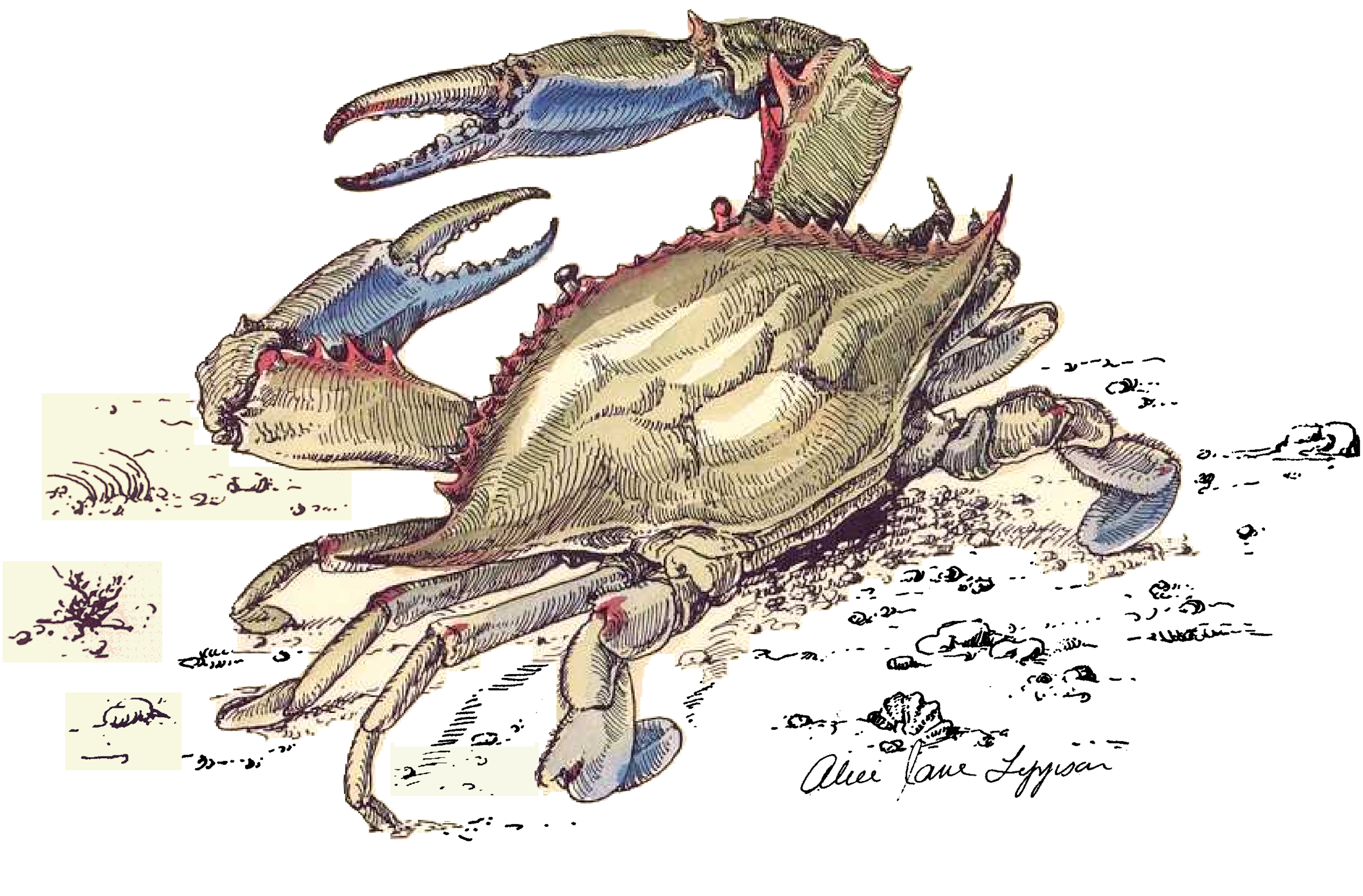
Virginia

MARINE RESOURCE

BULLETIN



Virginia Sea Grant Program, Virginia Institute of Marine Science
College of William and Mary
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Virginia
MARINE RESOURCE
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Contents

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The Blue Crab Fishery

The blue crab (*Callinectes sapidus*) fishery is presently the most valuable fishery* in the Chesapeake Bay. From 1982 to 1992, the commercial fishery averaged landings of approximately 42 million pounds** with a dockside value of 12-13 million dollars. In 1990, dockside value peaked at about $17 million for landings of almost 49 million pounds. In 1992, the number of pounds fell to about 24 million, a number representing almost half of the decade's average harvest. This downturn caused real concern, if not alarm to some, especially since many watermen had turned to the blue crab harvest after the oyster fishery collapse, and after the decline of many traditional fisheries in the Bay and its tributaries.

Historically, peaks and lows have occurred before. In the past 50 years, there was a high of 63,731,000 pounds in 1966, and a low near that of 1992's: 25,760,947 pounds in 1976. One of the problems with historical information about landings, is that the effort exerted by harvesters is often not known. Said another way: other fisheries may have been more important to harvesters in some years. Consequently, fishing effort was spread over a variety of Bay species. Today, in 1995, the blue crab fishery *is the main wild food fishery in Chesapeake Bay.*

Complicating an already complex picture is the very preliminary figure for landings in 1993: 52,808,467 pounds. Prior to 1993 reporting was voluntary in Virginia and random samples were conducted in Maryland.

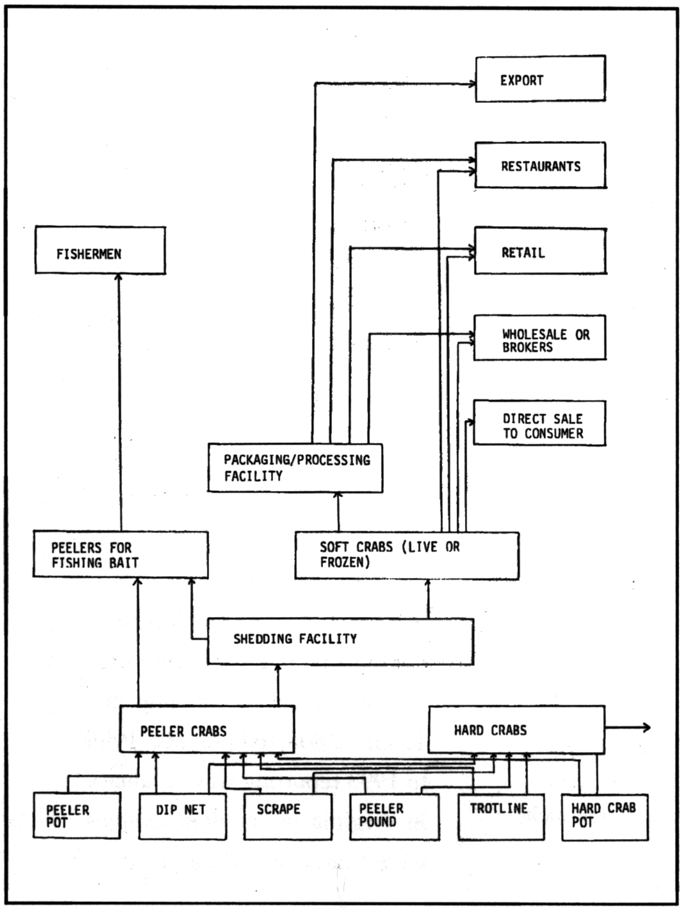
*The blue crab fishery's status as the most valuable fishery does not take into account the various aquaculture ventures in the Bay or the non-food fisheries. The blue crab industry is actually two different commercial fisheries, one directed toward the harvest of hard crabs and the other toward the harvest of peeler (pre-molt) crabs for soft crab production or recreational fishing bait.
**All landings cited in the article reflect *Virginia* landings.

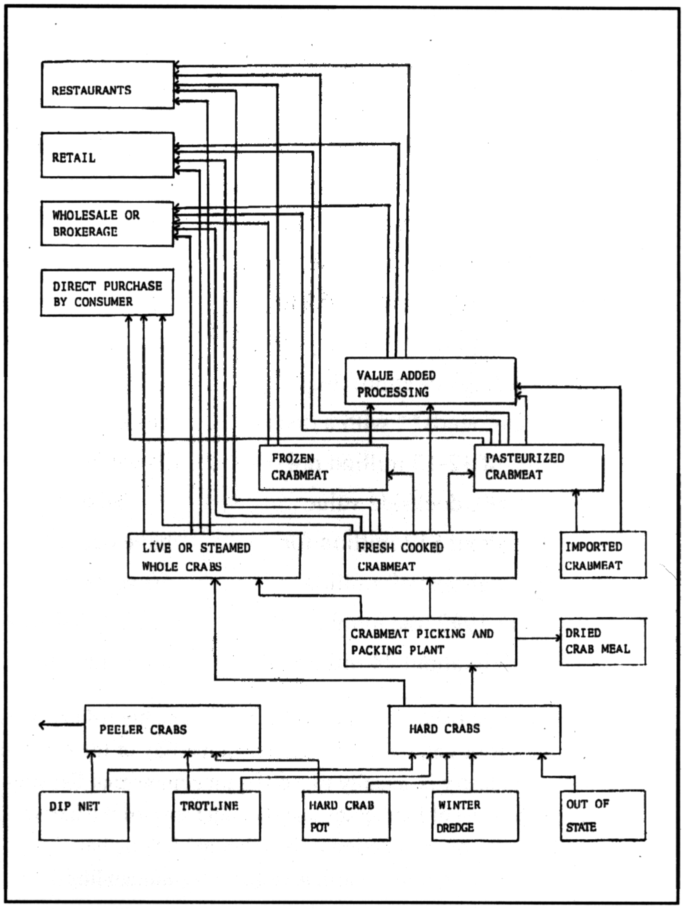
Since 1993, both states have converted to mandatory reporting by all commercial harvesters. Because the blue crab's life history spans the entire Bay and is a unified stock across state lines, uniform Bay-wide catch records for both commercial and recreational harvests were believed to be necessary to monitor the stocks.

Central to the continuing debate about the fishery is the status of the stocks—are they actually very low, and to what extent can they be exploited? Agreement is not the norm here. Various researchers contend that most indicators point toward a serious decline, one which could endanger the resource, and that conservative measures should be enacted immediately. Other scientists and regulators believe that the blue crab's short life span, and consequently its ability to reproduce in a short amount of time, means that the stocks could rebound quickly. Yet another group of researchers suspect that the stocks are cyclic, accounting for the apparent highs and lows in abundance.

Another potentially contentious debate is among the users of the resource. When a marine resource becomes not as plentiful or scarce, harvesters invariably try to ensure that they have their fair share, and that no one group is harvesting more than another, or causing damage to future stocks. An Alice-In-Wonderland maze of harvesting gears, product forms and markets complicates this issue, making it difficult to quantify the actual harvest by any one sector.

The Alice-in-Wonderland maze of harvesting gears, product forms and markets. The bottom boxes in the flow charts denote the gear; the boxes point to the type of crab being sought. In the middle maze are the product forms, which point to the various markets. The left flow chart is the soft crab fishery; the right chart is the hard crab fishery.





This issue of the *Bulletin* is not intended as an "answer" to any of these issues. Rather, it is meant as an open forum for discussing current scientific information about the various fisheries. In previous issues, the biological studies were given in-depth treatment; many of these studies were conducted by the Virginia and Maryland Sea Grant programs. This issue of the *Bulletin* concentrates on recent work devoted to the management and description of the blue crab fishery.

The Virginia Institute of Marine Science (VIMS) is not a regulatory agency, and does not make the laws governing the fishery. VIMS conducts research in response to informational and scientific needs. The Virginia Marine Resources Commission is the regulatory agency, and all questions on clarifying laws and regulations should be directed to the Commission.

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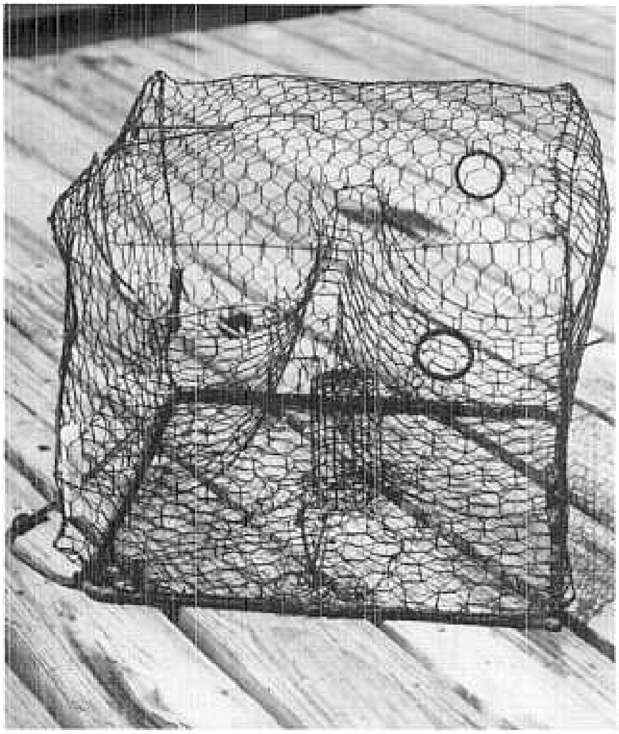
Why are the Stocks Low?

Most researchers believe it is a combination of environmental factors and fishing pressure. Natural fluctuations in the population might show up as a severe decline in terms of the harvest. Environmental factors, such as the wind events that are believed to help transport post-larvae (megalopae) back into the Chesapeake Bay, are not necessarily constant, and may have ramifications for the resource. A lack of seagrasses for habitat and protection may lead to high mortality. Add to this fishing pressure and it becomes hard to delineate the exact importance of any one factor.



Crab pot.

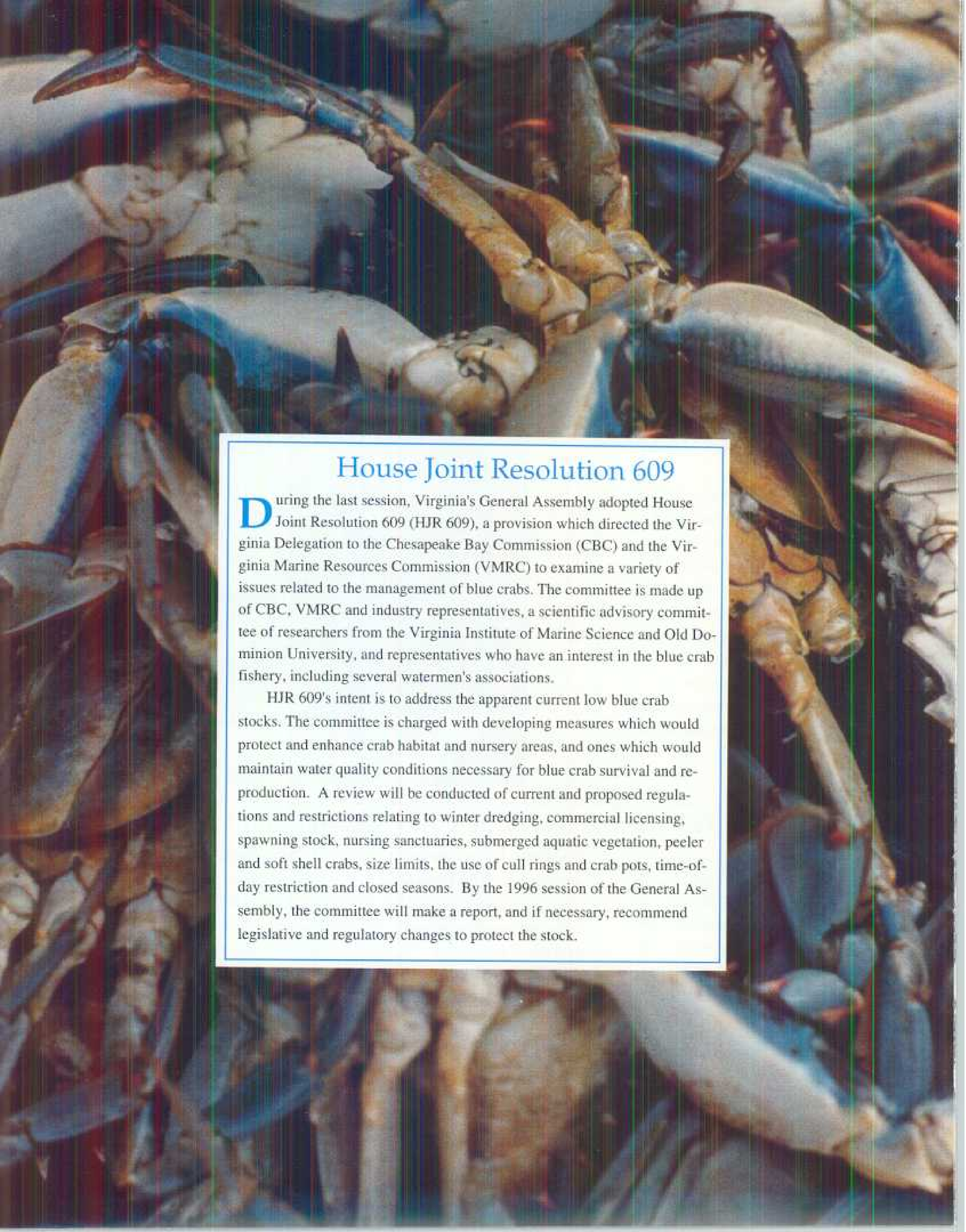
Chesapeake Bay Blue Crab Management Plan

In 1989, the first Chesapeake Bay Blue Crab Fishery Management Plan (BCFMP) was adopted under the auspices of the Chesapeake Bay Agreement. Participating in the plan are Virginia, Maryland, Pennsylvania, the federal government, the District of Columbia and the Chesapeake Bay Commission.

The intent of the plan is to manage blue crabs in the Chesapeake Bay in a manner which conserves the Bay-wide stock, protects its ecological value, and optimizes the long-term use of the resource.

Problem areas which are being addressed in 1995 include the increased fishing effort, wasteful harvesting practices, stock assessment deficiencies, regulatory issues, and habitat degradation.

While the BCFMP group this year did not come to a consensus about the current status of blue crabs, the group agreed that there are many signs which are indicative of a population under stress. The indicators were bay-wide, regional and local.



House Joint Resolution 609

During the last session, Virginia's General Assembly adopted House Joint Resolution 609 (HJR 609), a provision which directed the Virginia Delegation to the Chesapeake Bay Commission (CBC) and the Virginia Marine Resources Commission (VMRC) to examine a variety of issues related to the management of blue crabs. The committee is made up of CBC, VMRC and industry representatives, a scientific advisory committee of researchers from the Virginia Institute of Marine Science and Old Dominion University, and representatives who have an interest in the blue crab fishery, including several watermen's associations.

HJR 609's intent is to address the apparent current low blue crab stocks. The committee is charged with developing measures which would protect and enhance crab habitat and nursery areas, and ones which would maintain water quality conditions necessary for blue crab survival and reproduction. A review will be conducted of current and proposed regulations and restrictions relating to winter dredging, commercial licensing, spawning stock, nursing sanctuaries, submerged aquatic vegetation, peeler and soft shell crabs, size limits, the use of cull rings and crab pots, time-of-day restriction and closed seasons. By the 1996 session of the General Assembly, the committee will make a report, and if necessary, recommend legislative and regulatory changes to protect the stock.

Resource Management Issues

No state agency or scientific group would ever want to be accused of incorrectly assessing the status of a fishery. Dismal, too, would be a charge that a fishery closure had not been necessary and had caused economic hardship. Bleaker yet, would be the collapse of an important resource. Yet these three scenarios typify the risky traps inherent in managing fishery resources, resources which can be more difficult to enumerate than terrestrial ones.

Implicitly, state and federal agencies are involved in a balancing act; they are charged with maintaining the resource while allowing fair access to it—a task which sounds simple, but which can resemble a minefield. Yet, when so much information is available, why does uncertainty exist?

State management and regulatory agencies rely on information from a myriad of sources, sometimes differing in their assessment. Conflicting views have been perceived as a fundamental uncertainty about the status of a fishery resource. Historically, this "uncertainty" has often been capitalized upon, allowing for over-exploitation of the resource. Politics can muddle the situation even further. When extreme pressure was put on the Chesapeake Bay oyster resource during last century and this, an ample amount of scientists and individuals loudly warned about the probability of collapse. Still, without a definitive consensus about use, and an awareness about the need for conservation, the financial gain was too enticing, especially at the industry's peak in the late 19th century. Today, the oyster resource isn't even a shadow of its former self. Not only did a monetary resource disappear, but also an important facet of the ecosystem. Oysters are filter feeders, and an abundant amount of the bivalves can prove a factor in improving water quality in the Chesapeake Bay.

Scientific Uncertainty

In a *Science** editorial, Daniel Koshland, Jr. talks about the difficult interface between scientific inquiry and society. "...when science is asked to solve a problem, its instinct is to start from fundamentals and proceed on its slow but inexorable timetable. When society—through its agent government—says 'I need the answer now,' the two systems have serious misunderstandings. Science, trying to

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**Science*, Vol. 260, 9 April 1993, p. 143.

Blue Crab Fishery Terminology

Intermolt— Time or state of crab growth between molts.

Molting— Ecdysis, the process in which a blue crab sheds its shell. A crab's skeleton is external, so it must shed its shell to grow.

Shedder— A commercial operator who tends blue crabs when they molt, normally in an on-shore facility. The final product, soft-shell blue crabs, is considered a delicacy both here and abroad. If the crabs are not restaurant quality, they may be sold as fishing bait.

Peeler— Hard crab about to molt, ideal for shedding operations or fishing bait.

Buster— A crab in the process of molting, when the shell splits and the crab starts to back out of its old shell.

Soft-shell — Blue crabs that have shed their hard outer shells in preparation for growth. In this in-between stage, before the new shell hardens, these crabs are sought after as a delicacy.

be accommodating, frequently says, 'I'll give you a progress report, but understand that we need more data to get a definitive answer.' The 'but' clause soon gets forgotten, so science gives an educated guess as to whether saccharin is carcinogenic, or dioxin is deadly poisonous, or the climate is warming, and later revises the first estimate, bewildering the public and making it distrustful of science." And, as Koshland points out, "The great discoveries of science are the result of a range of discoveries in which an initial notion was suggested, but the final understanding required lots of work."

The difficult interface that Koshland describes is fundamental to management problems with the blue crab fishery. The solution? Overly conservative or liberal management approaches are not possible; both portend disaster. No action—for whatever reason—may be the same as advocating over-exploitation.

Understanding the complexity of resource issues, comprehending the nature of scientific inquiry, and displaying a willingness to forgo immediate gain may be difficult, but perhaps the only means for maintaining this Chesapeake Bay resource.

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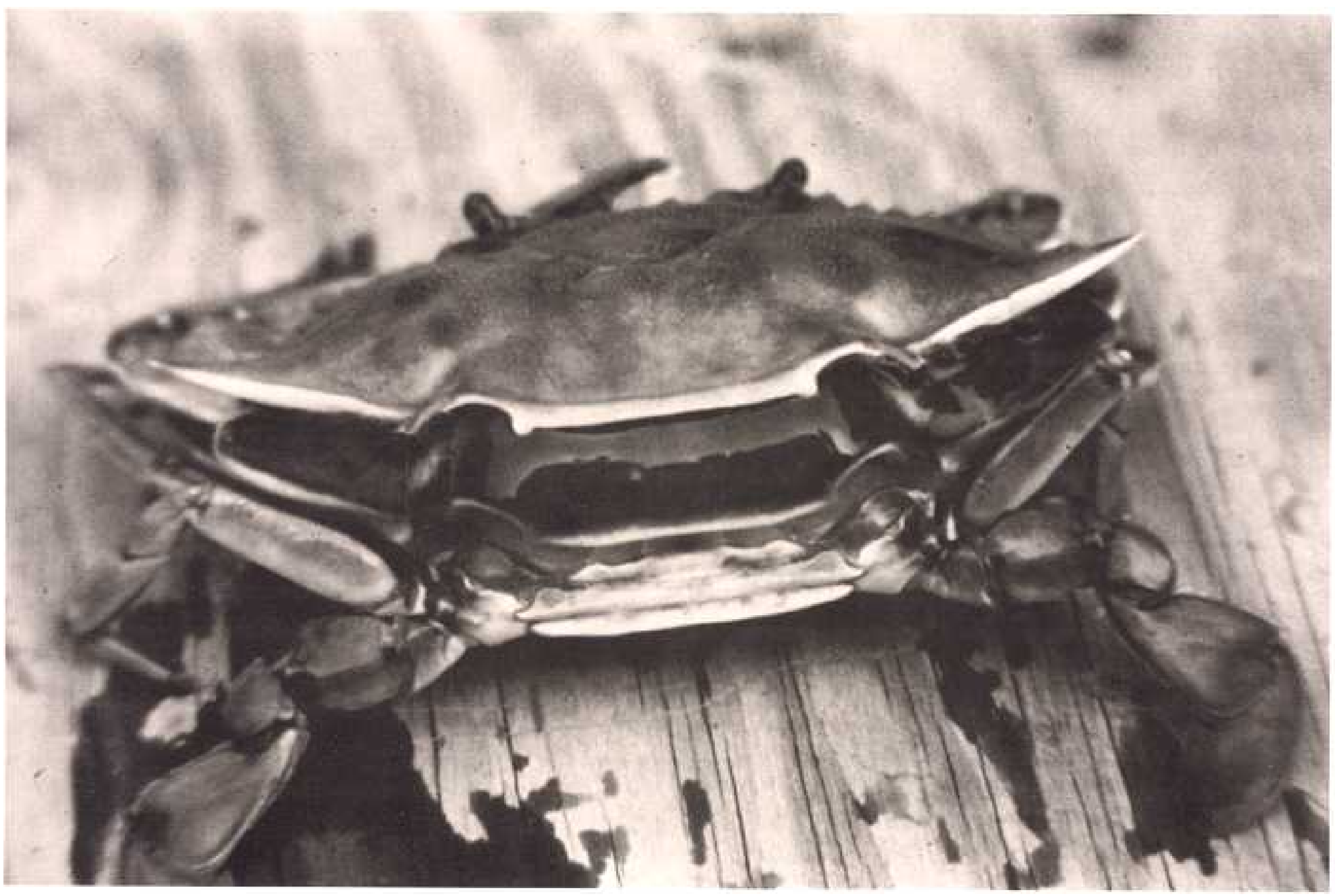
Buster crab starting to back out of its shell.



Blue Crab Natural History

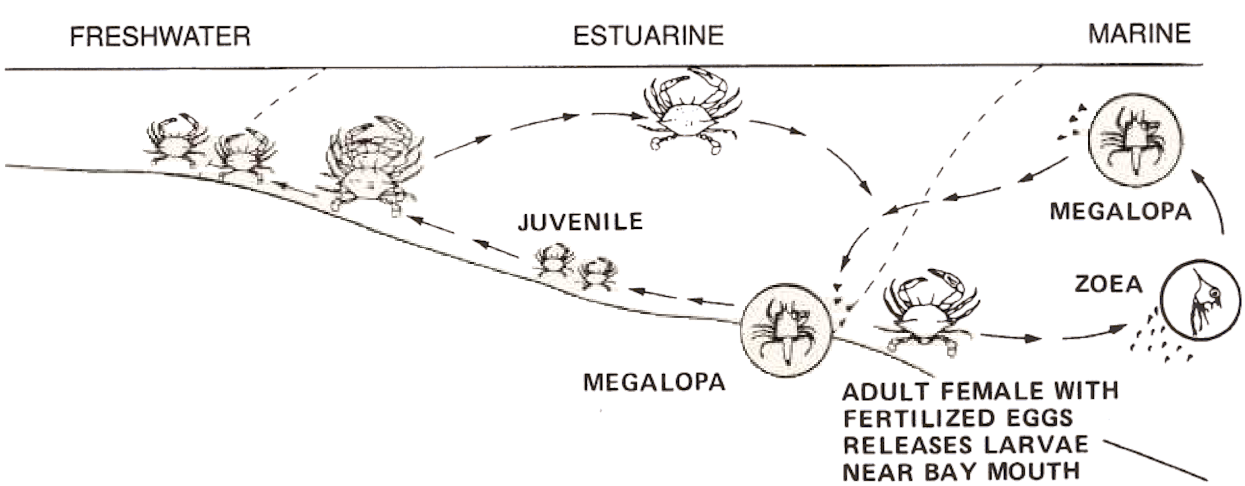
Even though a blue crab (*Callinectes sapidus*) may live only one and a half to two or three years, they are ones of change—in the form of 18-22 molts—and they are years in which sometimes enormous distances are traveled.

A crustacean's mode for growth is very different than a human's. A crustacean's skeleton is external, and is much like a close-fitting suit of armor. As opposed to a vertebrate, which adds length to the internal skeleton, a crab must shed its exoskeleton to grow. With a blue crab, the back of the shell splits and the "buster" crab backs out of its old shell. After the crab emerges, soft and wrinkled, it will absorb water, expanding its newly forming shell. It can take from several hours to several days for the new shell to harden completely. In its short life, a blue crab may molt 18-22 times from the first juvenile stage through adulthood.

The great distances traveled by the blue crab—in proportion to its body size—is obviously not unique to the blue crab. Both terrestrial and aquatic animals migrate sometimes spectacular distances. However, the distance traveled—actually the state boundaries crossed—is central to one of the debates about blue crabs in the Chesapeake Bay. Marylanders have long contended that the Virginia fishery harvests too many sexually mature female crabs ("sooks"), and, as a consequence, disrupts the Maryland fishery.

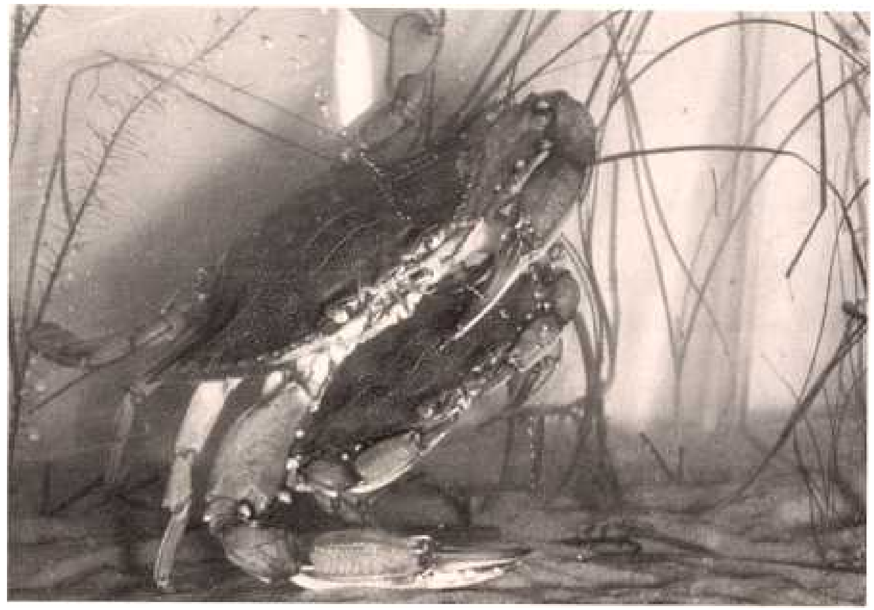
Female crabs from both "Maryland" and "Virginia" waters migrate down to the Bay mouth to release their eggs, which can number between 800,000 to 8,000,000, depending on the size of the female. The larvae drift in oceanic waters of the inner continental shelf nursery, kept in place by the long shore drift. The larval stages develop into the postlarval stage known as the megalopa. It is this stage which reinvades the estuary. How exactly the megalopae reinvade the Chesapeake Bay is still in question, but the entire process, from hatching to settlement of the postlarvae is thought to take at least 45 days. Via currents, tidal flow, wind-driven surface circulation and the blue crab's own movement, the

Blue Crab Life Cycle

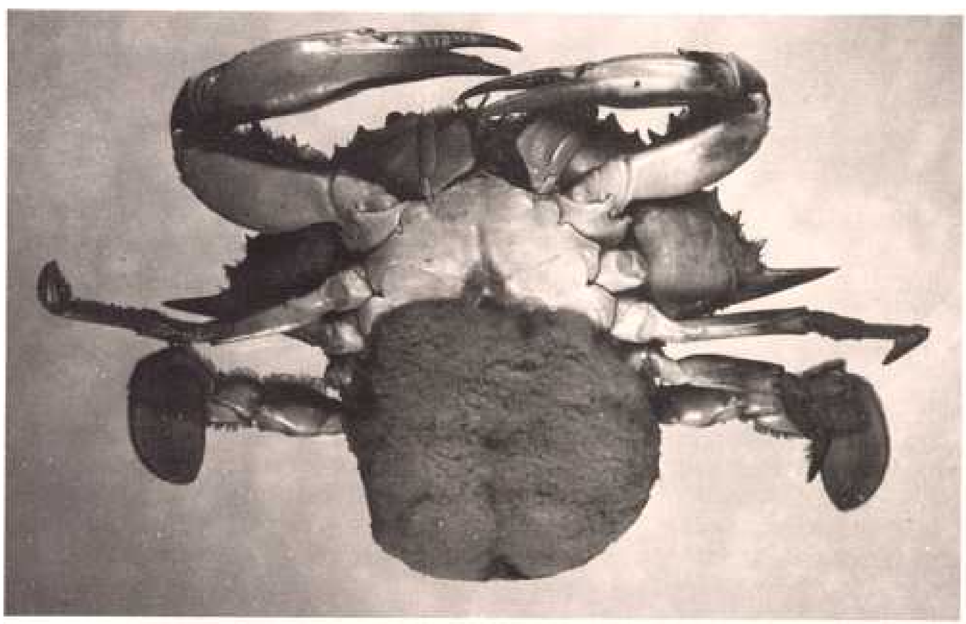


surviving megalopae eventually move into their adult habitat, the Bay, where they settle out of the water column to the bottom.* At this point they metamorphose into their crab-like form as a juvenile.

The reason behind the migration from the Bay, to the Bay mouth, and the retention of larvae on the inner shelf is like many theories of migration—up for debate. It could be a mechanism for gene flow between populations, hypothetically leading to the colonization of new habitats. It could hark back to the species' origins and the fact that the eggs or larvae survive better in marine waters. In the case of the blue crab, the larvae require high salinity for optimal development. Blue crabs are therefore not "completely" evolved to take on a totally estuarine existence. Also, it is thought that predation rates are generally lower in the coastal ocean than within the estuary.



"Doubler" crabs. Males "cradle" females in two situations: before and after the female's terminal molt—the time at which she becomes sexually mature. From an evolutionary perspective, these behaviors have to do with ensuring that a male's genes are passed on. The need to cradle a female before the terminal molt, guarantees that a male is present when the female is ready to reproduce. When the female molts, sheds her shell, mating takes place. Crabs are very vulnerable to predators during the molt and in the soft stage. The male will cradle the female until her shell hardens, again protecting the future progeny.



Female crab with sponge. At the Chesapeake Bay mouth, female crabs release eggs which can number between 800,000 and 8,000,000 per animal.

*Many aquatic life forms utilize different parts of the ecosystem before "settlement" into the adult habitat. Before settlement on the bottom of the Bay and its tributaries, blue crabs utilize various parts of the water column.

Down to a Fine Art

Years of observation by both watermen and scientists, and applied research have made shedding operations more predictable and less backbreaking.

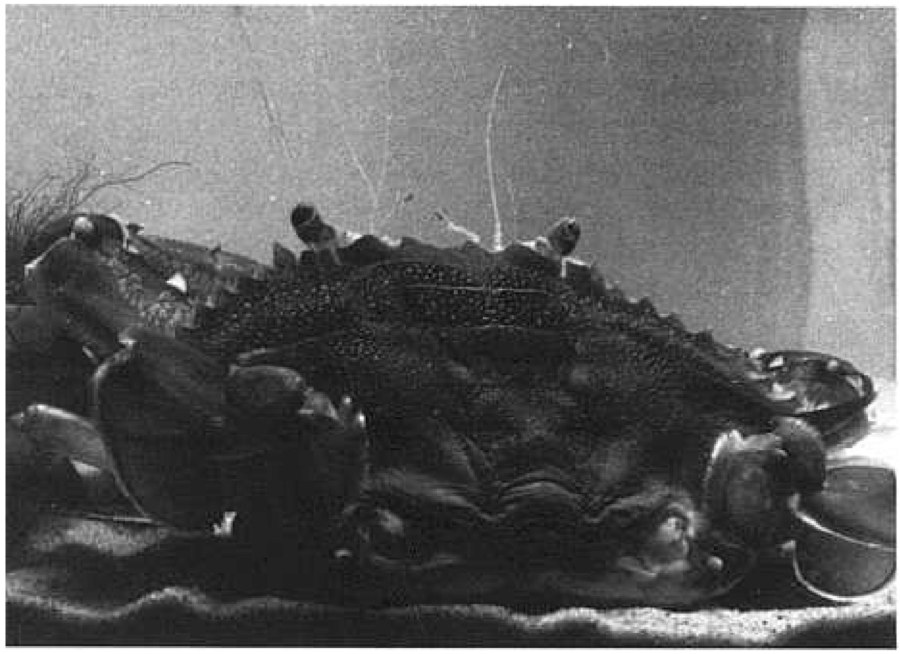
The crab itself provides the visual clues to when it will molt. A portion of the paddle fins will show color changes, from white (about three to ten days before molt); to pink (two to five days), to red (one to three days). Then the back of the shell splits and the crab backs out of its shell.

Advances in shedding systems, many of which were Sea Grant initiatives, have made crab shedding less physically taxing, and the operations more predictable. Formerly, watermen used floating boxes for shedding. Initially, floats were near shore, but by moving the floats to deeper water with tidal currents, watermen were able to take advantage of the better water conditions for the crabs. However favorable the results from better flow rates, the floats did not protect crabs from eels and other predators.

By moving operations to land and making them closed systems, watermen were able to provide protection from predators,

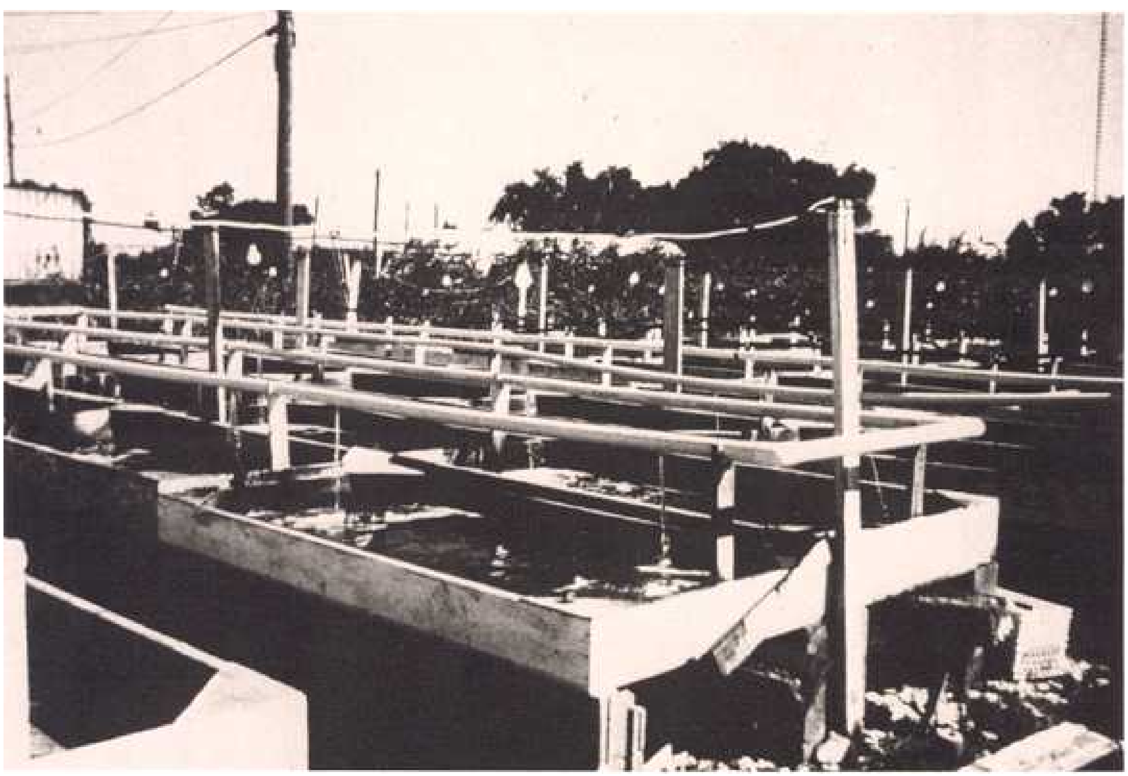
Historical photo showing floating boxes used to contain shedding crabs.

and to control environmental conditions, such as salinity and oxygen levels in the water. These technological advances resulted from a joint effort by the Sea Grant programs in a number of states. ✣ ✣



Soft crab.

A basic shedding facility. Some are more complicated and even enclosed.



The Soft Crab Fishery

The apparently diminishing number of blue crabs in the Bay caused different commercial fisheries to take a hard look at competitors to see if the resource was being drained especially by any one gear or fishery. The soft crab fishery came under fire because some suspected that the fishery's harvest of female crabs prior to mating was having a real impact on the overall future number of blue crabs.

In an effort to begin understanding the impact of the soft crab fishery on the entire blue crab fishery, and to present a characterization of the soft crab industry, Virginia Sea Grant supported the following research by Michael Oesterling, Commercial Fisheries Specialist with Marine Advisory Services, Virginia Institute of Marine Science. The information is now being analyzed and a report should be available during fall 1995.

In the following article, Oesterling gives an overview of the fishery, some of the perceived problems, and the approaches used for the study. —ed.

By Michael Oesterling

The blue crab industry is actually two different commercial fisheries, one directed towards the harvest of hard crabs and the other towards the harvest of peeler crabs for soft crab production or recreational fishing bait. The hard crab fishery harvests the largest portion of the total, but the soft crab fishery is more valuable on a per poundage basis (soft crabs, $2.69 per pound; hard crabs, $0.39 per pound). In addition to the commercial harvest of blue crabs, there is a sizable, but undocumented, recreational harvest.

As with any common property resource that is exploited by multiple user groups there are potentials for conflicts regarding resource allocations. When the blue crab is plentiful, these conflicts are minimal and do not cause questions to be posed concerning management issues. However, during times of reduced abundance, various management schemes are proposed by the differing factions to increase their own harvest of crabs. Many times these proposals are directed at limiting the competing use of the resource. Recently, participants in the hard crab fishery (both harvesters and processors) have implied that the soft crab/peeler fishery has been responsible for an apparent blue crab stock reduction. They claim that the practice of harvesting female crabs prior to mating by the use of "peeler pots" and the harvest of small peelers combine to reduce the subsequent availability of hard crabs. Essentially, the question that has been posed is—What, if any, impact has the soft crab/peeler fishery had upon the hard crab fishery?

An exceptionally poor hard crab harvest during 1992 (a 46% reduction in landings from the previous year), coupled with the expansion of the soft crab fishery over the past decade, prompted the Virginia Marine Resources Commission (VMRC) to actively consider regulatory restrictions on the soft crab/peeler fishery. Proposals were brought forward to limit the number of peeler pot harvesting gears, as well as other considerations. These proposals were subjected to a series of public hearings that culminated in the November 23, 1993 meeting of the VMRC. At that time the proposed soft crab/peeler regulations came under attack from industry participants. The universal argument from all opponents was that there was no data to support any regulations on the soft crab/peeler fishery. The members of the Commission agreed with this argument and rejected the proposed regulations on the soft crab/peeler fishery. However, in the discussions, it was made clear that the Commission would revisit these issues and that it was vitally important that accurate data be available on

Blue crab backing out of its shell.

the magnitude of the soft crab/peeler industry.

The initial stage of the Virginia Sea Grant study addressed the conflict between the soft crab/peeler fishery and the hard crab fishery by developing a profile of the soft crab/peeler industry. This will serve to document the role the soft/crab peeler fishery plays in the overall economic impact of the blue crab industry. Not only was it necessary to identify the current state of the soft crab/peeler industry, but also the changes that have occurred over the past 10 to 15 years. While some historical production data is available, there is no information on how effort patterns have changed over the years. This type of data was only available directly from those who participate in the fishery. Additional information needed was the waterman's involvement with both hard and soft crabs and how, if any, his or her participation in these sectors has changed. Once all this information was assembled, then the interactions of both the hard crab and soft crab/peeler fisheries could be evaluated.

Two approaches were used, direct mail surveys and personal interviews. The implementation of licensing for soft crab production by the VMRC provided the opportunity to identify and contact producers to assess their level of production, sources for peelers (i.e., harvesting methods), relative value of each harvesting method, timing of production, production history, and how their production practices have changed over the years (e.g., more production tanks, more peeler harvesting gear, purchase of peelers, etc.).

With the data and the information from the survey, better management decisions can be made. Additionally, the information obtained in this study could lead to a better understanding of the biological relationship between peeler crabs and subsequent hard crab harvests. It could also serve as the starting point for identifying and quantifying the recreational aspects (biological and economic implications) of the peeler crab fishery, a totally unknown portion of the entire blue crab fishery.

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The "Typical" Virginia Soft Crab Producer:

- Is 50 years old with 3 people in his family
- Has been shedding crabs for 16 years
- Uses a flow-through shedding system with 22 wooden tanks
- Has 1 or 2 family members that assist him and probably does not hire additional help
- Besides soft crabs, also harvests hard crabs, but has some non-fisheries income as well
- Makes less than 50% of his or her total income from soft crabs
- Harvests his or her own peeler crabs using less than 300 peeler pots and less than 200 hard crab pots
- Begins shedding crabs in May and stops by the end of September
- Produces about 2,500 dozen soft crabs which is sold fresh to a wholesaler

The Blue Crab Pot Fishery

By Poul Olson

To glean a comprehensive understanding of the commercial blue crab pot fishery, Virginia Sea Grant sponsored a study to ascertain the effects of fishery management strategies on the harvest and income levels of blue crab potters in Virginia. Graduate student Anne Rhodes and Professor of Agricultural and Applied Economics Leonard Shabman, both of Virginia Polytechnic Institute, undertook this two year investigation which focused specifically on the blue crab pot fishery in Virginia. Results of this study, conducted in 1992 and 1993, were reported in *Virginia's Blue Crab Pot Fishery: The Issues and the Concerns,* an advisory published in 1994.*

The blue crab fishery employs different types of gear, including scrapes, pound nets, dredges, and the most common method, pots. Pots are designed primarily for harvesting hard crabs, but are also employed for catching peeler crabs.

For making an accurate assessment of the commercial blue crab pot fishery, the researchers conducted a comprehensive monthly survey of individual license holders from March through November 1992. Sixty-two percent of those questioned responded to the survey. Based on the information provided, Rhodes and Shabman found wide demographic variation in the blue crab pot fishery.

Crabbers reported using anywhere from one to 600 pots; their vessels ranged in age from new to 60 years old. Crabbers earned from none to 100 percent of their incomes from the fishery.

Overall, Rhodes and Shabman determined that small potting operations constituted the majority of licenses. Large scale operators who fished more than 300 pots per day comprised only about 16 percent of the license holders.

The researchers divided crab pot license-holders into three general categories. Defined as those who live in Maryland but hold a Virginia crab pot license, Maryland commercial crabbers made up 3.4 percent of the population; Virginia commercial crabbers comprised 64 percent of those watermen engaged in the fishery; and Virginia non-commercial crabbers included 32.6 percent of all crab potters.

For the fishery as a whole, Rhodes and Shabman found that traditional methods of calculating harvest result in under-reporting of the catch. Compared to what was reported by the Virginia Marine Resources Commission (VMRC) in 1992 from picking house reports, the survey results showed that the hard crab pot harvest was 60 percent greater and the peeler crab harvest more than 70 percent greater. As for price levels, the primary problem was that watermen sold their harvest in places other than picking houses where they typically received more for their catch. These alternative market channels were not used by the VMRC.

A breakdown of the Virginia commercial sector showed that 54 percent of crabbers were medium-size operators who fished between 100 and 300 pots per day. Of the remaining 46 percent, roughly 25 percent fished more pots and 21 percent fished fewer. Most large-scale commercial operators reportedly worked on the Eastern Shore and mainly fished for hard crabs.

Rhodes and Shabman's study determined that license holders kept about eight percent of their catch for personal use. About 60 percent of harvested hard crabs were sold to picking

*For a copy of the report, write Virginia Sea Grant College Program, University of Virginia, Madison House, 170 Rugby Road, Charlottesville, VA 22903.

houses, while retail or wholesale buyers purchased the remainder of the catch. Of the peeler crabs harvested, about half went to shedders. Harvesters shed about another third of their catch and sold the soft crabs to retailers or wholesalers. The remainder of the catch was retained for personal use or sold as bait.

Excluding maintenance, vessel depreciation and travel costs, average net income levels for a small-sized crab potter in 1992 was $4,199, $12,823 for a medium-size operator, and $22,951 for a large-size operator.

After modeling the hard crab fishery, Rhodes and Shabman examined how various resource management strategies, if these were instituted during 1992, might have affected levels of harvest and income for crabbers. In general, the researchers detected little likely consequence on harvest and income for the overall fishery from most management policies. Some policies, however, produced effects on specific segments of the fishery.

Quotas, for instance, only reduced income levels of hard crab potters. Rhodes and Shabman said this result owes to the fact that peeler crab harvest levels are less than one-fiftieth of total blue crab harvest levels.

Some management policies reduce either blue crab harvest or crabbers' incomes. Limited entry, however, seems effective in both reducing harvest and in raising incomes, though such a regulatory approach also limits the number of potters who can work the fishery.

Rhodes and Shabman note that their models of the effect of regulatory policies on blue crab harvest and watermen's income are "too simplistic for the real world." They attribute this to the difficulty for management officials in enforcing crab harvest regulations. In their survey, more than 80 percent of the respondents believed better enforcement of size and catch limits was needed in the crab fishery.

Despite an attitude generally supportive of greater regulation, developing regulatory policies consistent for and acceptable to the entire fishery is problematic. According to Rhodes and Shabman, different size crab operators tend to support policies which either benefit them or limit the activity of other operators. For example, large operators generally favor policies such as limited entry and the removal of part-time crabbers. Small pot operators, on the other hand, support policies that limit the activity of larger operations, such as pot limits and quotas.

From their analysis of the data provided by the survey, Rhodes and Shabman believe limited entry and a limited potting season are the most easily enforceable policies, but watermen may not favor them. In addition, the enforceability of policies such as pot limits and quotas proves precarious if crabbers do not favor them.

Rhodes and Shabman conclude their report with the observation that the currently strained relationship between watermen and regulators makes development of more effective conservation policies for the blue crab fishery difficult. Many crabbers, according to the researchers' survey results, distrust the VMRC because they feel that policy decisions in the past have often been made without regard to their effects on the watermen.

For this reason, the researchers suggest that the success of regulatory policies hinge on attracting the support of crabbers. According to Rhodes and Shabman, who have submitted the results of their survey to the VMRC and other regulatory bodies, comprehensive and accurate data on the blue crab fishery in Virginia is ultimately required for the formulation of more effective resource management strategies. At present, the researchers have secured additional support to study enforcement challenges in the fishery. A report will be available in fall of 1995.

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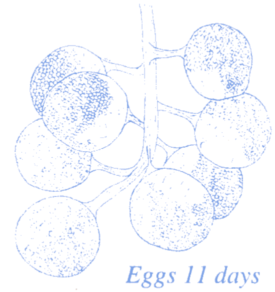
Status of the Fishery And Management Strategies



Eggs 11 days before hatching.

Blue crab studies have been a major initiative at the Virginia Institute of Marine Science, with support and funding from a number of agencies, including a significant amount from Virginia Sea Grant. —ed.

By Romuald N. Lipcius, Jacques van Montfrans, Karen Metcalf, and Marcel Montane

Status of the Blue Crab Stock in Chesapeake Bay

The blue crab represents the largest single-species crab fishery worldwide and within the continental United States, the Chesapeake Bay has historically accounted for more than half the national harvest of blue crabs. Various indices based on Virginia Institute of Marine Science (VIMS) long-term data sets and a more recent bay-wide index spanning 6 years indicate a significant decrease in Catch-Per-Unit-of-Effort (CPUE*) for the fishable segment of the stock in Chesapeake Bay, though juvenile blue crab indices are simply fluctuating in abundance. The blue crab population in Chesapeake Bay appears to have been and continues to be in a low phase of population abundance (Fig. 1). The decline in CPUE is also reflected in dredge fishery landings (Fig. 2; Virginia Marine Resources Commission data), in comparable measures of adult female abundance from the VIMS/William and Mary (W&M) Trawl Survey (Fig. 3) and in a recent bay-wide index of population abundance. Concurrently, as monitored by the Virginia Marine Resources Commission (VMRC), fishing effort has increased substantially in the blue crab fisheries with major declines in abundance of other fishery stocks (e.g., oysters). Finally, our most recent indices for juveniles and the fishable stock indicate that the blue crab population, though not near collapse (Fig. 4), is likely to remain in a low phase over the next 6-12 months (Fig. 5). These collective patterns are symptomatic of a fishery in the process of being overharvested. Prudent management practice argues strongly for controls on fishing effort to prevent a major decline in the fishery, or worse yet, a collapse if environmental conditions coincidentally deteriorate.

*Catch-Per-Unit-of-Effort is fisheries science terminology. The results of CPUE indicate the density of the resource.

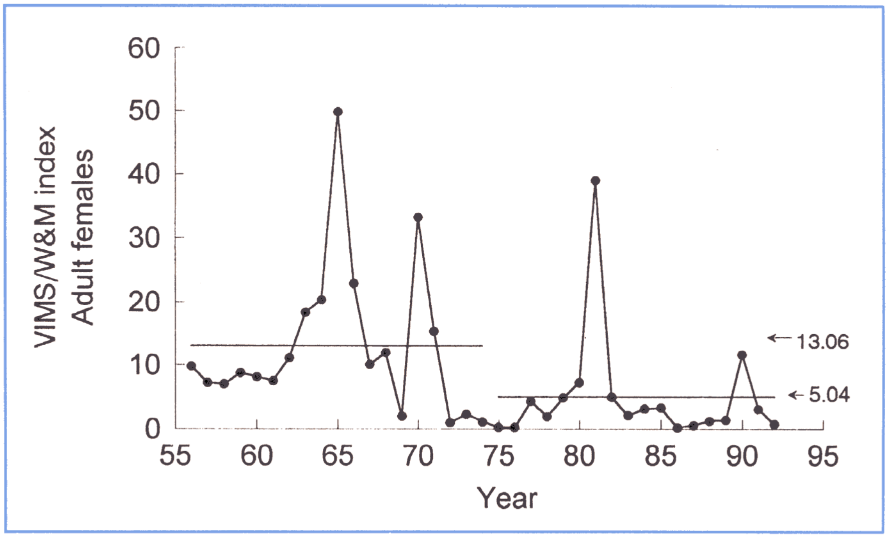
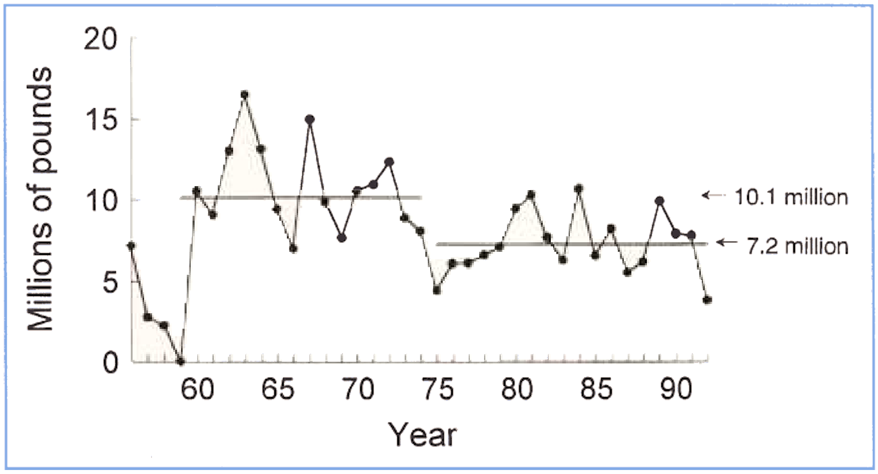


FIGURE 1: The index of adult female crab abundance (Catch-Per-Unit-of-Effort; CPUE) from the VIMS/W&M Trawl Survey by year from 1956-1992. The survey was conducted throughout the three major tributaries (James, York and Rappahannock rivers) of the western shore of Chesapeake Bay. Solid horizontal lines represent means (averages) for the periods indicated. Note the relatively low level of abundance during the past two decades (5.04; 1976-present) relative to the previous two decades (13.06; 1955-1975) representing approximately a 2½ fold decrease in abundance.

FIGURE 2: Landings in the Virginia commercial dredge fishery from 1956-1992 based on data from the VMRC. Solid horizontal lines represent means (averages) for the periods indicated (10.1 million pounds from 1956 - 1975 vs 7.2 million pounds from 1976 -1992). These data demonstrate a similar, though not as dramatic, decline in population abundance due to the compensating effect of increasing fishing pressure over the period.

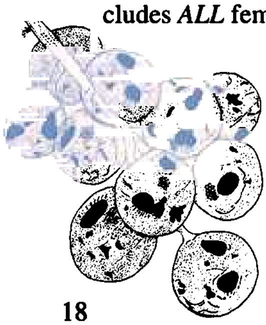


Components of the Fishery Requiring Regulation and Management Strategies

The demonstrated relationship between spawning stock and recruitment** of the blue crab in Chesapeake Bay dictates that the number of crabs recruiting to Chesapeake Bay in any given year relies, in part, on the size of the spawning stock (adult females) from which the recruits originated. Thus, the most serious concern for viability of the blue crab resource is the protection of the *POTENTIAL* spawning stock given this relationship. The potential spawning stock includes *ALL* females larger than about 3.5 inches, and is not merely limited to those crabs possessing a sponge (egg mass), nor to those mated adult females with well developed internal ovaries and about to produce an egg mass. Of particular importance are those juvenile and prepubertal females larger than 80-100 mm in carapace width (approximately 3.2-3.9 inches), since those females suffer relatively low natural mortality (except during molting), and therefore, would likely reproduce were they not fished.

Those females composing the potential spawning stock are susceptible to various fisheries in Chesapeake Bay, including the hard crab pot fishery, dredge fishery, and soft crab fishery . Hence, *ALL* fisheries require *equitable* and *effective* regulation, without undue restriction of any single fishery. Inappropriate emphasis on one fishery of the spawning stock, irrespective of the stage of maturity of the crabs caught in that fishery, might hinder effective regulation of other fisheries having a greater impact on the spawning stock. Further-

**Entry into the adult population.



Eggs five hours before hatching.

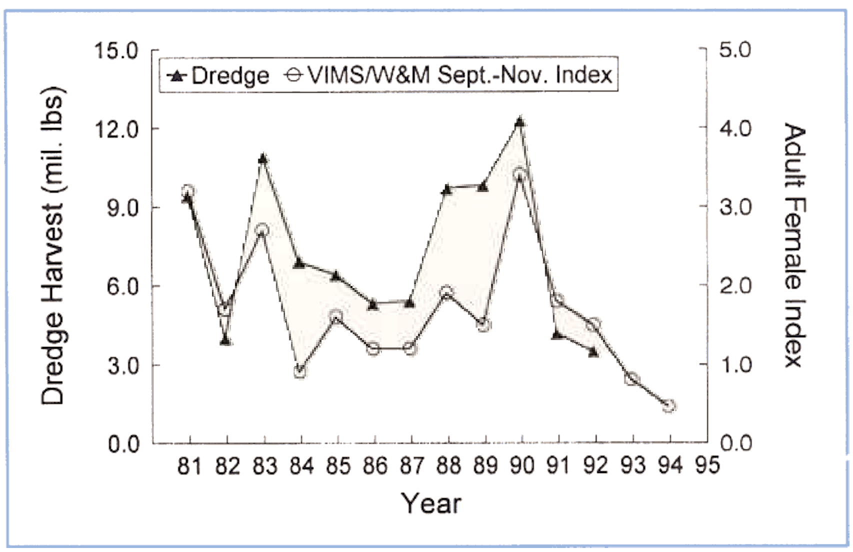
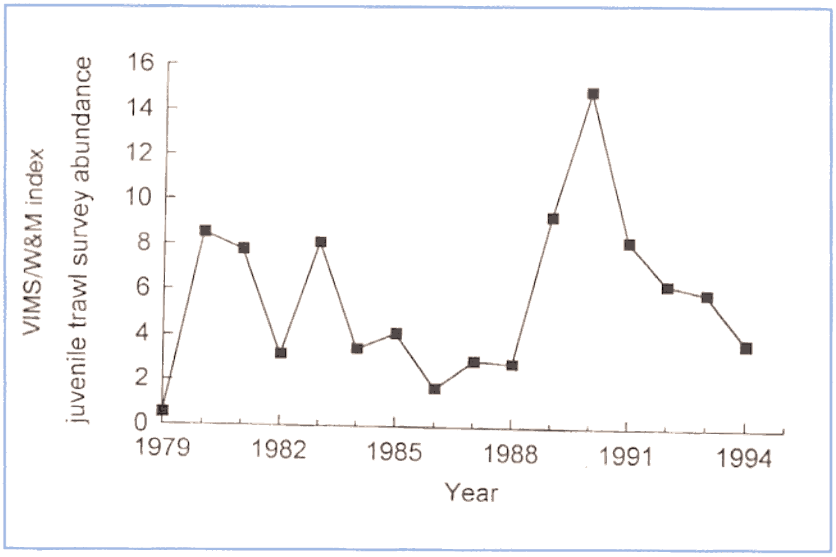


FIGURE 3: Indices of stock abundance for 1981-1994. Commercial dredge harvest (triangles) and the adult female index from the VIMS/W&M Trawl Survey (circles) are indicated. This figure illustrates that both the VIMS/W&M Trawl Survey and commercial dredge harvest exhibit similar trends and thus, that the Trawl Survey Index is a valid indicator of dredge fishery harvest.

Prezoea emerged from the egg capsule.

more, due consideration should be given to the fisheries depending on their *proportional harvest of those females comprising the potential spawning stock*. Our preliminary calculations based on VMRC landings data suggest that the hard crab pot fishery in Virginia captures well *over half* of the potential spawning stock; that the dredge fishery accounts for approximately *15%* of the spawning stock; and, that the soft crab fishery likely harvests *less than 10%* of the potential spawning stock, though various sources of error could alter these estimates. Of these estimates, the impact of the soft crab fishery on the potential spawning stock is least well known. Overall estimates await further refinement based on data derived from VMRC's mandatory reporting

FIGURE 4: Variation in abundance (CPUE) for 1979-1994 for the 0+ yearclass of small juvenile crabs (Trawl juveniles) captured during September in the VIMS/W&M Trawl Survey. Note the low index for 1994. These data support the concept that the population will continue in a low phase for at least the next 6 months and, furthermore, that although the population is in a low phase, it is not necessarily in a state of collapse. None-the-less, prudent management is necessary to prevent a potential collapse of the fishery.



system. Regardless, the hard crab pot fishery harvests the largest proportion of the potential spawning stock and initial attempts at management should be allocated proportional to available estimates of spawning stock harvest until more comprehensive estimates of fishery impact are available.

We recommend reducing effort in all segments of the fishery through limited entry in combination with gear restrictions. This would most likely lead to stability in the blue crab fishery and provide a stable economic base for the industry.

Other measures could also effect conservation of the blue crab resource. The sanctuary concept is often a productive and manageable way to protect and conserve an exploited resource. For the blue crab population, this

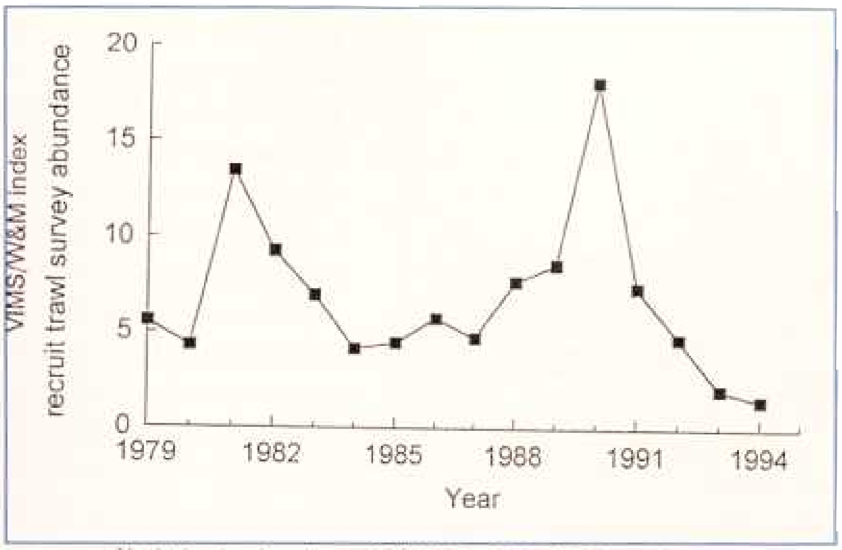


FIGURE 5: Variation in abundance (CPUE) for 1979-1994 based on the 1+ yearclass of larger juvenile and sub-adult crabs (Trawl recruits) captured during June-August in the VIMS/W&M Trawl Survey. Note the low index value for 1994 relative to all previous years. This data also corroborates indications in other indices of abundance and further supports the concept of prudent management.

Zoea three days after hatching.

issue comprises two important approaches to resource conservation. First is the concept of expanding the current breeding sanctuary for spawning female crabs in Virginia (Fig. 6). Second is the concept of a nursery sanctuary (currently not established) where postlarval blue crabs settle and grow during their early juvenile instar*** phases. Both can have beneficial effects on conserving the blue crab resource. Expansion of the existing sanctuary should include restrictions to *ALL* forms of fishing and will allow more egg-bearing females to gain refuge from fishing pressure. A new concept not yet considered in Virginia is the establishment of nursery sanctuaries of sufficient size to protect settling and growing juvenile crabs. Data collected over numerous years indicates that seagrass beds are of *vital importance as settlement and nursery habitat* during early growth stages for blue crabs in Chesapeake Bay. We estimate that over half of the blue crab population finds nursery habitat in submerged grassbeds despite their limited distribution throughout the bay (Fig. 7). These vegetated habitats, in large measure, likely account for the high population abundance of blue crabs in Chesapeake Bay, with annual harvests typically exceeding 100 million pounds, relative to Delaware Bay which lacks seagrasses and from which harvests rarely exceed 10 million pounds. Thus, protection of these habitats in concert with expanding the existing spawning sanctuary and the elimination of *all* fishing pressure in such areas will enhance

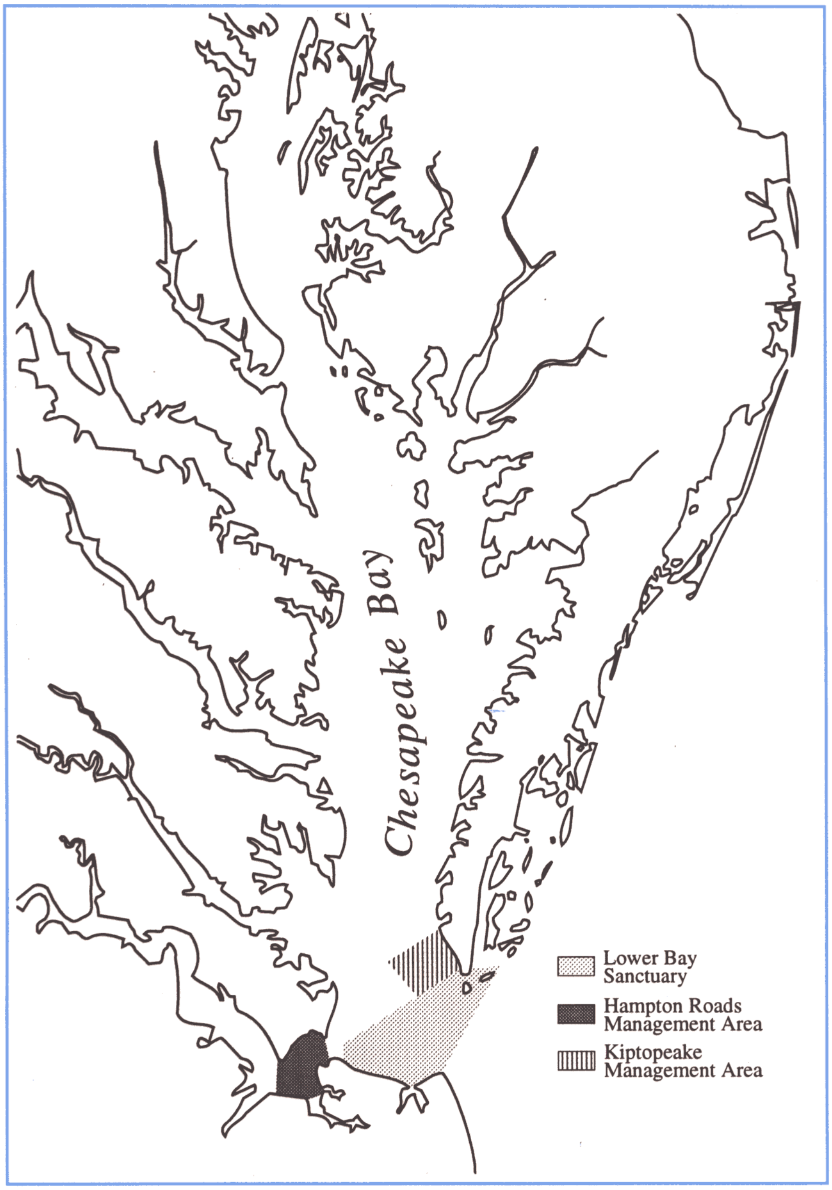


FIGURE 6: The current spawning sanctuary showing approximate locations of the Historical Spawning Sanctuary and expanded (1995) Kiptopeake Blue Crab Management Area in lower Chesapeake Bay. Both areas are closed to commercial fishing from 1 June to 15 September (i.e., targeting primarily the pot fishery) and recreational fishing is also restricted in the Kiptopeake Management Area. The new (1995) dredge sanctuary in Hampton Roads is also indicated where dredging (but not crab potting) is restricted.

***A stage between molts in the life of an arthropod.

Prezoea emerged from the egg capsule.

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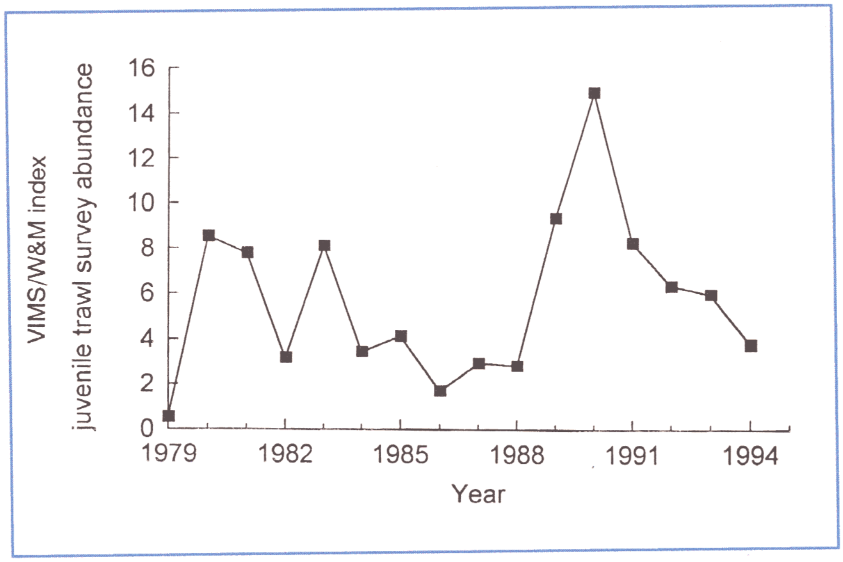

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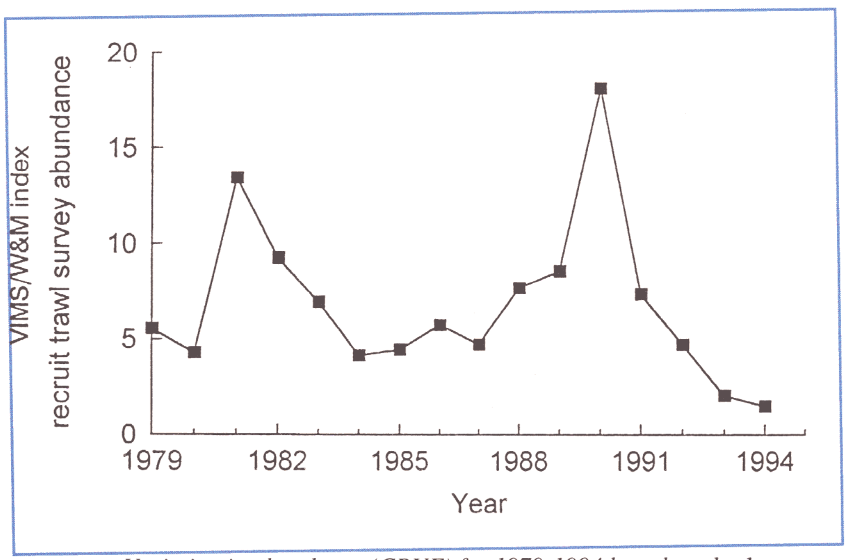

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Habitat's Role

This issue of the

In terms of habitats, not all are equal; how different habitats may impact population variation has not really been explored in terms of the Chesapeake Bay blue crab. Researchers are focusing now on habitats in a different light, as "sources," "sinks," or "intermediary" areas. A "source" would be one in which recruitment is sufficient, mortality is low, and output to the spawning stock is high, making it a critical habitat. A "sink" would be the opposite, providing no output of crabs to the spawning stock. Intermediary areas may be neither sources nor sinks, residing somewhere between the two poles. Within these areas, specific factors being investigated include causes of mortality, recruitment relationships and the importance of vegetated and unvegetated habitat.

Researchers are interested in delineating the importance of various habitats because without that information, proper emphasis may not be given to the conservation or enhancement of these areas. Also, researchers believe that insufficient attention to the basic concepts of sources and sinks may result in undue importance given to other factors. If critical habitats for a population were identified, funding and effort could be concentrated on those habitats deemed most important. ✣

*Basically, a spawning stock-recruitment model developed from a 20-year data base. This model basically calculates the recruitment (entry into the adult population) based upon the available spawning stock, with factors like expected mortality (particularly cannibalism) figured into the model.

Causes of blue crab population fluctuations are poorly understood and may be related to many factors, including the availability and type of habitat, the size of the spawning stock, the supply of larvae or postlarvae, settlement behavior, or post-settlement processes influencing juvenile survival.

Submerged Aquatic Vegetation

One of the ongoing, long-term research projects at the Virginia Institute of Marine Science entails the mapping of submerged aquatic vegetation (SAV) in the Chesapeake Bay. SAV is important to the life cycle of blue crabs, and beyond that, the survival and growth of seagrasses appears to be a good indicator of water quality.*

SAV research by a number of scientists—including Robert Orth, Kenneth Moore and Richard Wetzel—was used as a scientific basis for amendments to the Chesapeake Bay Agreement, amendments which called for a 40% reduction in nutrient enrichment of the Bay.

For the non-marine science minded, mapping underwater vegetation may pose a logistical puzzle. How could one possibly map and yearly evaluate the amount of grassbeds in every part of the Bay, especially when these beds are submerged? Science has a way. Vertical aerial photographs are taken at an altitude of 12,000 feet under optimal atmospheric, water, and biological conditions (low sun angle, little or no wind, minimal cloud or haze cover, low tide, lack of turbidity, and maximum standing biomass—when the most vegetation is evident). In short, the aerial photos are interpreted (SAV beds appear as a dark band situated between the shoreline and a lighter shaded, offshore, unvegetated area), and the beds are plotted hectare by hectare. Various state, federal, and public organization corroborate the photographic data base with ground- truthing data, in-the-field observations of the actual beds. The result? A massive amount of work for the mappers at the Virginia Institute of Marine Science, and a yearly report which documents the distribution of this important aquatic habitat.

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*SAV can serve many functions: a habitat for vertebrates and invertebrates, and a nursery area for commercially important species. Seagrass beds can baffle currents and stabilize sediments, serving as a means to reduce shoreline erosion. Seagrass meadows can also be important in nutrient cycling between sediments and the overlying water. Approximately ten SAV species are commonly found in the Bay and its tributaries, and 11 other species can occasionally be present in the Bay. Salinity levels limit a species' distribution.

Submerged aquatic vegetation is an important habitat for the blue crab.

Biological Profile for Chesapeake Bay Blue Crabs*

Fecundity:	750,000 to 8,000,000 eggs per spawn, may spawn 2 to 3 times.
Longevity:	2 to 3 years, possibly longer if not harvested.
Spawning and Larval Development:	
Spawning Season	May to September.
Spawning Area	Concentrated in high salinity regions between Cape Henry and Cape Charles and also outside the Bay.
Development Location	Lower Bay (early larval stages) and coastal (later larval stage of megalopa postlarvae) out to 40 miles (25 Km).
Salinity	23 to 33+ ppt.
Temperature	66° to 84° F (19° to 29° C).
Young-of-Year:	
Location	Lower and central Chesapeake Bay, primarily shallow water in beds of submerged aquatic vegetation. Migration to the upper Bay and tributaries may begin as early as September through November.
Subadults and Adults:	
Location	Chesapeake Bay from Virginia Capes to tidal fresh water.
Salinity	0 to 33 ppt. Males most abundant in 3 to 15 ppt salinity, females most frequently found in >10 ppt. Most mating occurs where salinity preferences overlap.
Temperature	Upper limit approximately 90° F (32° C).
Dissolved Oxygen	Recommended Bay goal for blue crabs is 6.0 mg/L monthly average. Exposure to 0.5 mg/L at 77° F (25° C) is lethal within 4.3 hours; tolerance decreases with increased temperature.

* Sources of this biological profile: the Chesapeake Bay Blue Crab Management Plan and researchers at the Virginia Institute of Marine Science.

Bycatch in the Virginia Menhaden Fishery:

A Reexamination of the Data

By James Kirkley

Bycatch or the unintentional harvesting of species other than those directly being sought by a fishing operation is becoming a problem of increasing concern throughout the world. In April 1995, a conference on bycatch attended by worldwide scholars was held in Rhode Island. Another conference on bycatch is scheduled to be held in Washington state in September of this year. The bycatch problems most familiar to the public are the incidental harvesting of porpoises in the tuna fisheries and the inadvertent capturing of sea turtles in the Gulf shrimp fishery. The incidental taking of porpoises in the tuna fishery caused such an outrage that the public refused to purchase certain brands of tuna until the tuna companies adopted procedures to eliminate the bycatch of porpoises. The National Oceanic and Atmospheric Administration has a high priority for research that attempts to mitigate bycatch in our nation's fisheries.

Why the big concern about bycatch? For porpoises, other marine mammals, and sea turtles, there are laws prohibiting the incidental harvesting of marine mammals and sea turtles. Society perceives few, if any, benefits from exploiting marine mammals. In some fisheries, the bycatch may consist of economically important species that will simply be discarded and wasted. A major concern, which has not been fully explored by researchers, is the role of bycatch species in the ecosystem. That is, what happens to the ecosystem and abundance of other species when there is bycatch?

Here in our own backyard, the Chesapeake Bay and coastal waters, recreational anglers have expressed concern about bycatch in the menhaden fishery. The menhaden fishery, one of the most economically important commercial fisheries of Virginia, occasionally harvests in varying quantities gamefish and prey species for commercial and recreational fish. For example, bluefish, spot, and croaker are inadvertently harvested along with menhaden in the Chesapeake Bay. All three species are recreational species. Alternatively, spot, croaker, and other species are also prey for larger gamefish such as bluefish and striped bass.

Article 2, §28.2-408 of the Laws of Virginia Relating to The Marine Resources of The Commonwealth, 1992 Edition states "It is unlawful to take, catch or round up with purse net, for any purpose, food fish in an amount greater than one percent of the whole catch. If food fish represent more than one percent of the whole catch, the net shall be opened immediately and the food fish released while alive." The Article also states "It is unlawful for any vessel licensed for the purpose of menhaden fishing to catch any food fish for the purpose of marketing; for any person to have in his possession food fish in an amount greater than one percent of the bulk for the purpose of manufacturing them into fertilizer, fish meal, or oil; or for any person to use in any manner any food fish, in an amount greater than one percent of the bulk for the purpose of fertilizing or improving the soil."

The Virginia laws that regulate bycatch are primarily concerned with possession. That is, the laws focus on the vessel having possession of bycatch. The laws do state, however, that it is unlawful to take, catch, or round up with purse net, for any purpose food fish in an amount greater than one percent of the entire catch. This particular law is difficult to enforce. Enforcement personnel must be on the master vessel or purse boats to determine the bycatch in any given set. Moreover, it is often difficult to determine if there is significant bycatch in the purse net until onboard pumping of the menhaden begins. Bycatch species that could be harvested in large quantities (e.g., bluefish and Spanish mackerel) typically are below the menhaden and only after pumping begins can the captain or onboard enforcement personnel determine the potential magnitude of the bycatch. More important, captains typically release or discard bycatch when the number of fish and marine invertebrates appear to be high relative to the catch of menhaden.

In general, the state laws that control bycatch in the menhaden fishery are difficult to enforce. First, the Laws of Virginia Relating to the Marine Resources of the Commonwealth do not define "bulk." That is, what is one percent of the bulk? Is bulk a volume or weight measure? Webster defines bulk as a spatial dimension, magnitude, mass, or volume. Second, the laws do not provide a formal listing of species that constitute food fish. That is, which species are food fish? This is very important because large fish such as cownose rays and sandbar sharks are occasionally harvested as bycatch but are not generally considered to be food fish. Because the laws do not adequately define bulk and food fish, the Chief of Enforcement for the Virginia Marine Resources Commission (VMRC) believes that the bycatch law is difficult to enforce except when a menhaden vessel has possession of a prohibited species (e.g., striped bass).

The VMRC does, however, enforce the bycatch law. They have adopted a "common sense" approach. They stop a vessel and inspect the hold contents, observe a set, or inspect the offloading of menhaden at the dock. If they observe any species of fish other than menhaden, they further examine the catch to determine the extent of bycatch. It then becomes a "judgement call" by the enforcement agent as to whether or not there is an excessive bycatch. There have been no citations issued to a menhaden vessel for having an excessive bycatch over the past several years.

In a previous study by the Virginia Institute of Marine Science (VIMS),* it was reported that the bycatch in the menhaden fishery constituted less than .02 percent of the total catch. This determination was based on number of fish and invertebrates with respect to samples pooled over dockside and at-sea observations. Some members of the recreational community expressed extreme concern about the use of number of fish and pooling of data over dockside and at-sea observations. Their reasons were that number of fish was not consistent with the concept of "bulk" and the study by VIMS stated that dockside sampling was inappropriate for assessing bycatch. A major objective of the VIMS study, in fact, was to determine procedures for assessing bycatch in the menhaden fishery.

Members of the Atlantic Coast Conservation Association, and the Virginia Anglers Association requested additional analysis of bycatch using weight of fish and restricting the analysis to at-sea observations. This is a reasonable request given the importance of the commercial and recreational fishing industries to Virginia. As concluded in the VIMS study, however, we claim that it is the number of fish and invertebrates harvested

*Austin, H., J. Kirkley, J. Lucy. 1994. Bycatch and the Fishery for Atlantic Menhaden, *Brevoortia tyrannus*, in the Mid-Atlantic Bight. Virginia Sea Grant Marine Resource Advisory No. 53, VSG 94-06.

rather than the weight or biomass that is critical for future populations of any given resource. That is, which is more important to future resource conditions, the loss of 5 one pound striped bass or the loss of one 5 pound striped bass? It must be recognized, though, that the number of fish by age or size is critical for defining future populations of any given species; juveniles do not spawn and larger animals are more fecund (i.e., have more eggs) or contribute more to the future population. It was because of this concern that the VIMS study assessed length and size of bycatch species.

In this issue of the *Bulletin*, we reexamine bycatch in terms of weight rather than number of fish and marine invertebrates relative to Virginia's menhaden fishery. We limit our reexamination to data obtained only from the at-sea samples. Data obtained from offloadings or dockside are not included in the present analysis. In our original study, we did not examine bycatch in terms of weight. We did, however, obtain information on size frequency for the purpose of estimating weight. Using scientifically available mathematical/statistical relationships that relate animal weight to size, we estimate the weight of most bycatch species. When more than one weight-length relationship is available, we utilize the relationship that estimates the highest weight for a given species. Weight-length relationships, however, are not available for all bycatch species. For species with no available relationship between weight and length, we assume strict proportionality between weight and length and consequently overestimate the weight of the species being considered. For species with no available information about weight and length, we assign an arbitrarily inflated weight given the size of the bycatch species (e.g., we assign one pound to a five inch harvestfish or John Dory and a 0.50 pound weight to a two inch spider crab).

Assessment of Weight

Relative to assessing the impact of bycatch on the population of a species, the more important concerns are numbers of fish caught by age or size. It also is quite difficult to obtain accurate weights of fish and shellfish while at sea. Lengths of fish, however, were recorded to obtain a size frequency distribution by species. Using appropriate measures on the size of fish and marine invertebrates, we estimate weights by using available weight-length relationships for most bycatch species.

A total of 21 species other than menhaden were harvested as bycatch (Table 1, see page 28). Spotted and gray trout were grouped together. The weight of each unit of bycatch was assessed according to the equations or relationships available in the scientific literature. We further assumed that the sample frequency or size distribution applied to the entire catch observed during sampling.

Based on the equations and other information contained in Table 1, weights were estimated for all bycatch species. The mathematical values of the coefficients have been rounded off to nearest values to reduce the complexity of the equations. References for the weight-length equations as well as other methods used to estimate weight are also listed in Table 1.

Analysis and Results

A total of 43 sets were sampled in August, October, and November 1992. Each set was sampled to determine the number of menhaden and bycatch species and the size frequency or number of fish by size of fish harvested. A total of 2,513,000 standard menhaden were harvested in the 43 sets; menhaden are reported in terms of standard menhaden and 1,000 standard menhaden weigh 670 pounds. Total bycatch from the 43 sets was 5,338 fish and marine invertebrates. Relative to the number of menhaden harvested in the 43 sets, bycatch equalled 0.21%. On a monthly basis, the ratio of the number of species caught other than menhaden to the number of menhaden was 0.287%, 0.145%, and 0.075% for August, October, and

Table 1. Weight-length relationships used to estimate weight of bycatch species

Species	Weight-length relationship[a]	Source of weight/length relationship
Blue crabs	$W = .00062420\ L^{2.55}$	Olmi, E.J. and J.M. Bishop. (1983). Variations in total width-weight relationships of blue crabs, *Callinestes sapidus,* in relation to sex, maturity, molt stage, and carapace form. J. Crust. Biol. 3(4):575-581.
Bluefish	$W = .00001120\ L^{3.04}$	Wilk,S.J., W.W. Morse, and D.E. Ralph. (1978). Length-weight relationships of fishes collected in the New York Bight. Bull. New Jersey Acad. Sci. 23:58-64.
Butterfish	$W = .00000650\ L^{3.26}$	DuPaul,W.D. and J.D. McEachran. (1973). Age and growth of the butterfish, *Peprilus triacanthus,* in the Lower York River. Ches. Sci. 18, 205-207.
Croaker	$W = .00000620\ L^{3.10}$	Parker, J.C. (1971). The biology of spot, *Leiostomus xanthurus* Lacepede, and Atlantic Croaker, *Micropogon undulatus* (Linnaeus), in two Gulf of Mexico nursery areas. Sea Grant Publ. No. TAMU-SG-71-210. Texas A&M Univ., College Station.
Cownose rays	$W = .00000450\ L^{3.20}$	Smith, J.W. (1980). The life history of the cownose ray, *Rhinoptera bonasus* (Mitchill 1815), in lower Chesapeake Bay, with notes on the management of the species. Master thesis, College of William and Mary, Virginia Institute of Marine Science.
Summer flounder	$W = .00000190\ L^{3.29}$	Morse W.W. (1981). Reproduction of the summer flounder, *Paralichthys dentatus* (L). J. Fish. Biol. 19(1):189-203.
Harvest fish	Assume one pound weight	None available.
Hog choker	$W = .01510800\ L^{3.11}$	Koski, R.J. (1978). Age, growth, and maturity of the hogchoker, *Trinectes maculatus,* in the Hudson River, New York. Trans. Am. Fish. Soc. 107(3):449-453.
Lady crab	$W = .00034670\ L^{2.89}$	Davidson, R.J. and I.D. Marsden. (1987). Size relationships and relative growth of the New Zealand swimming crab, *Ovalipes catharus* (White 1843). J. Crust. Biol. 7(2):308-317.
Oyster toad	$L = 2.0700 + .013\ W$	Wilber, C.G. and P.F. Robinson. (1960). The correlation of length, weight, and girth in the toadfish, *Opsanus tau.* Ches. Sci. 1:122-123.
Sandbar shark	$W = 50.118723\ L^{0.33}$	Lawler, E.F. (1976). The biology of the sandbar shark, *Carcharinus plumbeus* (Nardo 1827) in the lower Chesapeake Bay and adjacent waters. Master thesis, College of William and Mary, Virginia Institute of Marine Science.
Silver perch	$W = .00001000\ L^{3.10}$	Rhodes, S.F. (1971). Age and growth of the silver perch, *Bairdiella chrysura.* Master thesis, College of William and Mary, Virginia Institute of Marine Science.
Spanish mackerel	$W = .00001152\ L^{2.98}$	Powell, D. (1975). Age, growth, and reproduction in Florida stocks of spanish mackerel, *Scomberomorus maculatus.* Fla. Mar. Res. Publ. 5. 21 pp.
Spider crab	Assume 0.50 pound weight	None available.
Spot	$W = .00000030\ L^{3.76}$	Pacheco, A.L. (1957). The length and age composition of spot, *Leiostomus xanthurus,* in the pound net fishery of lower Chesapeake Bay. Master thesis, College of William and Mary, Virginia Institute of Marine Science.
Squid	$W = .00056510\ L^{2.43}$	Pierce, G.J., P.R. Boyle, L.C. Hastie, and L. Key. (1994). The life history of *Loligo forsbesi* (Cephalapoda: Loliginidae) in Scottish waters. Fish. Res. 21:17-41.
Striped bass	$W = .00578100\ L^{3.15}$	Mansueti, R.J. (1961). Age, growth, and movements of the striped bass, *Roccus saxatilis,* taken in size selectivity fishing gear in Maryland. Chesapeake Sci. 2:9-36.
Thread herring	Assume one pound weight	None available.
Spotted Sea trout	$W = .00000460\ L^{3.11}$	Moffett, A.W. (1961). Movements and growth of spotted seatrout, *Cunoscion nebulosus* (Cuvier). Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 36: 1-35.
Weakfish	$W = .00000930\ L^{2.98}$	Shepherd, G.R. and C.B. Grimes. (1983). Geographic and historic variations in growth of weakfish, *Cynoscion regalis,* in the Middle Atlantic Bight. U.S. Nat. Mar. Fish. Serv. Fish Bull. 81(4): 803-813.
Witch flounder	Proportionality assumed Maximum weight of 4.5 pounds and maximum length of 24 inches.	Page 66 of "Status of Fishery Resources off the Northeastern United States for 1991." National Marine Fisheries Service, Woods Hole, Massachusetts.

[a]Weights (W) are in terms of grams, ounces, or pounds, and lengths (L) are in millimeters, centimeters, or inches. All estimated weight-length coefficients are rounded off in value.

November, respectively (Tables 2-4). The laws require assessment of bycatch relative to the entire catch and not solely the catch of menhaden.

A critical question posed by the recreational associations was "What was the bycatch in terms of weight?" Overall, the total harvested weight of menhaden from the 43 sets was 1,683,710 pounds. The weight of all bycatch was 9,845.9 pounds which equalled 0.585 percent of the harvested weight of menhaden. Bycatch in terms of weight relative to the weight of menhaden was higher than the percent of bycatch calculated using numbers of fish but well below the one percent legal limit. In October, however, the ratio of the weight of bycatch to the weight of menhaden was below the ratio expressed in terms of numbers of fish. Bycatch in October in terms of numbers of units equalled 0.145% of the total number of menhaden harvested; in weight terms, bycatch equalled 0.083% of the harvested weight of menhaden.

What about the number of sets in which bycatch in terms of weight exceeded one percent of the weight of menhaden? For comparative purposes, we note that 24.0%, 8.3%, and 0.0% of the sets in August, October, and November exceeded one percent of the number of menhaden harvested. On a weight basis, the number of sets in which bycatch exceeded one percent of the harvested weight of menhaden was 32.0%, 0.0%, and 33.3% during August, October, and November, respectively. If we examine bycatch relative to food fish and discarded or released fish, however, there were no sets in August, October, or November in which the possession of bycatch exceeded one percent of the weight of the entire catch or the weight of menhaden.

If the analysis assumes that sandbar shark and cownose rays are not generally considered as food fish, only 16% of the sets in August had bycatch exceeding

Table 2. Bycatch in menhaden fishery in terms of numbers and weight, August 1992

Species	Number of Observations	Average Size (inches)	Average Weight (pounds)	Total Weight (pounds)
Blue crabs	119	3.54	0.133	15.83
Bluefish	801	13.95	1.180	945.56
Butterfish	141	5.91	0.183	25.79
Croaker	507	8.40	0.257	130.30
Cownose rays[a]	148	16.54	12.235	1,810.72
Summer flounder	71	7.48	0.132	9.37
Harvest fish	124	5.02	1.000	124.00
Hog choker[a]	472	4.72	0.144	68.19
Lady crab[a]	0			
Oyster toad[a]	0			
Sandbar shark[a]	51	30.00	6.700	341.70
Silver perch	0			
Spanish mackerel	1,144	26.33	3.167	3,622.70
Spider crab[a]	49	1.97	0.500	24.50
Spot	46	7.49	0.183	8.42
Squid	126	2.76	0.039	4.93
Striped bass	0			
Thread herring[a]	95	6.26	0.100	95.00
Sea trout	220	8.99	0.196	43.00
Witch flounder	0			
Total bycatch	**4,114**		**1.767**	**7,270.01**
Menhaden	1,433,000		0.670	960,110.00
Percent of bycatch:				
Total bycatch[b]	0.29[c]			0.76[d]
Food fish[b]	0.23[c]			0.51[d]

[a]Not traditional food fish species.
[b]Bycatch assessed relative to all species (total) and only traditional food fish species.
[c]Ratio of number of bycatch to number of menhaden expressed in terms of percent.
[d]Ratio of weight of bycatch to weight of menhaden expressed in terms of percent.

one percent of the weight of menhaden. If we further acknowledge that most of the Spanish mackerel were discarded or released by the captain and crew (onboard observation), there were no sets in August in which the bycatch in terms of weight and retained by the vessel exceeded one percent of the weight of the entire catch. In addition, the 4 sets in August in which bycatch, comprised mostly of Spanish mackerel, exceeded one percent of the weight of the entire catch were relatively small sets. The number of standard menhaden harvested in the four sets were 15,000, 20,000, 35,000, and 100,000. If we also acknowledge that striped bass is a prohibited species and must be released or discarded, the number of sets in November in which the total weight of bycatch exceeded one percent of the weight of menhaden drops to zero.

Table 3. Bycatch in menhaden fishery in terms of numbers and weight, October 1992

Species	Number of Observations	Average Size (inches)	Average Weight (pounds)	Total Weight (pounds)
Blue crabs	104	4.38	0.228	23.68
Bluefish	32	9.51	0.425	13.60
Butterfish	181	4.69	0.086	15.55
Croaker	84	6.58	0.115	9.70
Cownose rays[a]	0			
Summer flounder	148	8.43	0.207	30.67
Harvest fish	0			
Hog choker[a]	48	4.53	0.129	6.19
Lady crab[a]	32	2.00	0.065	2.08
Oyster toad[a]	8	6.81	0.452	3.63
Sandbar shark[a]	0			
Silver perch	80	5.04	0.751	6.01
Spanish mackerel	0			
Spider crab[a]	0			
Spot	16	6.22	0.223	3.57
Squid	0			
Striped bass	8	32.48	18.987	151.90
Thread herring[a]	0			
Sea trout	85	9.28	0.215	18.32
Witch flounder	31	7.61	1.427	44.24
Total bycatch	**857**			**329.12**
Menhaden	590,000		0.670	395,300.00
Percent bycatch:				
Total bycatch[b]	0.15[c]			0.08[d]
Food Fish[b]	0.13[c]			0.08[d]

[a]Not traditional food fish species.
[b]Bycatch assessed relative to all species (total) and only traditional food fish species.
[c]Ratio of number of bycatch to number of menhaden expressed in terms of percent.
[d]Ratio of weight of bycatch to weight of menhaden expressed in terms of percent.

Conclusions

In general, the updated analysis presented in this issue of the *Bulletin* indicated that bycatch in Virginia's menhaden fishery did not pose a problem with respect to the laws in 1992. The updated analysis found that regardless of whether or not weight or number of fish and marine invertebrates was used to assess bycatch, the percent of bycatch relative to the entire catch or only the catch of menhaden was generally below one percent in 1992. The updated analysis did reveal, however, that the number of sets in which bycatch exceeded one percent did increase when weight rather than number of fish and marine invertebrates was used to assess bycatch.

The number of sets in which bycatch exceeded one percent of the entire catch increased from 7 to 10 when weight rather than number of fish and marine invertebrates was used to assess bycatch.

However, if the analysis was restricted to traditional food fish, the number of sets having bycatch in excess of one percent of the weight of the entire catch declines from 10 to 6 out of 43. If we further acknowledge that striped bass caught in the November sets and most of the Spanish mackerel caught in the August sets were released or discarded by the crew, there were no sets in any of the months in which the vessel possessed bycatch in excess of one percent of the weight of the entire catch.

It must be recognized, however, that the VIMS study and the updated analysis in this *Bulletin* offer, at best, a limited snapshot. The VIMS study was conducted in 1992 given resource conditions prevailing at the time. The focus of the VIMS study was to determine procedures for accurately assessing bycatch, test the procedures, and provide an assessment of bycatch relative to menhaden during 1992. The VIMS study could not assess bycatch relative to a wide range of resource conditions. Obviously, changes in the abundance of striped bass, bluefish, or other species could cause a change in bycatch relative to menhaden or alter the composition of bycatch. A more thorough assessment of bycatch, regardless of using weight or numbers of fish and invertebrates, would require a study conducted over several years and with variable resource conditions. ✣ ✣

Table 4. Bycatch in menhaden fishery in terms of numbers and weight, November 1992

Species	Number of Observations	Average Size (inches)	Average Weight (pounds)	Total Weight (pounds)
Blue crabs	0			
Bluefish	102	19.10	3.501	357.10
Butterfish	45	5.49	0.144	6.49
Croaker	0			
Cownose rays[a]	0			
Summer flounder	4	9.00	1.000	4.00
Harvest fish	0			
Hog choker[a]	0			
Lady crab[a]	132	2.80	0.154	20.37
Oyster toad[a]	0			
Sandbar shark[a]	0			
Silver perch	0			
Spanish mackerel	0			
Spider crab[a]	0			
Spot	0			
Squid	0			
Striped bass	84	34.06	22.13	1,858.82
Thread herring[a]	0			
Sea trout	0			
Witch flounder	0			
Total bycatch	**367**		**6.122**	**2,246.78**
Menhaden	490,000		0.670	328,300.00
Percent bycatch				
Total bycatch[b]	0.08[c]			0.68[d]
Food fish[b]	0.05[c]			0.68[d]

[a]Not traditional food fish species.
[b]Bycatch assessed relative to all species (total) and only traditional food fish species.
[c]Ratio of number of bycatch to number of menhaden expressed in terms of percent.
[d]Ratio of weight of bycatch to weight of menhaden expressed in terms of percent.

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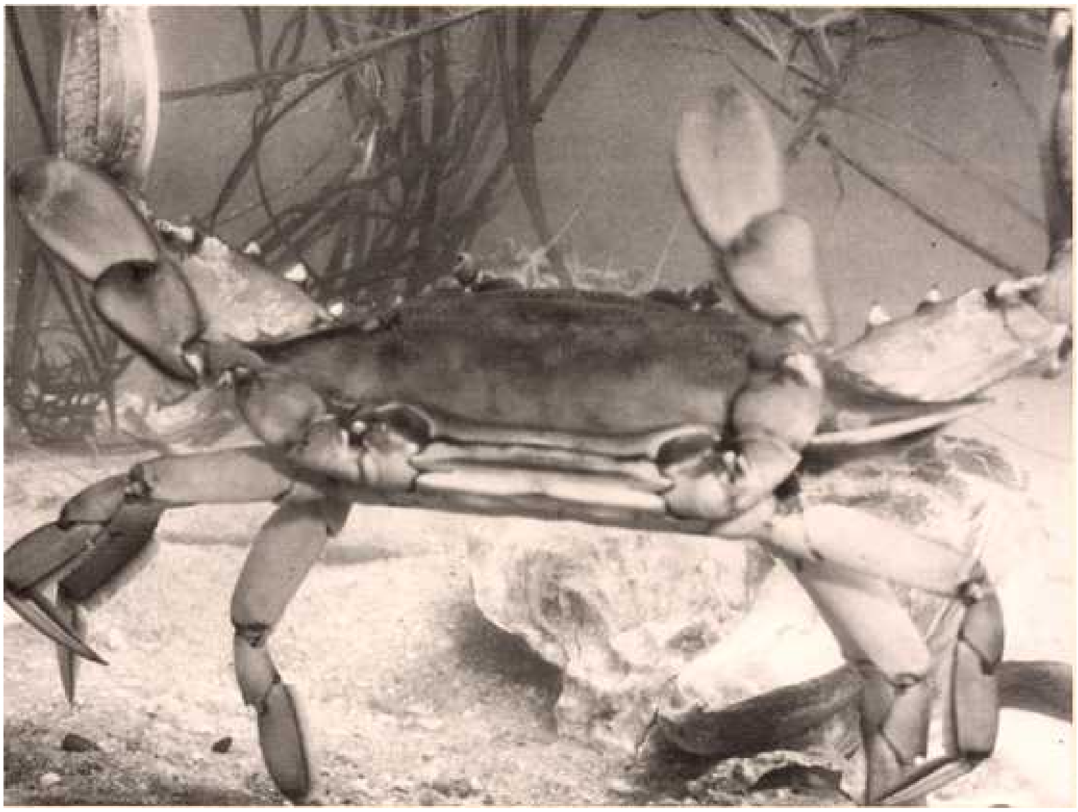
On the cover:
Callinectes sapidus, *the blue crab, by Alice Jane Lippson.©*

On the right:
Typically, male crabs show a display like this for two reasons—territorial and sexual. In this case, the male is putting on a display for a female—a blue crab's sign of availability.

On the bottom:
First stage crab (left) and megalopa.



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