as bay anchovy, menhaden, spot, and croaker. In a study by the Maryland Department of Natural Resources, scientists Kenneth Booth and Martin Gary analyzed numerous feeding studies which indicated that fish comprised about 95 percent of the large striped bass's diet in the Chesapeake Bay; crustaceans, made up only two percent.

Young-of-the-year and juvenile stripers were less selective in their choice of prey. In the Maryland study, indications were young rockfish preferred fish and invertebrates, not blue crabs, a conclusion that concurs with work by Paul Rudershausen, graduate student at the Virginia Institute of Marine Science (see page 10 for a summary of Rudershausen's work).

Scientists Booth and Gary concluded their analysis by saying that, "There appears to be no data to support the theory that striped bass abundance has a direct relationship to the 1992 scarcity of blue crabs in the Chesapeake Bay. . .The high numbers of crabs in striped bass stomachs reported this year may also be a function of increased availability due to a strong year-class of young crabs. However, the more than 10 years of food habit studies would surely have encountered more incidents of high predation on small crabs if they consistently constituted a large part of the striped bass diet." ✣ ✣ ✣



Striped Bass Tagging Program

That scientists know the whereabouts of striped bass with any amount of certitude, is the result of an extensive and long-term tagging program by a number of states. Through the anadromous fish program at the Virginia Institute of Marine Science, approximately 7,000 striped bass are tagged each year in the James and Rappahannock Rivers, Virginia. The time of tagging coincides with spawning in both rivers. An additional tagging program is conducted in fall in the Rappahannock River.

Through a publicity campaign, fishermen have been alerted about the need to send the tags into the U.S. Fish and Wildlife Service, which collects the information. This reporting system is done in cooperation with North Carolina, Virginia, Maryland, New Jersey, New York, Rhode Island and the District of Columbia. The information gleaned from the tags assists scientists in plotting coastal migration as well as movement within the Chesapeake Bay system. Scientists are able to ascertain striped bass exploitation within and outside the Bay region, and also are given clues about the stripers' fidelity to natal rivers. ✣

The Striped Bass as a Predator On The Chesapeake Bay Blue Crab

by Herbert M. Austin,
Professor of Marine Science
Virginia Institute of
Marine Science

That fish feed upon crabs is nothing new. In fact, many species of fish eat crabs on a regular basis. So why then has the fact that striped bass eat blue crabs raised such a concern of recent? Partially because the blue crab fishery is one of the only "healthy" fisheries in the Bay and the striped bass is a very efficient crab predator. Partially too, some have cynically suggested, because there is a very real desire to increase the striped bass harvest allocations, and to suggest that the rockfish are endangering the blue crab population is a lever to increase harvest allocations.

The striped bass/blue crab predator/prey relationship is an interesting paradox indeed, a valuable protected species feeding on a valuable, managed species. This situation, however, is not new. The sea otter, a protected species off California, feeds on abalone, and abalone are overharvested. Currently the sea otter is the prime predator of the critically depleted managed abalone stock, but nothing can be done about the otter. It is a federally protected endangered species. How effective then is abalone management if sea otters can continue to take what they want? A parallel situation also exists in the Pribilof Islands where endangered sea lions are harvesting salmon at a time when salmon fishing is restricted due to low stocks. Here in the Chesapeake Bay we now have a similar situation; the depleted, but recovering, striped bass is accused of heavy blue crab predation. Watermen have, during the

In a 1928 edition of Fishes of Chesapeake Bay, *a number of other names were used to describe striped bass, names which were used in the Baltimore wholesale market. Shinie rock was the designation for a small fish; hank rock was a fish weighing three pounds; boilers were stripers of three to six pounds; and big rock was a striper weighing six pounds or more. During 1922 rockfish from the Chesapeake Bay system commanded a good price: fishermen received from 16 to 24 cents a pound.*

winter of 1992-1993 reported seeing from a few to nearly 50 juvenile blue crabs in the stomachs of striped bass. Similar accusations have been directed at the striped bass before. During the winter of 1983-1984 there was a dominant year class of croaker produced, and the one inch young-of-the-year croaker filled the Bay. There were numerous reports that winter of striped bass being "chocker block full" of croaker. "The rock are going to destroy the croaker population," was the cry. This was at a time when the striped bass population was at an all-time low, and croaker very abundant.

Just how real is the problem, are the striped bass "overharvesting" the blue crab? A definitive study, focused on just this problem would be costly and could take several years. If a problem does exist, it could be too late. In an effort to use existing data to shed some light on the question, scientists at the Maryland Department of Natural Resources* (MdDNR) and Virginia Institute of Marine Science** (VIMS) looked at existing data to see if any relationship between striped bass abundance and blue crab abundance was discernable.

The Maryland study used commercial landings of striped bass and blue crabs for the period 1960 to 1980 as an index for bass and crab abundance. From this they tested whether the striped bass catch historically had a demonstratable and predictable relationship to the blue crab catch. This was compared for the same years, and up to four years into the future to see if bass abundance had a measurable impact on crab abundance. They could find none.

The Virginia study was comparable, but used the Virginia and Chesapeake Bay-wide juvenile striped bass index with the crab landings. The striped bass index was compared to the crab landings two year later on the assumption that the juvenile index accurately predicts the abundance of striped bass two years into the future, an assumption that has been shown to be true. Two year old bass were chosen as they are year-round residents and further up-river where the young crabs are found in both winter and summer. The relationship here is that striped bass two years old would impact the crab harvest. No statistical relationship was found to support this premise.

Past studies of striped bass feeding habits have shown, however, that blue crabs are found in their diet, but always in insignificant numbers. When they were reported the crabs were always in the one inch size category. Appropriate then for continued scientific investigation would be juvenile striped bass indices examined against juvenile blue crab abundance two to four years into the future, or striped bass landings (pre-Atlantic States Marine Fisheries Commission management plan, years 1982 and before) and the Maryland and/or VIMS juvenile blue crab survey.

While the MdDNR and VIMS studies do not show a significant relationship between the examined indices of abundance for striped bass and blue crab, it does not mean that striped bass do not prey on juvenile crabs in the Chesapeake Bay. The juvenile blue crabs, which are transported into the Bay each winter, when they are about an inch long, can be found in large concentrations in those mid-segments of the rivers where the "salt wedge" has dropped them. The larger striped bass arrive in the lower Bay during late November and December, after their summer-fall migration from New England. Smaller, two to three year old bass are in the rivers. Normally, the large adult bass are down-Bay, and the inch-long crabs up-river; but during warm winters the large bass can be found further up-river. Further, during warmer winters the adult crabs do not bury into the mud as early as they usually do; consequently they are exposed to bass predation in the main stem Bay. If the juvenile crabs are found in large concentrations near the salt wedge and adult crabs have not buried for the winter, and the bass are mobile and hungry, it is not surprising then that some are found with many crabs in their stomachs. The demonstratable impact of this on the crab population however, appears to be nil. ✣ ✣

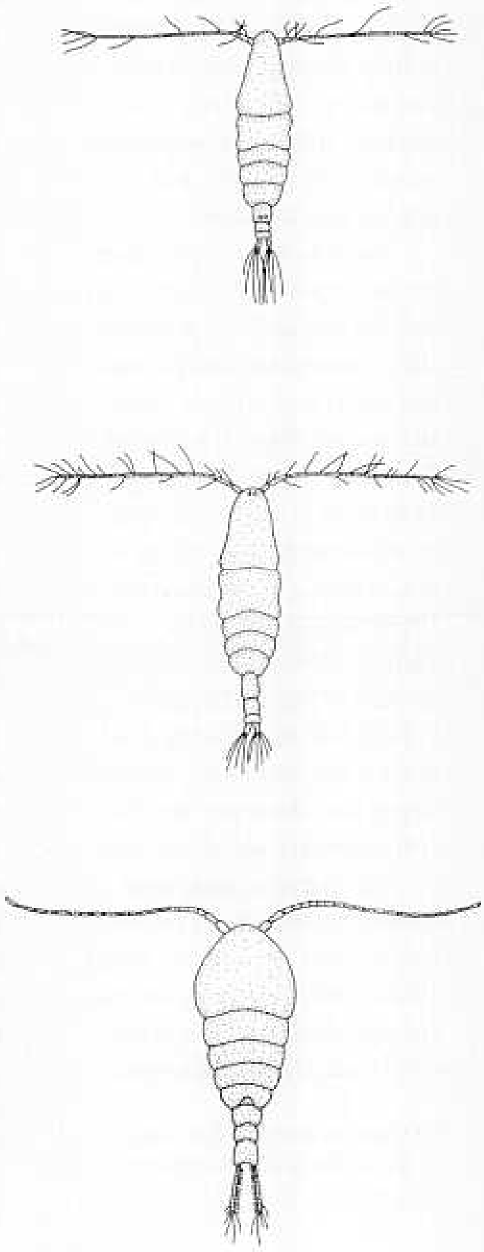
* Dave Goshorn and Jim Casey
** Tom Mosca and Paul Rudershausen

Striped Bass: Young-of-the-Year Feeding Behavior

The Chesapeake Bay nursery zones for striped bass (*Morone saxatilis*) and white perch (*Morone americana*) are often characterized by highly turbid waters, and the nursery habitat is as varied as the food sources. Near a riverbank, near roots and undergrowth, insect larvae and pupae might be more abundant; further out, planktonic life would be the norm.

The feeding behavior of young-of-the-year in a highly fluctuating estuarine environment influences both the growth and survival rates of these two valuable species. If two species are competing for similar food sources and one is more successful in foraging, the more effective species would have a better chance of survival. The amount of suitable food, too, within a column of water, would impact issues of survival and could be a factor in habitat selection. These issues of survival and habitat were the focus of graduate work by Paul Rudershausen, student at the Virginia Institute of Marine Science (VIMS). Rudershausen examined young-of-the-year perch and striped bass stomachs from the middle tidal section of the James River, Virginia.

Preliminary conclusions of Rudershausen's work indicate that striped bass and white perch, less than 30mm, feed principally on small zooplankton (minute aquatic animals) such as copepods, ostracods, and cladocera. Striped bass and white perch greater than 30mm feed on a wider variety of invertebrates, including insect larvae, amphipods, cladocera, copepods, decapods, isopods, and small fish. Nearer shore, the species will feed on more insect larvae and pupae. Both species feed equally well at day and night. Rudershausen's findings are in agreement with VIMS researchers Sureyya Ozkizilcik and Fu-lin Chu, who have found that chemosensory reception (as opposed to purely visual clues) plays an important role in feeding by young striped bass. The ability to detect prey through chemosensory reception is an important adaptation for both striped bass and white perch since their Bay nursery zones are often quite turbid. ✣ ✣



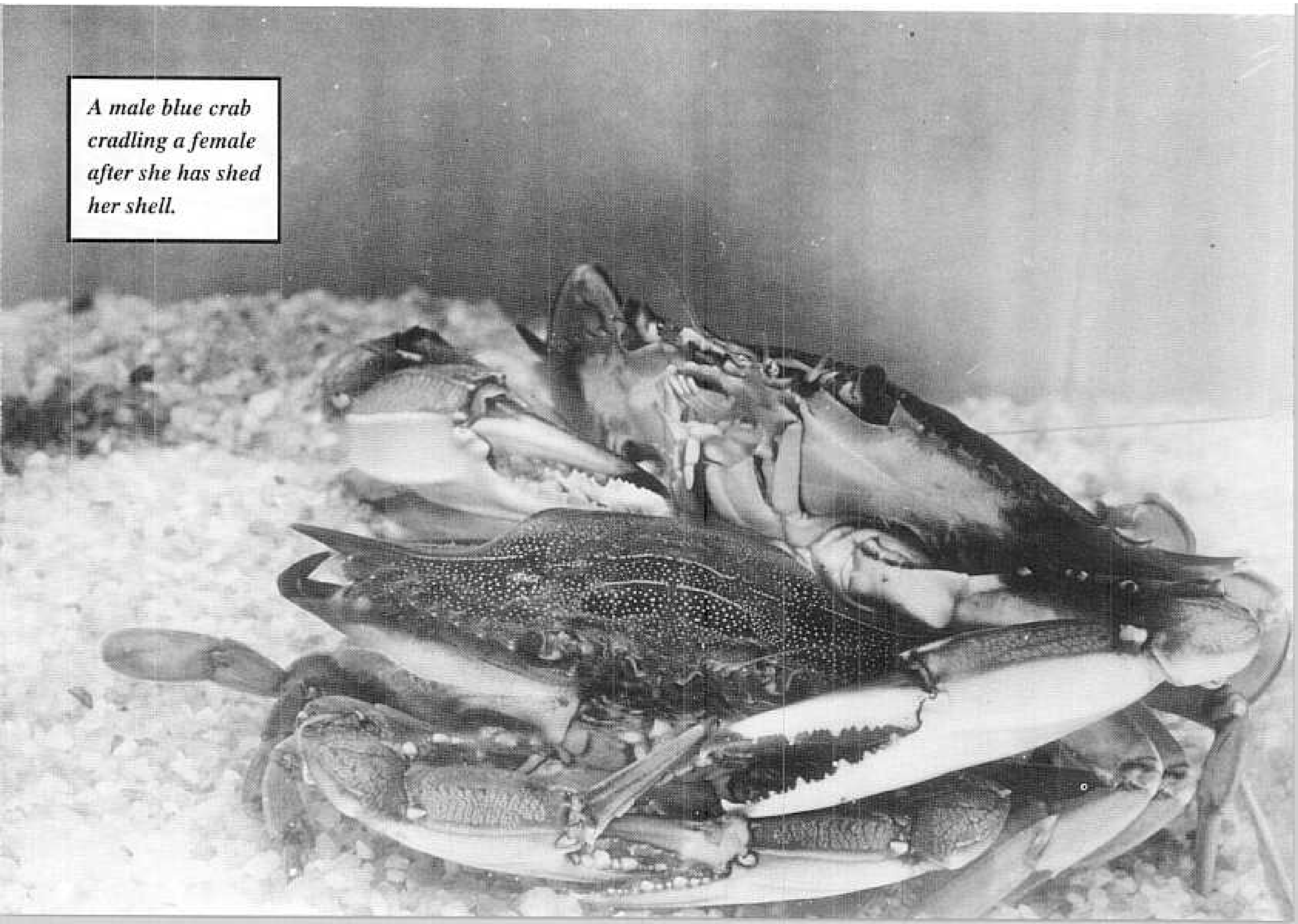
Copepods

About *Callinectes sapidus*, The Blue Crab. . .

Blue crabs, the current cause for concern among those dependent upon that fishery, are one of the most celebrated inhabitants of the Chesapeake Bay. Crab festivals are part of the local culture and at those events one can find blue crab paraphernalia ranging from hats bedecked with the crustacean, to wreathes ringed with shellacked crab shells and other marine life. No wonder blue crabs receive so much attention: they taste fabulous and they support a large industry around the Bay.

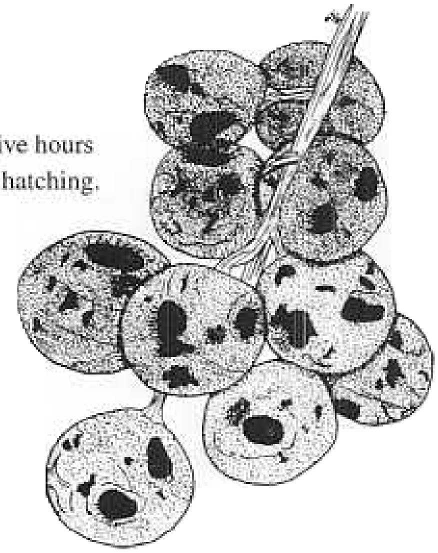
Blue crabs are not just lauded by local culture and business, they have been studied, studied and studied some more. A wealth of information has been amassed about blue crabs—information which has aided practically every segment of the industry, from shedding operations to processing.

Still, even though a great deal has been elucidated about the blue crab, enigmas remain. The following pages are devoted to scientific research which seeks to unravel some of the less understood portions of a blue crab's life history. ✣ ✣

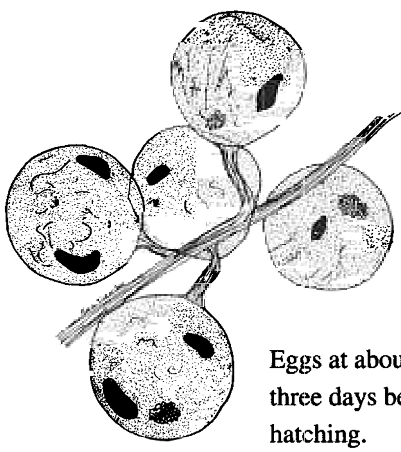


A male blue crab cradling a female after she has shed her shell.

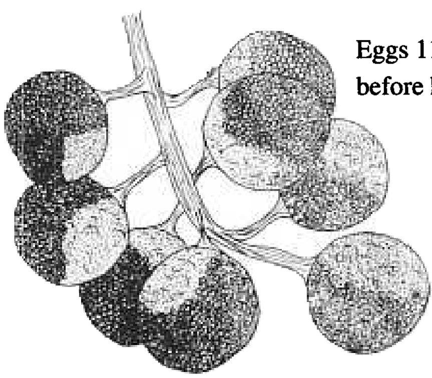
Life Stages



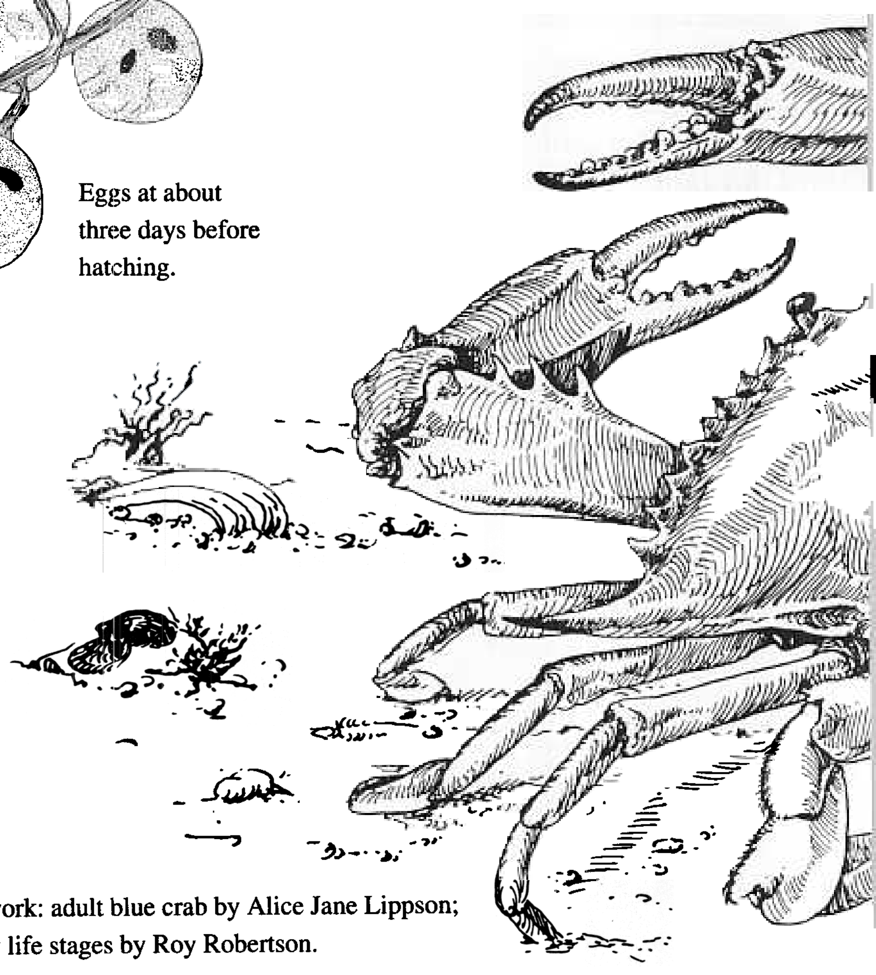
Eggs five hours
before hatching.



Eggs at about
three days before
hatching.

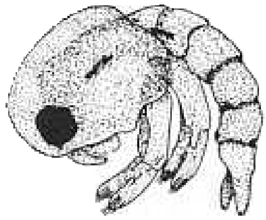


Eggs 11 days
before hatching.

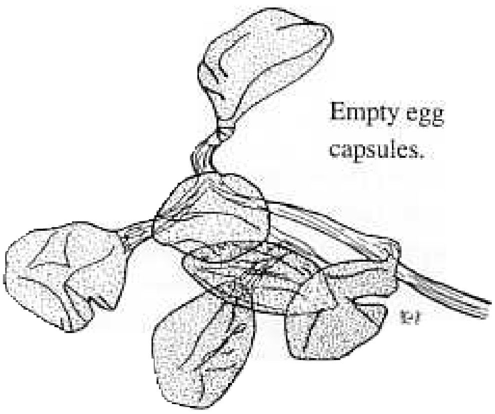


Artwork: adult blue crab by Alice Jane Lippson;
early life stages by Roy Robertson.

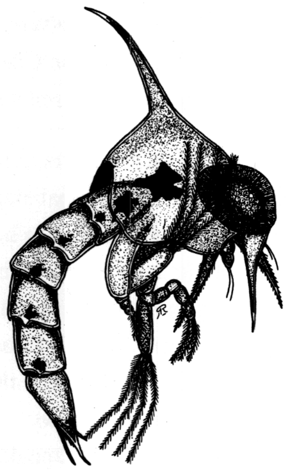
Prezoea just emerged from the egg capsules.



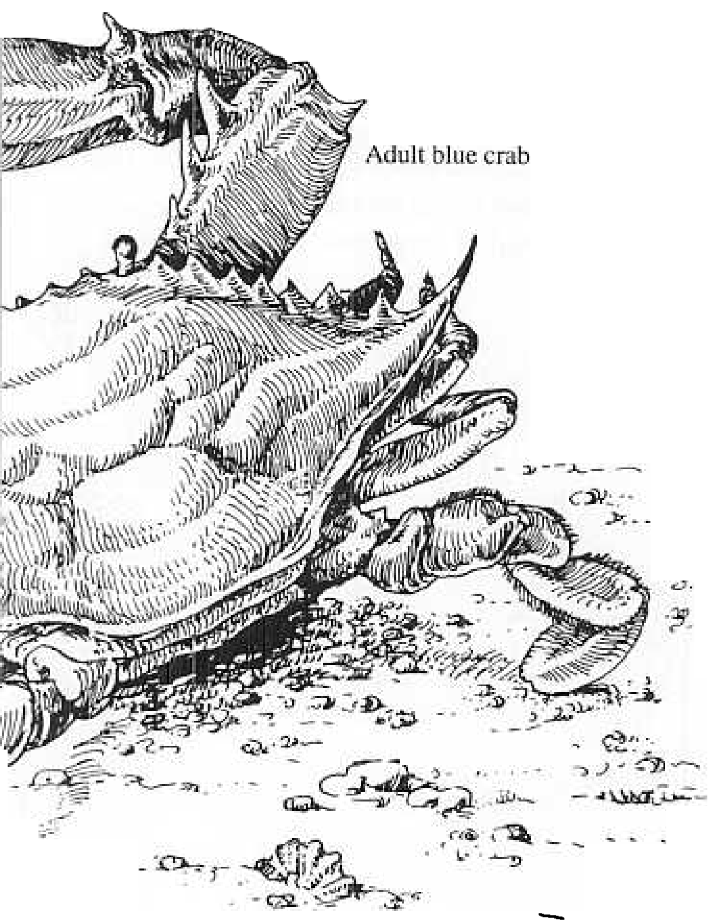
The female blue crab carries up to two million eggs on her underside for approximately two weeks before she spawns near the Chesapeake Bay mouth. Larvae undergo dramatic transformations in this initial stage of life, from the almost sci-fi appearing zoeae larva to the crawfish-look of the megalopa. As a zoeae larva, the blue crab is planktonic, drifting in the water. The megalopa is able to move vertically in the water column, and will—via currents, tidal flow, wind-driven surface circulation and perhaps the blue crab's own movement—eventually move into its adult habitat, the Chesapeake Bay. ✣



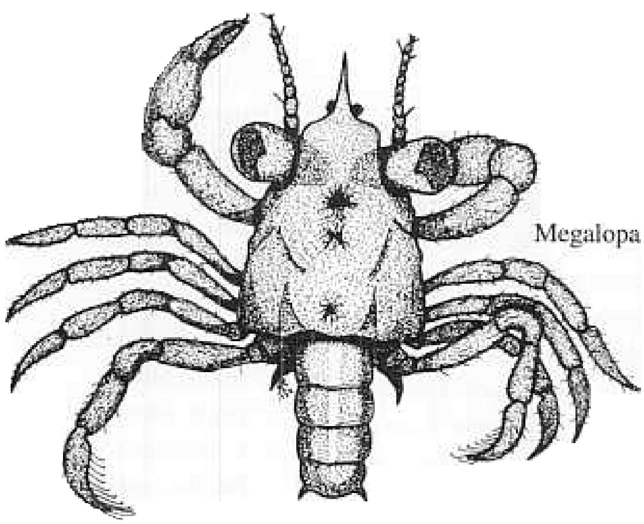
Empty egg capsules.



Zoea three days after hatching.



Adult blue crab



Megalopa

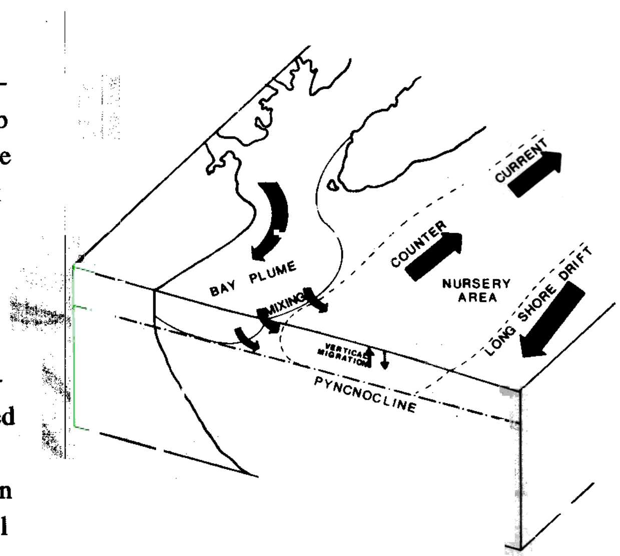
The Journey From The Continental Shelf To The Chesapeake Bay

Virginia Sea Grant has consistently supported research which has significantly added to the body of information about the early life stages of the blue crab. This Sea Grant support has been instrumental in the development of models for larval transport and retention on the continental shelf; biological interactions; and habitat selection by megalopae and juveniles following reinvasion of the estuary. The following article addresses part of the continental shelf phase, and a new area of concern: the transition from the shelf nursery to the Chesapeake Bay. For Sea Grant research within the Chesapeake Bay, see page 16).

When a species declines in numbers, especially a species with an acute economic value, speculation often focuses on pollution or another species as the source of the problem. Even though those components could well be a cause, the interactions of meteorological, physical and biological processes can factor in heavily. Annual fluctuations occur in all marine populations. If those populations were left alone, that is not harvested, and if other factors did not intercede, the fluctuations would have little impact on the long-term stability of a population. In the short term, from the viewpoint of a fisherman dependent on a catch, these normal population size changes can appear as wide variations in the commercial harvest.

From a scientific perspective, inter-annual population variations are generally attributed to the success or failure of larval/juvenile recruitment into the adult population. For the blue crab, the early-life journey is precarious. It is a progression from egg, to a planktonic larval phase in which the animal drifts in the water, to the megalopal stage in which the crustacean has both planktonic and benthic affinities, meaning that it can rise in the water column and ride flood tides, or it can settle near the benthos during ebb tide. Spawned at the Chesapeake Bay mouth, adrift in the inner continental shelf nursery, the blue crab will ultimately be transported back to the Chesapeake Bay system, its adult habitat.

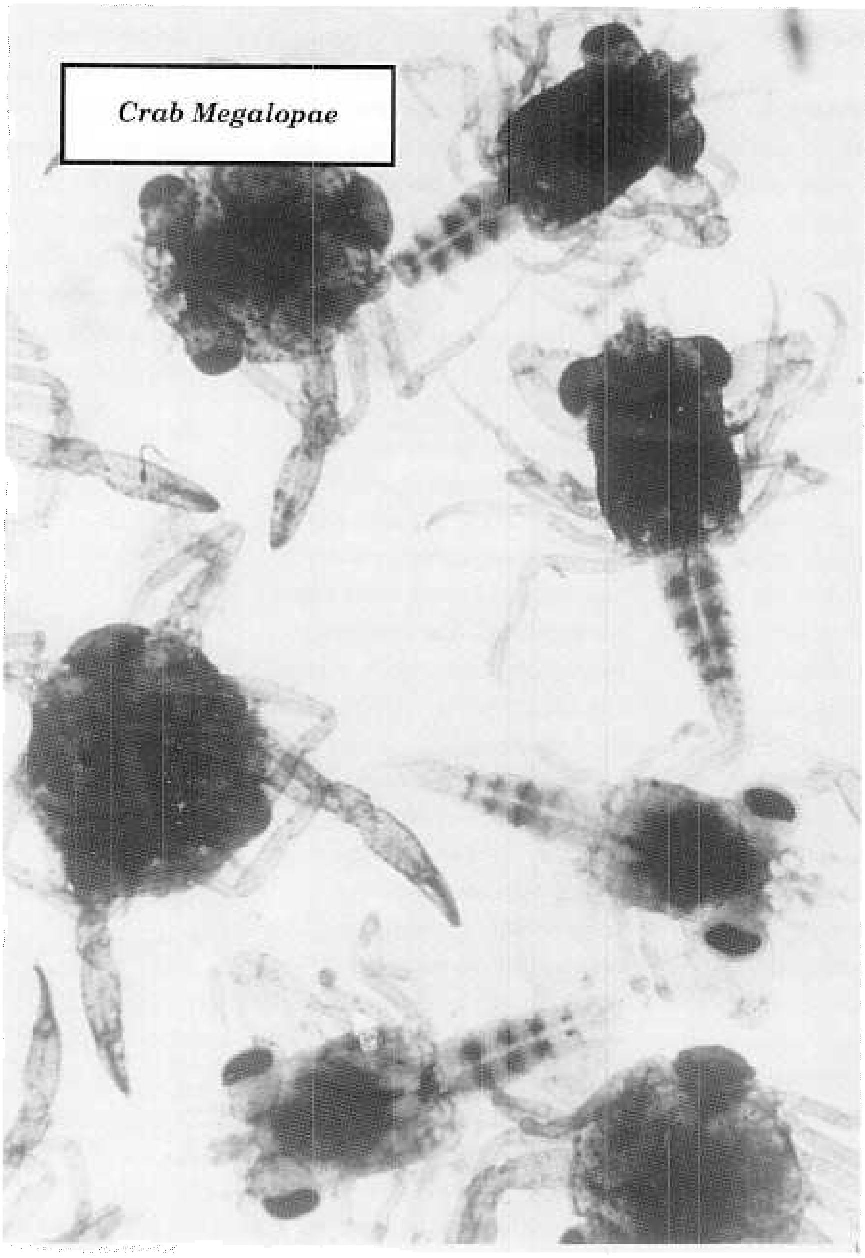
Previous research, sponsored in part by Sea Grant, resulted in a working model for blue crab larval transport out of the estuary and development on the inner shelf nursery. With this research, scientists could pinpoint significant mortality at those two stages, information which could be used to help estimate the strength of a year class.



The hydrographic conditions that result in the retention of C. sapidus *larvae in nursery grounds of the Mid-Atlantic Bight. Conditions for retention are dependent on up-welling favorable winds (Southwest) and development of a strong seasonal pycnocline (a water layer that exhibits a relatively rapid increase in density with increasing depth).*

John McConaugha, Sea Grant researcher at Old Dominion University, has spent a considerable amount of time elucidating influences which could have bearing on survival both on the continental shelf and in the transition zone between the continental shelf and the Chesapeake Bay.

For almost every reproductive phenomena there supposedly is a reason, usually the long-term survival of a species. The transport of blue crab eggs and larvae to the inner part of the continental shelf could be part of a long-term survival strategy, long-term meaning an especially protracted amount of time. . .over 100 generations. Export from an estuary might be a mechanism for a gene flow between populations, leading hypothetically to a colonization of new habitats.*



Crab Megalopae

What is perhaps remarkable is that the megalopae remain on the inner shelf. The longshore current and the southerly flow at some depth on the shelf, would theoretically transport the larvae and megalopae southward to Cape Hatteras, where the early stage blue crabs would be lost to the Chesapeake Bay system. Yet, that does not occur. It is this retention on the shelf and the reinvasion of the estuary which McConaugha and a number of other scientists have sought to define.

Samples taken across the continental shelf off the Chesapeake Bay indicated a progressive movement of larvae offshore, and as they matured, a shoreward movement of megalopae. A number of forces, and even the young blue crab's movement, combine to keep the larvae within the shelf. The prevailing winds along the Atlantic coast are characteristically from the

*This theory could be countered by the contention that the seaward movement is to avoid predators, or is a evolutionary remnant; *Callinectes* is of tropical oceanic origin and might require oceanic conditions in the early life stages.

southwest toward the northeast. Even if it is weak, the wind stress in the Middle Atlantic Bight is of sufficient strength to develop a northward-flowing surface current—a current which could help retain larvae on the inner shelf. The larvae also have a role in this by maintaining a specific position within the water column. They are above the southerly flow found at a depth on the shelf of the Middle Atlantic Bight, thus avoiding an inadvertent journey southward to Cape Hatteras. Larvae and megalopae are concentrated in the upper one meter, in the segment influenced by wind-generated surface currents, the driving force for *C. sapidus* larvae transport. Although these currents are strong enough to keep the larvae and megalopae on the shelf, they are normally not strong enough to drive the crabs back into the estuary.

The mechanism, or mechanisms, that transport larvae from oceanic waters to the Bay are not well understood. A few theories about the reinvasion exist: that the crabs migrate to the bottom during ebb tides and vertically migrate into the water column during flood tides. Another possibility is the megalopae are transported into the estuary from the shelf via rapid water exchanges due to wind forcing of the lower estuary—in commonplace language, water masses are pumped into the estuary along with *C. sapidus*. The first theory calls for the blue crab to react behaviorally to a physical force. The second concept casts *C. sapidus* in a passive role; the crabs' recruitment into the estuary is solely a result of physical forces.

McConaugha is examining very closely another possibility: that the megalopae are concentrated by water mass fronts** near the estuary-shelf interface, and that in response to this changing environment, the megalopae migrate or are forced to mid-depth and thereby enter the estuary.

The estuary-shelf interface is dynamic, is a place of formidable forces. The tide is one of the more obvious phenomena, but there are a number of others, including the flow of warm, low salinity water from the estuary and the wind forcing of the upper water column. The latter can plainly vary dramatically in intensity and can be into or out of the Bay.

McConaugha's data suggests that megalopae concentrate. The Sea Grant researcher consistently found densities of one to two thousand megalopae per cubic meter in water mass fronts located on the shelf adjacent to the Chesapeake Bay. McConaugha seeks to determine if these patches are caused by the fronts and also what happens to these high-density patches. His work will attempt to determine if water mass fronts act as a physical barrier to the movement of blue crabs into the estuary, or if they facilitate transport by concentrating blue crabs and then causing a downward mixing of the crabs into the water column which would expedite transport into the estuary. McConaugha also seeks to determine if the conditions around the water mass fronts somehow trigger a behavior in blue crabs which aids in their reaching the appropriate water column for their passage into the Chesapeake Bay.

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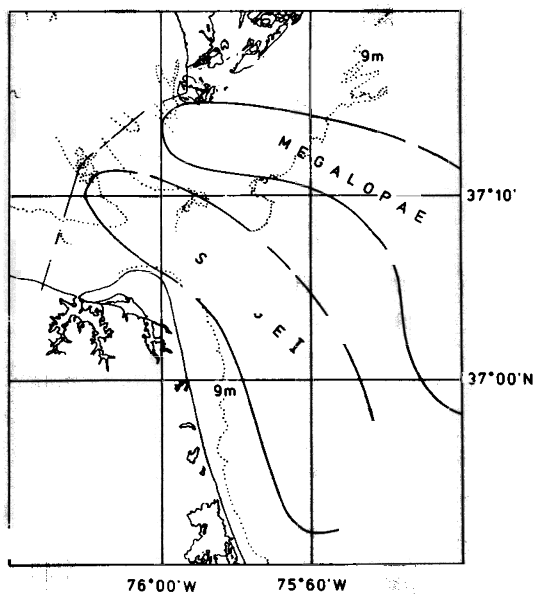
**A front is the interface of two water masses that differ in density (temperature and/or salinity).



Generalized distribution of peak numbers of Callinectes sapidus *stage-I larvae and megalopae on the inner continental shelf adjacent to Chesapeake Bay.*

Juvenile Blue Crabs. . . What Happens to Them Once They Enter the Chesapeake Bay?

The word "valuable" is constantly used to describe the blue crab fishery, yet what exactly does that mean from an economic point of view? Dollar wise, the Chesapeake Bay harvest accounted for about fifty percent of the national harvest during the past two decades. Since 1981, this species outranked in total dollar value all other Bay shellfish harvested in the Commonwealth. The blue crab even has significance on a worldwide level: over the past decade it has become the world's primary crab fishery. In other words, *Callinectes sapidus*, the beautiful swimmer, undoubtedly ranks as an important resource wherever it is found.

Natural resources, however, are finite and can disappear. Given the increased fishing pressure on the blue crab and the decline in other major exploitable fisheries, concern centers now on the need for fishery management within a sound ecological framework. This is particularly important since the blue crab population fluctuates widely. Sustained or even increased fishing pressure could possibly jeopardize the blue crab population in the Chesapeake Bay.

The eventual recruitment into nursery habitats appears to be linked not just to complex physical oceanographic processes, tidal flow and wind-driven surface circulation, but also to how the blue crab behaviorally responds to environmental stimuli such as light, water pressure and salinity.

Research, supported by Virginia Sea Grant*, has focused on revealing more about the factors which influence recruitment (the addition of new individuals to the population). Scientists Rom Lipcius, Jacques van Montfrans, Bob Orth, and Karen Metcalf—at the Virginia Institute of Marine Science (VIMS)—and Geno Olmi of Virginia Sea Grant—are examining causes for population fluctuations in the commercial harvest, information which would assist in developing a scientifically sound management policy.

During the past decade the VIMS researchers have been examining the patterns and processes of transport, settlement by blue crabs after the larval stages, and the importance of various habitats for newly settled juvenile blue crabs.

The initial research on blue crab habitat use and population dynamics identified just how significant seagrass beds are as a nursery habitat for post-settlement blue crabs (ones which have metamorphosed into the familiar crab body form), and as a refuge for molting crabs. Compared to unvegetated areas, seagrass habitats support between ten and 90 times the densities of

*This research was also funded by the National Oceanic and Atmospheric Association's Chesapeake Bay Stock Assessment Committee and by the National Science Foundation.

blue crabs less than once inch in width (measured spine to spine).

Further research resulted in meaningful insights into patterns of postlarval recruitment**, behavior as it relates to physiological state, and predator-prey dynamics during the juvenile phase.

The eventual recruitment into nursery habitats appears to be linked not just to complex physical oceanographic processes, tidal flow and wind-driven surface circulation, but also to how the blue crab behaviorally responds to environmental stimuli such as light, water pressure and salinity. When it comes to the blue crab, the transport of an individual is *not* thought to be passive, one in which the blue crab is simply transported. For instance, in its megalopal form, the blue crab is found deeper in the water column during the daytime and is in surface waters during flood tides at night. By vertically migrating to the surface at night and during a flood tide, the megalopae would better foil predators that are visually oriented and would use the flood tide to hopefully arrive at suitable nursery habitats for settlement.

Suspecting that what happens during the settlement phase might, in some way, correspond to the large population fluctuations, VIMS researchers started

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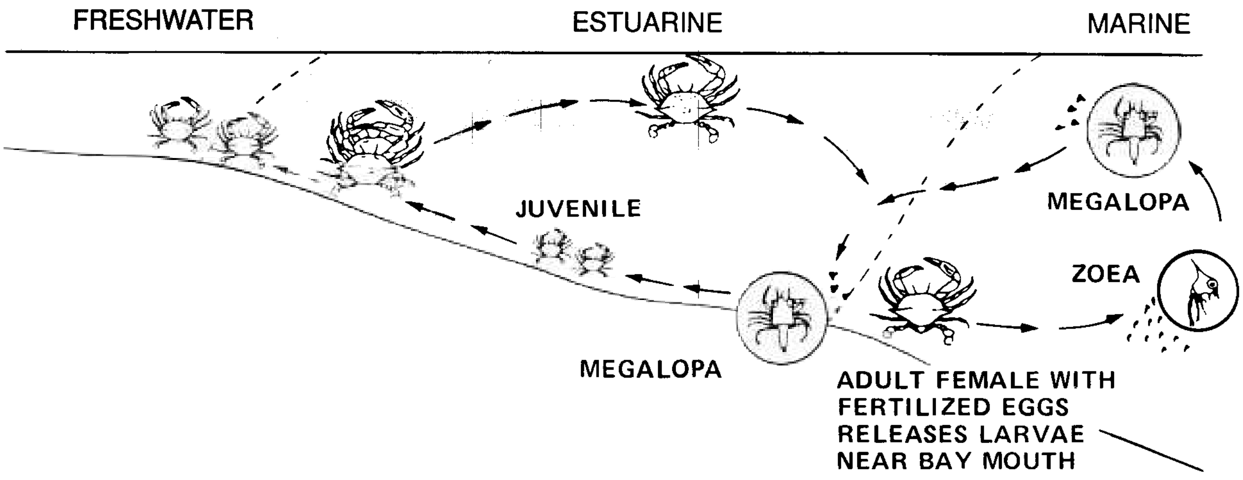
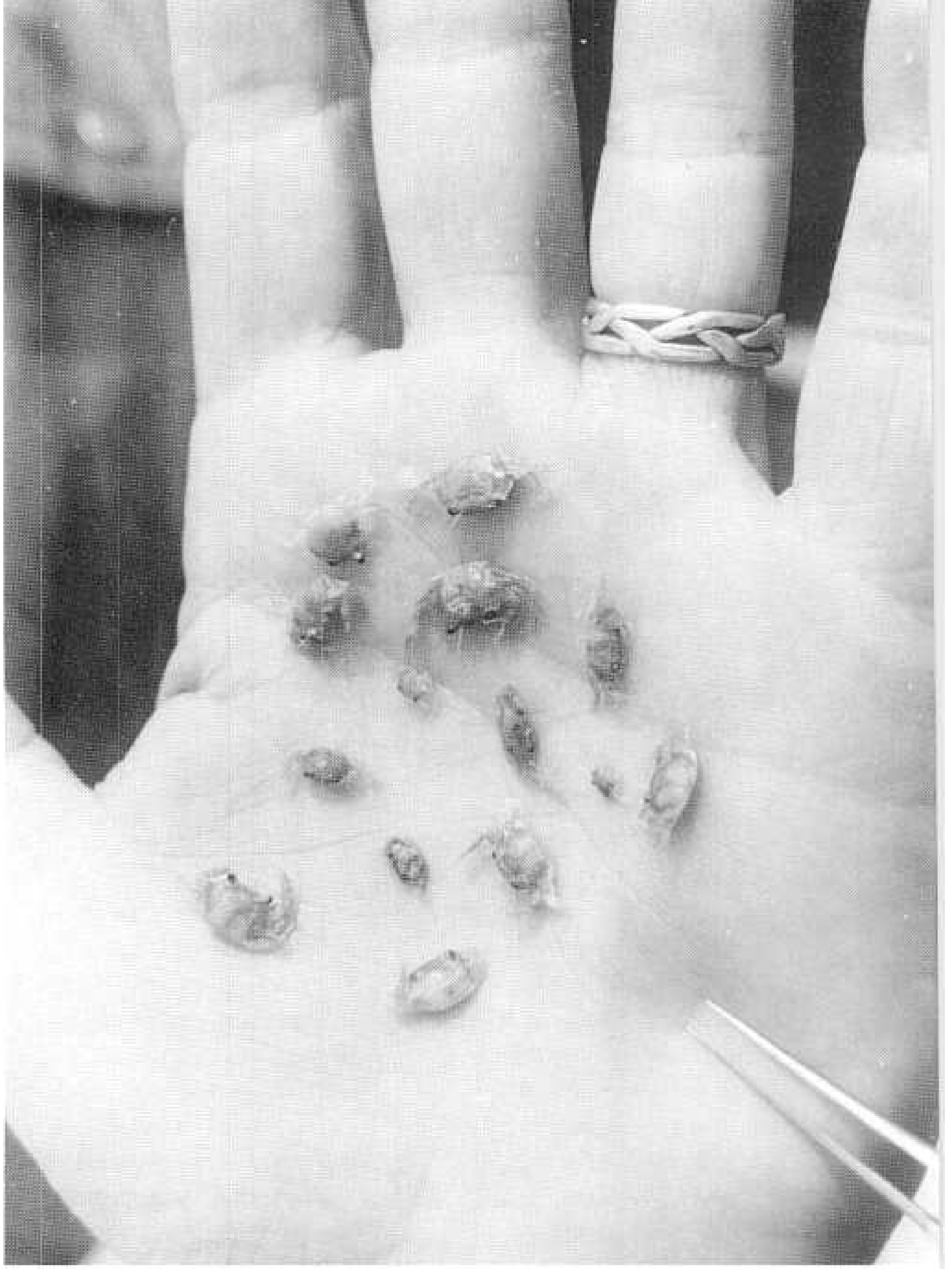
**"Recruitment" is scientific jargon and here denotes the point at which an animal joins an existing population.

The scientific designations—larval, postlarval and adult—all refer to quite distinct stages in an animal's life. The larval, immature form (zoea) of a blue crab is fundamentally different from its parent and must undergo metamorphosis before the transition to the postlarval (megalopa), and then the adult stage.

Blue Crab Life Cycle



Research of blue crab recruitment is a major VIMS initiative in conjunction with researchers at ten marine research institutions. The coastal states involved in this project range from Delaware to Florida along the Atlantic coast, and from Alabama to Texas in the Gulf of Mexico. VIMS researchers are the data base managers for these efforts and they also coordinate research on blue crab ecology. ✣



Juvenile blue crabs.

experiments in 1985, examining blue crab postlarval settlement on artificial settlement substrates. Over the course of about seven years, the settlement was characterized by a series of peaks, mainly between mid-July and mid-November, and generally around the new and full moon. Even though this pattern of peaks was the norm for all the years studied, the number of crabs which settled fluctuated substantially.

From a scientific point of view, the plot thickened. . .If the peaks seemed to fall into a norm, what was impacting the population? A number of possibilities exist and a definitive answer is not yet apparent, given the number of variables. A few clues, however, exist. The population size of a year class could obviously be impacted by survival success before the blue crabs settle, during the journey from oceanic waters to the Chesapeake Bay. But the nursery in which the crabs settle may well be full of peril for the settling crab.

VIMS graduate students Kirt Moody and Adele Pile, and Swedish exchange student Per Moksnes looked closely at the nursery habitat. Their research indicated that mortality of newly settled blue crabs is substantial and due in large part to cannibalism, accounting for as much as a 90% loss in numbers in grassbeds and near 100% loss in unvegetated areas for the smallest crabs. Mortalities are greatly reduced as crabs grow in size except for times of high vulnerability during molting, when crabs shed their outer shell and remain in a soft condition for short periods.

In the future, researchers plan to look at fish predators of newly settled crabs, and to further elucidate the dynamics which determine how many crabs will survive to become a part of the adult population.

The Feeding Ecology Of Blue Crabs in the Lower Chesapeake Bay

Randa A. Mansour,
Adjunct Professor,
University of North Carolina,
and
Romuald N. Lipcius,
Professor of Marine Science,
Virginia Institute of
Marine Science

The following article is based on Randa Mansour's dissertation work at the Virginia Institute of Marine Science. Randa's investigation focused on predator-prey dynamics and sought to quantify blue crab feeding habits and preferences in the lower Chesapeake Bay. Her graduate work involved two years of sampling and amassing information from one of the more telling parts of crabs. . .the stomachs. The contents of an animal's stomach can reveal its prey preferences and even what a crab will resort to when the preferred prey is not around—in this case often other blue crabs.

The

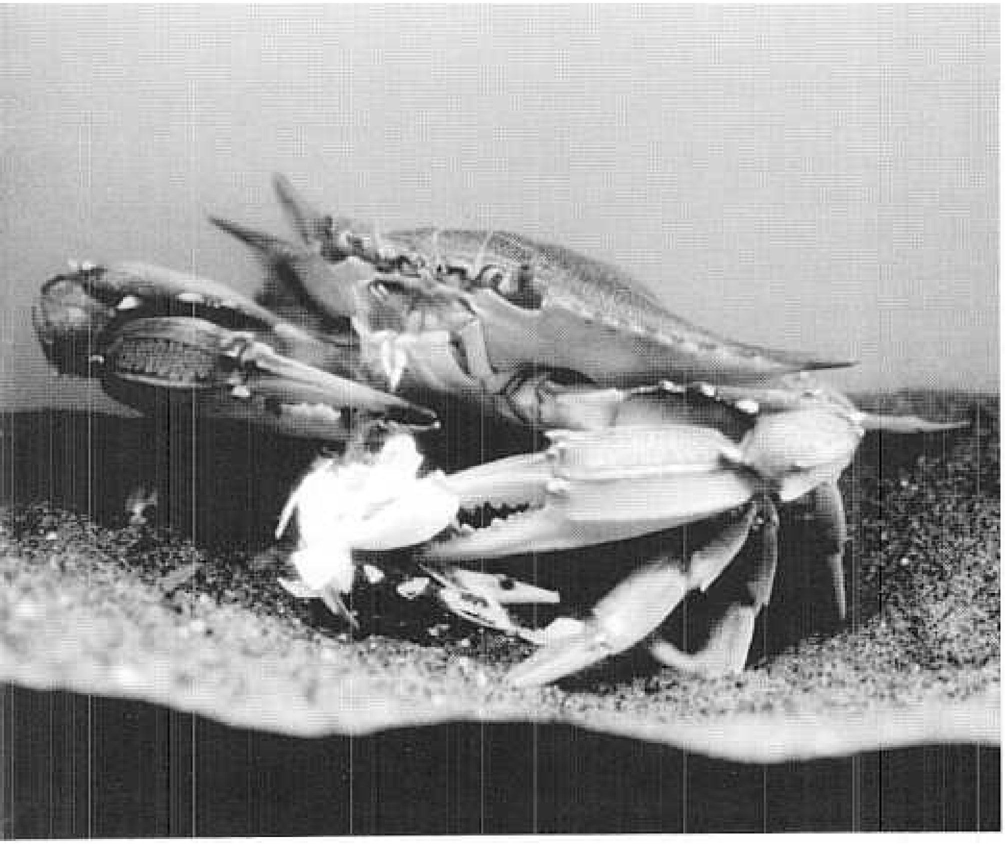
trawling), blue crabs are placed on ice immediately to slow digestive processes, as well as to sedate the crabs. After about 5-10 minutes, these iced crabs are sacrificed by peeling off the back of the shell to reveal the gut. Forceps are used to remove each stomach, which is then placed in individual containers, labelled with the date and place of collection, crab size, sex and molt stage. Buffered formalin in each container quickly enters the gut and preserves the food, thus providing an accurate picture of what the crab was eating around the time of capture. In the laboratory, a dissecting microscope is used to estimate the percent fullness of each gut. The stomach contents are removed by dissection, prey are identified to species (if possible), and the volumetric proportion of each prey type is determined. The information acquired from gut contents studies is useful for understanding nutritional requirements of blue crabs, as well as predation effects on other Chesapeake Bay species. Diet quality may affect growth rate, and some food types, such as clams and crabs (calcium-rich species), may be important for hardening of the shell after shedding.

The preferred food item of all age/size groups of blue crabs is clams, especially thin-shelled clams (i.e., *Macoma* species) and the soft-shelled clam (*Mya arenaria*). Other prey include crabs (both mud crabs and blue crabs), worms, fish, shrimp, amphipods, snails, hydroids, brittle stars, insects and plants. Sand and gravel are also ingested, probably as a consequence of feeding on buried clams or other bottom-dwelling prey. In general, blue crabs in the James, York and Rappahannock Rivers, Virginia, eat similar prey, and diet does not vary from summer through early fall. However, food selection changes with location within a river. Although all crabs eat clams and crabs, the relative amounts of these items in the diet differ and can be related to their abundance or availability. In areas of low clam abundance (i.e., downriver habitats), blue crabs expand their diets to include other prey types (as well as clams and crabs), such as worms, snails, fish, crabs, hydroids, amphipods, isopods, insects and plants. Upriver, where clams are relatively more abundant, blue crab diets consist mostly of clams, and few of any other prey types.

As with location within rivers, the blue crab diet also varies with crab size/age. Crabs of all sizes prefer to eat clams. However, the relative amounts of clams in the diet vary: small juveniles and new recruits (2-1/2" carapace width) eat numerous amphipods and worms; larger juveniles (2 1/2" carapace width) and adults eat bivalves and crabs (i.e., blue crabs and mud crabs). Cannibalism is common, and is practiced most frequently by large adults, which prey on small juveniles. Cannibalism occurs more frequently in the fall during the period of juvenile blue crab recruitment into the rivers of the lower Bay, and is relatively more common in rivers that have fewer numbers of clams (i.e., James and York).

Blue crabs undergo extensive physiological and behavioral changes in association with the molt cycle. Molting (or shedding) is the process whereby blue crabs shed their shells and grow. Before molting, a new shell is formed beneath the hard outer shell of the crab. Watermen and scientists alike use color changes (i.e., signs), observable by examination of the last two sections of the swimming legs, to determine proximity to shedding. In short, white sign crabs are within two weeks of molt, pink sign crabs are within one week of molt, and red sign crabs are within 1-3 days of shedding.

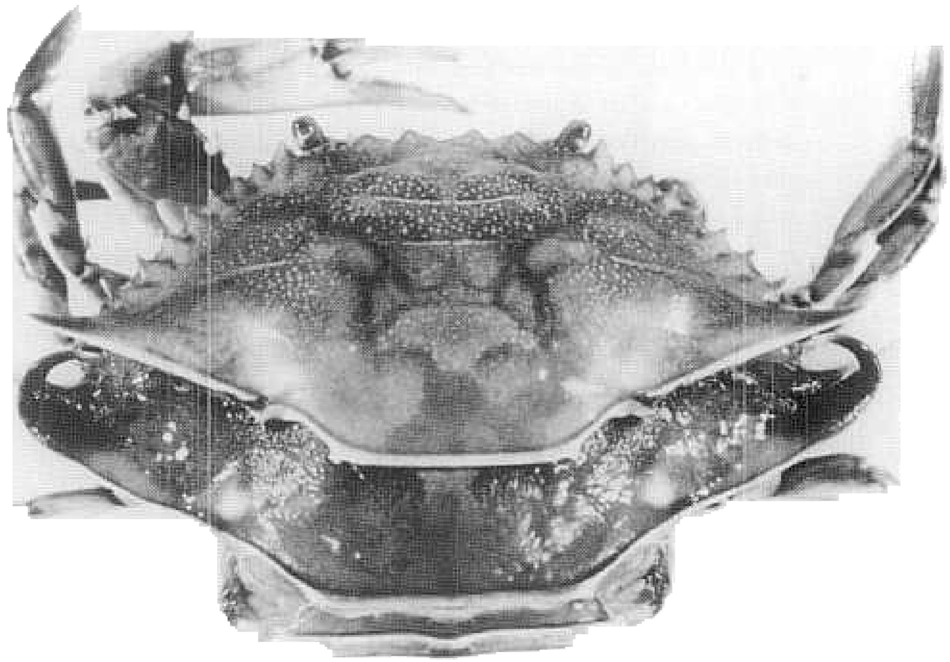
In general, crustaceans (e.g., lobsters, crabs and shrimp) cease feeding directly before, during, and immediately after shedding. Until recently, however, there has been no direct documentation of changes in blue crab diet over the molt cycle. Blue crab diet varies substantially with proximity to molting. First, crabs stop feeding immediately prior to and during molt, whereas papershell crabs (i.e., crabs who have already molted, but their shells have not fully hardened) have fuller guts than crabs approaching a molt (e.g., either crabs within one week or those



*A blue crab feeds on a preferred food, the soft-shell clam (*Mya arenaria*).*

within 1-3 days of molt). Second, crabs consume different prey types depending on where they are in the molt cycle. For example, hard-shell, white and pink sign crabs predominantly eat clams; papershell crabs consume clams, but also eat more crabs (i.e., blue crabs and mud crabs). In fact, blue crab remains occur most frequently in the guts of papershell crabs. At present, it is unclear whether these papershell crabs are predominantly cannibals, or if blue crab remains simply represent consumption of molted shells or dead crabs. In summary, regardless of location, crab size, season (at least the summer-fall period), or molt stage, blue crabs like to eat clams. However, when clams are scarce, blue crabs will eat other prey types, including juvenile blue crabs. Blue crabs are voracious predators and cannibals in Chesapeake Bay, whose foraging activities affect the distribution and abundance of their preferred prey (i.e., clams), as well as potentially impacting their own population. ✣ ✣

'Buster" crab backing out of its shell.



The formidable-looking *Callinectes sapidus*, armed with large claws, does not live a long life. . .an average of two to three years. However, during that lifetime this skillful swimmer can molt some 18 to 22 times. Molting is the forte of crustaceans, which periodically shed their shells to grow. In a time span of only hours, a split develops on the posterior edge of the blue crab's shell. The crab, now called a "buster," carefully backs out of its old shell. The wrinkled, soft shell crab will absorb water and in several hours to several days its new shell will completely harden.

It is during the female's terminal molt, when she is sexually mature and will probably not shed again, that mating happens. A male cradles the female and when she sheds her shell, mating occurs. The male will continue to cradle the female until her shell hardens. The female carries up to two million eggs on her underside for approximately two weeks before she spawns near the Chesapeake Bay mouth. ✣

For commercial and recreational fishermen

New Publications

Mid-Atlantic Zebra Mussel Fact Sheet

Since their inadvertent arrival to U.S. waters, zebra mussels (*Dreissena polymorpha*) have rapidly spread throughout the Great Lakes and into several major river systems, including the Ohio, Illinois, Mississippi, Mohawk, Hudson, Susquehanna, Tennessee and Arkansas rivers. Zebra mussels arrived in the Great Lakes via the discharge of European shipping ballast water.

To date, Great Lakes industries and municipalities have spent millions of dollars in efforts to control the spread of zebra mussels into water intake pipes and to control the repair the damage caused by their prolific colonies. The one- to 2-inch-long mollusk will attach to nearly any surface.

To date, the mid-Atlantic region—North Carolina, Virginia, Maryland, Delaware and New Jersey—has been free of zebra mussels. Yet, concern exists that the prolific colonizer will make its way into the region.

For those interested in more information about the mollusk, the *Mid-Atlantic Zebra Mussel Fact Sheet* is a thorough summary written for the layman. The author is Barbara Doll, University of North Carolina Sea Grant Specialist. The publication can be obtained by writing Sea Grant Communications, Virginia Institute of Marine Science, Gloucester Point, Virginia 23062. *Mid-Atlantic Zebra Mussel Fact Sheet* is free of charge. ✣ ✣

An Evaluation of Processed Atlantic Sea Scallops

When warning letters were sent to several scallop processors about the potential misuse of sodium tripolyphosphate (STP), it became evident that part of the federal government and the sea scallop industry could be on a collision course. At issue was the use of STP during processing and the resultant addition of excess water which could have been seen as a fraudulent practice. Additionally, unresolved issues existed about the addition of water (weight) from ice-melt during vessel stowage and from other processing practices.

At the request of the American Scallop Association and The International Food Additives Council, Sea Grant specialists from Virginia and Florida joined efforts to arrive at standards for various at-sea handling practices, and for STP processing use. The work was conducted by Sea Grant scientists William DuPaul and Robert Fisher, Virginia Institute of Marine Science; by W. Steven Otwell, University of Florida; and Thomas Rippen, Virginia Polytechnic Institute. The results of their research, which include a draft set of good manufacturing practices, are contained in *An Evaluation of Processed Atlantic Sea Scallops*. The publication costs $10 and may be obtained by writing Virginia Sea Grant, Virginia Institute of Marine Science, Gloucester Point, Virginia 23062. ✣ ✣ ✣

On the cover: striped bass
by Duane Raver, Jr.

Sea Grant Communications
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

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