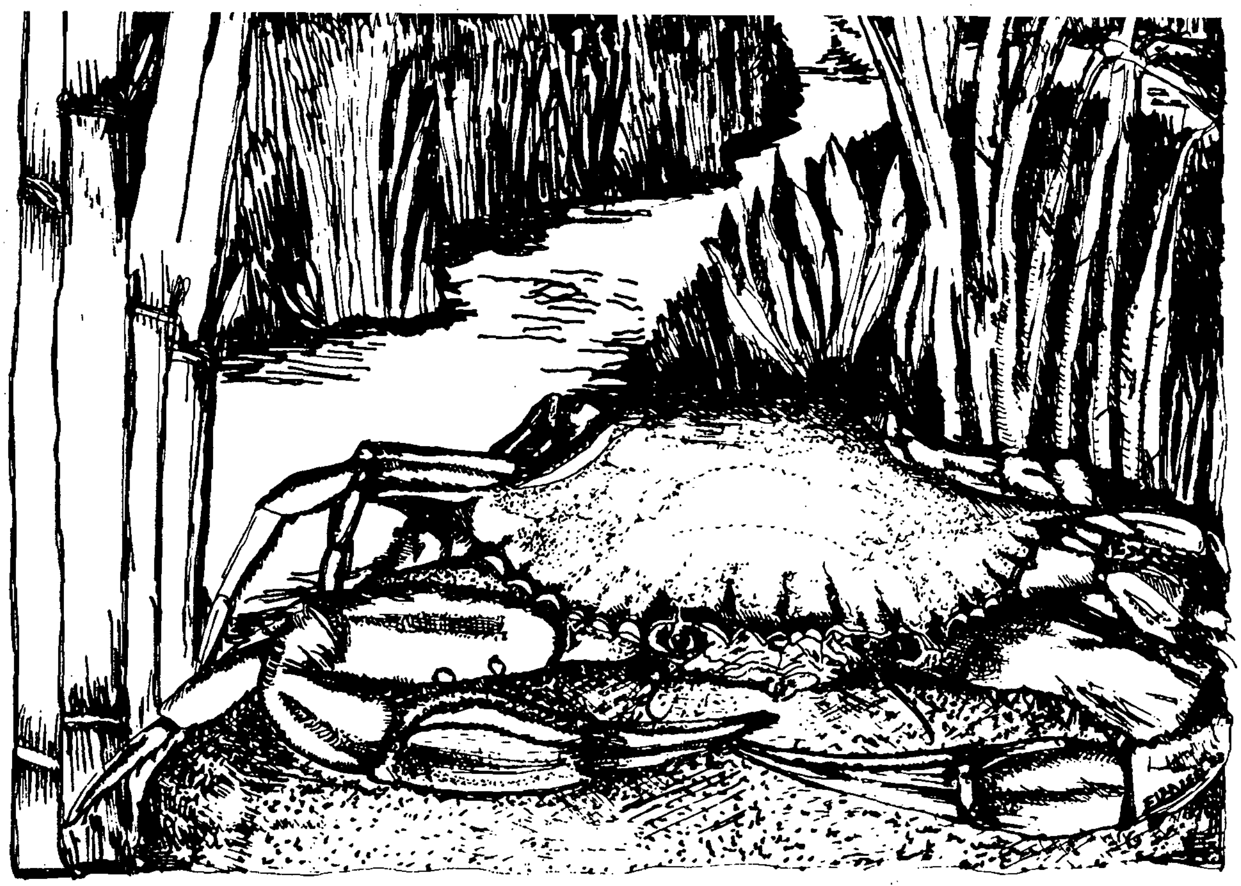

Fish and Wildlife Service

U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station

U.S. Army Corps of Engineers

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March 1989

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

BLUE CRAB

by

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Millikin and Williams (1984) previously published a review of the nomenclature, taxonomy, morphology, distribution, life history, population structure and dynamics, and the fishery of the blue crab.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180.

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

We are grateful to Maurice K. Crawford, Douglas E. Facey, and Timothy J. Welch for reviews and to Sue Anthony for editing and typing this manuscript. Technical reviews were provided by Kenneth Tenore of the University of Maryland and W. A. Van Engel of the Virginia Institute of Marine Science at Gloucester Point. We wish to thank the authors J. D. Costlow, Jr., and C. G. Bookhout for use of their drawing of the Zoea for our Figure 4.

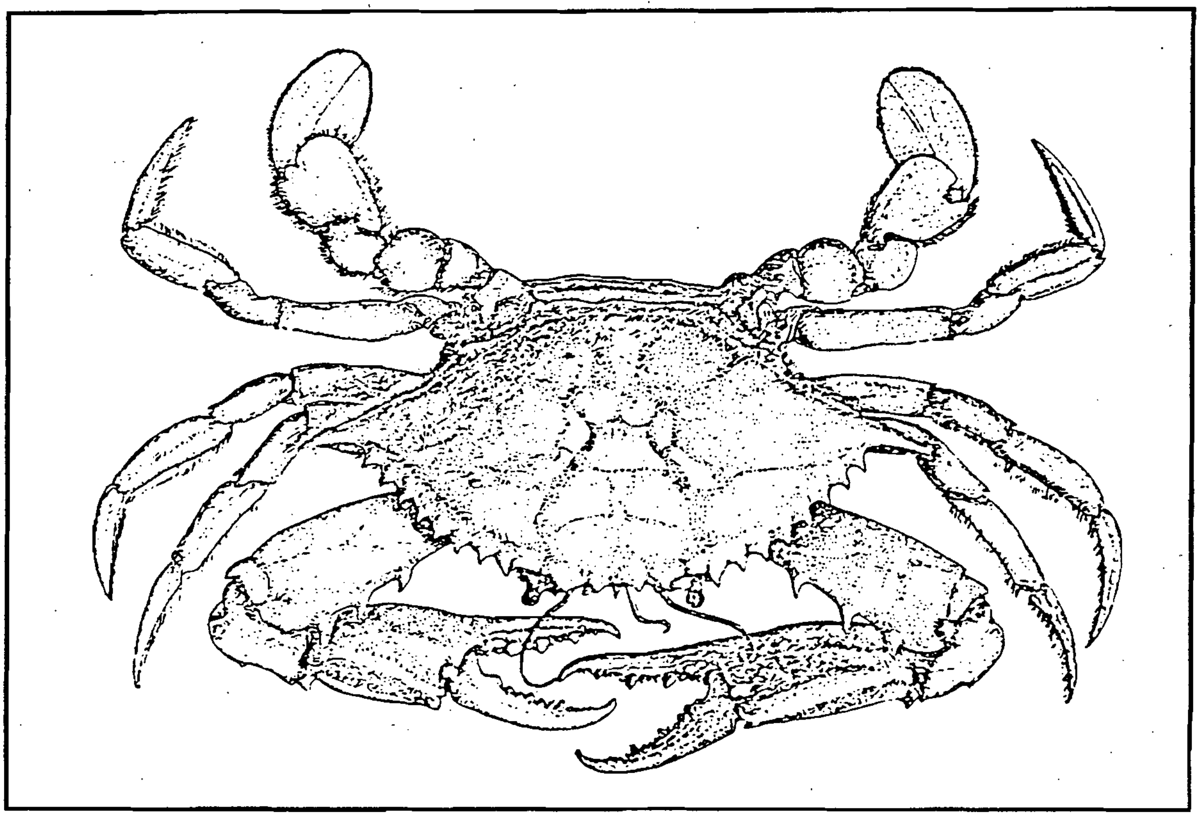

Figure 1. Blue Crab.

BLUE CRAB

NOMENCLATURE,TAXONOMY, AND RANGE

Scientific name....*Callinectes sapidus* (Rathbun)
Preferred common name........Blue crab
Other common names......Edible crab, crab; young females are called sally crabs; adult females are called sooks; and males are called jimmies, jimmydicks, or channelers (Van Engel 1958)
Class........................Crustacea
Order.........................Decapoda
Family......................Portunidae
Subfamily..................Portuninae

Geographic range: The blue crab (Figure 1) occurs in coastal waters--primarily bays and brackish estuaries--from Massachusetts Bay southward to the eastern coast of South America, including the Gulf of Mexico. It has been collected occasionally in Maine and northward to Nova Scotia (Piers 1923; Scattergood 1960). It occurs throughout the Mid-Atlantic Region (Figure 2) (Sullivan 1909; Churchill 1919; Van Engel 1958).

MORPHOLOGY AND IDENTIFICATION AIDS

The blue crab is grayish or bluish green, with red on carapace spines (Williams 1965). Pincers on the chelipeds are blue in males and red in mature females. Underparts are off-white with tints of yellow and pink (Williams 1965). Young crabs often are brownish with conspicuous white markings (Newcombe 1945).

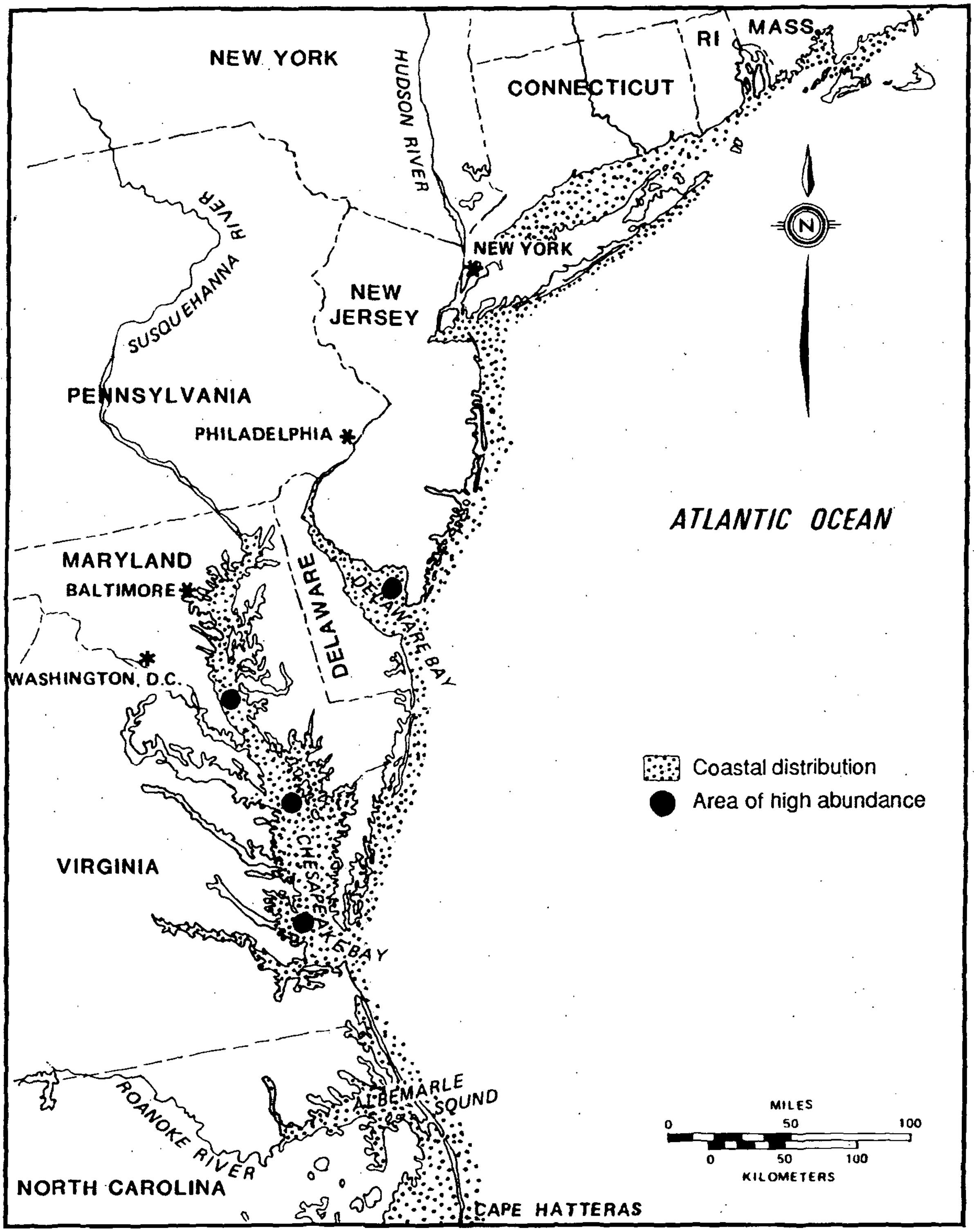

Figure 2. Distribution of the blue crab in the Mid-Atlantic Region, eastern United States. Chesapeake Bay supports the major commerical fishery in this region.

Although these are typical color patterns, rare forms have been captured that were entirely blue (Maryland Tidewater News 1950; Haefner 1961).

The carapace, including lateral spines, is usually 2.5 times as wide as long, moderately convex, and nearly smooth, except for small tubercles on inner branchial and cardiac regions. The anterior margin of the carapace has a median or frontal region that extends between the compound eyes, and two lateral regions.

Members of the subfamily Portuninae have nine anterolateral teeth on the carapace, with the lateral tooth similar to others in size. The genus Callinectes has an antenna that is not excluded from the orbit; male Callinectes also have a T-shaped abdomen. The abdomen is triangular in immature females and is broadly rounded and folded loosely against the ventral side of the thoracic sterna in mature females (Figure 3). The medial region of C. sapidus has two frontal teeth between the inner orbital teeth (Williams 1984).

REASON FOR INCLUSION IN SERIES

The blue crab supports a valuable commercial fishery throughout the

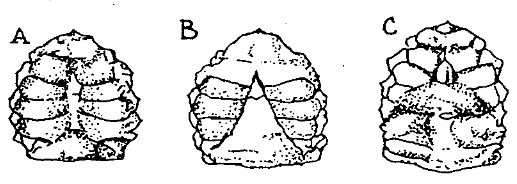

Figure 3. Ventral view of the blue crab male (A), immature female (B), and mature female (C) (Truitt 1939).

Mid-Atlantic States and along most of the eastern and gulf coasts of the United States. Estuaries are essential in its life history; the species' high abundance in estuaries and its omnivorous feeding habits suggest that it plays an important role in the structure and function of estuarine communities. It is a predator of commercially valuable clams and oysters (Newcombe 1945), and young are preyed upon by a large number of estuarine and marine animals, including other commercially important species such as the striped bass, Morone saxatilis (Manooch 1973).

LIFE HISTORY

Mating and Spawning

Blue crabs mate in Chesapeake Bay from May through October (Van Engel 1958; Williams 1984). The spawning season was significantly shorter during years in which temperatures were low for extended periods (Daugherty 1952). Mating occurs primarily in relatively low-salinity waters in the upper areas of estuaries and lower portions of rivers (Pyle and Cronin 1950; Darnell 1959; Williams 1965; Tagatz 1968).

Williams (1965) described the blue crab's mating behavior. The male may mate during its third or fourth intermolt phase after it matures. Females mate only once in their lives, but the sperm from this mating is stored in seminal receptacles and may be used as often as the female spawns, generally two or more times during a 1- or 2-year period (Van Engel 1958; Williams 1965). When the female is ready to molt into the mature stage, it is carried under the male's body; these pairs are called doublers. The female is released during molting and is then reclasped with the abdomens facing each other. Spermatophores produced by the male are then passed via copulatory stylets into the spermathecae. Pleopods of the male and swimmerets of the female are intromittent organs which aid in copulation. After copulation, the female is turned around and carried until her shell hardens (Williams 1984).

After mating, females migrate to high-salinity waters in lower estuaries, sounds, and nearshore spawning areas (Churchill 1919; Darnell 1959; Fischler and Walburg 1962). These overwinter before spawning by burrowing in the mud at the mouths of bays (Cook 1981; Schmidt 1985). Most females spawn for the first time 2 to 9 months after mating (Churchill 1919; Williams 1965). 1965).

From May through August, the female extrudes fertilized eggs into a cohesive mass or "sponge" that remains attached to setae on the appendages of the abdomen until the larvae emerge (Churchill 1919; Newcombe 1945; Pyle and Cronin 1950). The sponge, which may contain 700,000 to 2 million eggs, is formed in about 2 hours (Churchill 1919; Truitt 1939; Williams 1965). Incubation generally requires 1-2 weeks. In Chesapeake Bay, larval release appears to be concentrated between the Virginia capes (McConaugha et al. 1986). The presence of empty egg cases on swimmerets or the occurrence of large, bright-red adult nemertean worms (Carcinonemertes carcinophila) on the gills of a mature female indicates that the crab has spawned at least once (Churchill 1919; Hopkins 1947). After reaching sexual maturity, these worms feed on the egg masses carried by female crabs and live in the gills of the crab after the eggs hatch (Hopkins 1947). In lower Chesapeake Bay, mature red Carcinonemertes occurred in the gills of more than 95% of the female crabs that had spawned; immature crabs supported only immature, light-colored worms (Hopkins 1947).

Development

Growth and development of the blue crab, as in other crustaceans, consist of a series of larval, juvenile, and adult stages during which a variety of morphological, behavioral, and physiological changes occur. These changes are most dramatic when the animal molts (sheds its rigid exoskeleton) permitting growth and changes in body shape. Before molting, a new shell is formed beneath the old exoskeleton, which then loosens and is cast off. The new shell is initially soft, but it expands and hardens in a few hours. The stage between molts is termed intermolt. Much of the information summarized here was obtained from comprehensive studies of the blue crab in the Chesapeake Bay area by Churchill (1919), Newcombe (1945), and Van Engel (1958).

Eggs

The eggs are bright orange when first deposited, but become yellow, brown, and then dark brown before hatching (Van Engel 1958). The color change is caused by absorption of the yellow yolk and development of dark pigment in the eyes and on the body. Eggs are about 0.25 mm in diameter (Churchill 1919). Sandoz and Rogers (1944) reported that hatching of blue crab eggs only occurs at salinities of 23-33 ppt and temperatures of 19-29 °C. Mortality of eggs has been attributed to fungal infection, predation, suffocation in stagnant water, and exposure to extreme temperatures (Couch 1942; Humes 1942; Rogers-Talbert 1948). On the average, only one out of every million eggs survives to become a mature adult (Van Engel 1958).

Larvae

First stage larvae, called zoeae, measure approximately 0.25 mm wide at hatching (Figure 4). Churchill

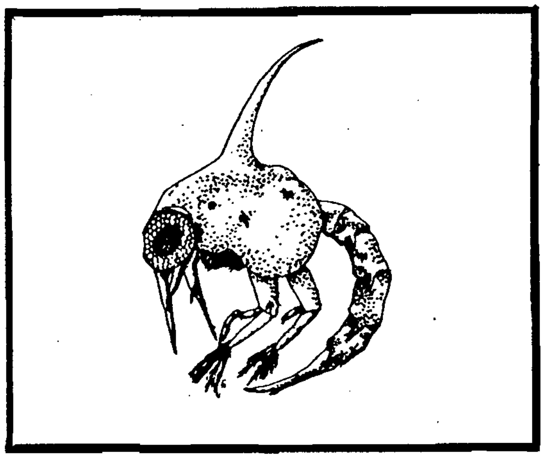

Figure 4. Zoea (from Costlow, Jr. and Bookhout 1959).

(1942), Hopkins (1943), and Costlow and Bookhout (1959) provided illustrated descriptions of the morphology of zoeae. The larvae bear little morphological resemblance to adults (Hopkins 1943), are filter feeders, and are planktonic (Darnell 1959).

Evidence suggests that blue crab zoeae hatch in Chesapeake Bay, Chincoteague Bay, Delaware Bay, and other estuaries and drift out to sea, where they feed and grow (Cook 1981; Finchham 1981; Sulkin et al. 1982). These larvae may migrate vertically in the water column to reach flood and ebb tides, which transport them back into the bay area.

The zoeae and all subsequent life stages can increase body size only by molting (Hay 1905). Zoeal development depends on salinity and temperature, but development time has been shown to be variable even in a single salinity-temperature regime (Costlow and Bookhout 1959). Larvae molt seven to eight times before entering the next stage of development (Costlow and Bookhout 1959). The final molt of the zoea is characterized by a conspicuous change to the second larval stage (megalops) at about 2.5 mm carapace width; development to this stage requires 31-49 days (Costlow and Bookhout 1959). The megalopa larva, illustrated by Churchill (1919) and Newcombe (1945), is more crablike in appearance than the zoea; its carapace is broader in relation to its length, and it has pinching claws and pointed joints at the ends of the legs. It swims freely, but generally stays near bottom in nearshore or lower-estuarine, high-salinity areas (Tagatz 1968). The megalopal stage lasts 6 to 20 days, after which the larva molts into the "first crab" stage, characterized by adult proportions and appearance.

Juveniles

The juvenile "first crab" is typically 2.5 mm wide (from tip to tip of the lateral spines of the carapace). Juveniles gradually migrate into shallower, less-saline waters in upper estuaries and rivers, where they grow and mature (Fischler and Walburg 1962). Van Engel (1958) reported that many juveniles had completed this migration by fall. New evidence, however, suggests that the bulk may not reach the upper parts of tributaries and Chesapeake Bay until the following summer (W.A. Van Engel, Virginia Institute of Marine Science, Gloucester Point; pers. comm.). Males, which prefer low-salinity waters, generally migrate farther upstream than do females, which tend to stay in the lower rivers and estuaries (Dudley and Judy 1971; Music 1979).

Growth and maturation proceed during a series of molts and intermolt phases; each of these crab stages is identified by the number of molts that have occurred since the megalopal stage. Churchill (1919) estimated that juveniles reached the 9th or 10th crab stage by October in Chesapeake Bay. Molting and growth stop during winter (Churchill 1919; Darnell 1959), but resume as waters warm. The crabs generally reach maturity during the spring or summer of the year following the year of hatching.

Adults

In the Chesapeake Bay, sexual maturity is reached after 18-20 postlarval molts, at the age of 1-1.5 years (Van Engel 1958; Williams 1965). Males continue to molt and grow after they reach sexual maturity, but females cease to molt and grow when they mature and mate.

After the females mate and migrate to spawning areas, they either remain there for the rest of their lives or move only short distances out to sea (Williams 1965). In warmer months, males generally stay in low-salinity waters such as creeks, rivers, and upper estuaries (Churchill 1919; Van Engel 1958; Dudley and Judy 1971; Music 1979). Early work by Fiedler (1930), Truitt (1937), and Cronin (1949) on blue crabs in the Chesapeake Bay indicated that females overwintered at the mouth of the bay and spawned there in spring, whereas the migration of males was nondirectional. Crabs bury themselves in mud in winter and emerge when temperatures rise in spring (Cook 1981; Schmidt 1985). The maximum age for most blue crabs in the Mid-Atlantic Region is 3 years (Churchill 1919; Williams 1965); adults thus live an average of less than 1 year after reaching maturity (Hay 1905; Truitt 1939).

Migrations

Adult blue crabs are excellent swimmers and also can move quickly on land. They rarely move from one estuarine system to another (Porter 1956; Cargo 1958; Fischler and Walburg 1962; Judy and Dudley 1970). When they do leave an estuary, they usually remain in adjacent coastal areas, though a few tagged female crabs have been recovered 100-540 km from their release sites.

Migrations of blue crabs within estuarine systems are related to phases of their life cycle, to the season, and (to a lesser extent) to searches for favorable environmental conditions (Churchill 1919; Fiedler 1930; Truitt 1939; Fischler and Walburg 1962). Most blue crabs move to relatively deeper, warmer waters in winter and return to rivers, tidal creeks, salt marshes, and sounds when conditions become more favorable in the spring (Livingston 1976; Subrahmanyam and Coultas 1980).

GROWTH AND MOLTING CHARACTERISTICS

From the first crab stage to the adult, successive intermolt stages of the crab are morphologically similar except for size. The number of molts during certain life stages (e.g., larval and juvenile) is relatively uniform among crabs, but the rate of molting (and hence growth) varies considerably and is affected by many environmental factors, including temperature and salinity. Consequently, it is generally not possible to determine the developmental stage of a particular crab from its size or external characteristics (Churchill 1919). Migrations and movements within estuaries further complicate estimation of growth rates, and repeated sampling at one location can lead to erroneous conclusions (Darnell 1959; Adkins 1972; Palmer 1974). Thus, the growth and molting patterns described here were derived in part from laboratory studies.

Crabs molt often when small, but less frequently as they grow larger (Van Engel 1958). Each molt typically results in a 25%-40% increase in carapace width (Churchill 1919; Gray and Newcombe 1939; Van Engel 1958). Results of Churchill's (1919) laboratory studies on growth of Chesapeake Bay blue crabs serve as a general guideline for growth patterns of blue crabs in Virginia and adjacent States

(Table 1). Rates of growth vary with age and sex (Newcombe 1948). The increase in size associated with specific molts may be genetically controlled, but environmental conditions are believed to have a greater influence. Unfavorable water conditions, inadequate food, or injuries such as the loss of one or more legs can cause smaller increases in size or no growth following a molt (Van Engel 1958). In juveniles, the increment of growth in successive molts appears to be greatest in high salinity waters (Tagatz 1968).

Van Engel (1958) reported that crabs hatched in late May in Chesapeake Bay were 64 mm wide by November and 127 mm wide (harvestable size) by the following August. The age of sexual maturity varies from 12-18 months in Chesapeake Bay (Newcombe 1945; Van Engel 1958). Average size at maturity is also variable; it has been estimated to be about 178 mm carapace width in Chesapeake Bay (Churchill 1919). Mature females range in size from 55-204 mm; males may reach 209 mm (Williams 1984).

THE FISHERY

The blue crab supports the largest crab fishery in the United States, representing about 50% of the total weight of all species of crabs harvested (Thompson 1984, NMFS 1986). Annual commercial landings in the United States averaged 86,000 t (190 million lbs) in 1980-85; the harvest in 1985 was valued at $53 million (NMFS 1986). In 1982, the average wholesale price for live blue crabs was $24 per bushel (NMFS 1982). Sholar (1982) summarized most aspects of the Atlantic blue crab fishery and reported landings, by State, for 1950-77. An annotated bibliography on the blue crab fishery and biology was published by Tagatz and Hall (1971). A report on the blue crab

Table 1. Growth of different life stages of blue crabs in the laboratory at temperatures and salinities typical of Chesapeake Bay (Churchill 1919).

Life stage	Carapace width (mm)	Increase in width (mm)	Molt interval (days)	Age (days)
Megalops	1.0			
1st crab	3.2	2.2	1	1
2nd crab	5.0	1.8	8	9
3rd crab	6.6	1.6	4	13
4th crab	8.8	2.2	5	18
5th crab	11.6	2.8	6	24
6th crab	13.1	1.5	13	37
7th crab	20.6	7.5	11	48
8th crab	27.0	6.4	13	61
9th crab	34.9	7.9	10	71
10th crab	42.8	7.9	15	86
11th crab	57.2	14.4	16	102
12th crab	79.4	22.2	20	122
13th crab	109.5	30.1	21	143
14th crab	139.7	30.2	25	168
15th crab	177.8	38.1	35	203

dynamics in Chesapeake Bay was published by the Chesapeake Biological Laboratory (Jones et al. 1983).

Harvests from the Mid-Atlantic Region during 1977-85 composed about half of the total U.S. commercial blue crab harvest; commercial landings were about 40,000 t or 90 million lbs (NMFS 1982). Almost 90% of commercial blue crab landings in the Mid-Atlantic are from the Chesapeake Bay region in Maryland and Virginia; landings are much smaller in Delaware and New Jersey (NMFS 1981, 1986). Much of the harvest is processed for commercial packaging singularly or mixed with other food products and represents a $60 million industry (NMFS 1985).

Blue crabs are caught throughout the year, but most are taken during the summer and early fall (Music 1979). Hard crabs (having hardened exoskeletons) are taken primarily in shallow water in the warmer months with crab pots or trotlines. The use of trotlines for blue crabs has generally diminished in the New England states (Sholar 1982), whereas the use of crab pots has increased (Tang 1983). Dredges (and less frequently, scrapes) are used in deeper offshore waters in winter to take crabs burrowed into the mud (Adkins 1972; Tang 1983; Schmidt 1985). Fishing pressure has been steadily increasing in the Chesapeake Bay area; numbers of fishermen, boats, and pots increased threefold between 1950 and 1975 (Table 2). Cronin (1983) reported a 7.6-fold increase between 1948 and 1981 in the number of licenses for crabbing issued in Maryland.

Recently molted "soft-shell" crabs represent a smaller portion of the total industry, although they have a higher value per crab (Haefner and Garten 1974). Methods of processing used in the soft-shell industry were reviewed by Haefner and Garten (1974). Few fishermen engage in the soft shell business because these crabs must be tended continuously (Adkins 1972).

Management of the commercial blue crab fishery is usually local, and has included measures such as carapace width limits, net mesh-size limits, constraints on gear type, closed seasons and areas, prohibition of the harvest of sponge crabs or other females, quotas, and licensing (Bearden 1978). Even so, an assessment of the blue crab fishery in Chesapeake Bay suggested that blue crabs are currently being overfished (Tang 1983).

The blue crab also supports a recreational fishery and a variety of small-scale commercial harvests and sales by "weekend operators." Gears used include handlines, pots, and collapsible traps. Recreational fishermen generally are limited to a maximum of five pots (Sholar 1982). Landings from these activities have rarely been quantified.

Commercial harvests of blue crabs fluctuate widely. For example, the annual harvest in Chesapeake Bay fluctuated between 45 and 94 million lbs from 1966 to 1980, typical of harvests over the last 50 years (Finchham 1981). Rees (1963) and More (1969) found no direct relationship between commercial catches and recruitment of harvestable crabs in subsequent years. Pearson (1948) found that the size of the spawning stock also failed to determine the size of the population that survived to legal size for commercial fishing. He noted that fluctuations in abundance were related primarily to rates of survival during the first year of life.

Apparently, there are no reliable methods for predicting harvests. Population fluctuations have apparently been caused by extreme cold weather, reduced salinities from heavy rains (Pearson 1948), parasitism by the leech *Myzobdella lugubris* (Hutton and Sogandares-Bernal 1959), toxic wastes

Table 2. Numbers of gear units, crab pounds, fishermen, and boats operating in the blue crab fisheries of the Chesapeake Bay states, 1950-1975 (from Sholar 1982).

Year	Pots	Trotlines	Dredges	Scrapes	Crab Pounds	Fisher-men	Boats
1950	85,530	1,596	268	596	-	4,653	3,879
1951	87,200	1,455	332	733	-	5,044	4,209
1952	72,250	1,479	364	640	-	4,574	3,834
1953	82,500	1,527	328	750	-	5,005	4,089
1954	88,650	1,306	333	802	-	4,896	4,006
1955	94,650	2,494	437	747	-	6,319	5,289
1956	95,552	2,914	450	466	1,783	6,418	5,668
1957	133,935	2,608	416	720	2,182	5,845	5,148
1958	129,430	2,604	370	611	2,441	5,737	5,064
1959	169,545	2,491	320	586	2,535	5,658	5,025
1960	195,073	2,231	348	563	2,550	5,506	4,855
1961	175,270	2,542	704	615	2,787	5,813	5,004
1962	188,164	2,314	596	392	2,787	5,687	4,938
1963	192,083	2,305	407	614	2,805	5,708	4,920
1964	184,595	2,342	366	579	2,839	5,304	4,826
1965	217,376	2,735	325	414	2,687	6,306	5,469
1966	213,622	2,976	298	373	2,815	6,414	5,524
1967	203,488	3,139	283	322	2,798	6,189	5,396
1968	212,490	3,080	320	355	2,168	6,194	5,435
1969	229,995	3,263	300	348	2,331	6,743	5,813
1970	254,435	5,650	324	197	1,990	9,237	7,981
1971	227,480	7,982	285	428	1,476	11,576	9,417
1972	235,270	8,130	273	410	1,588	11,697	9,330
1973	221,200	7,993	320	410	1,181	10,582	8,547
1974	232,599	9,272	158	428	3,168	13,841	11,454
1975	264,536	9,964	173	371	2,338	14,437	11,710

(Cottam and Higgins 1946; Mills 1952), and predation (McHugh 1967). Larval movements may affect recruitment back into bays (McConnaugha 1983). If larvae are scattered by winds and storms while they are offshore, or if water currents in fall do not allow larvae to return to the bay, harvests are likely to be low the next fall and following spring. Conversely, calm conditions or mild storms with onshore winds that direct currents into the bay may lead to exceptional harvests (Finchham 1981). In accord with this hypothesis, Van Engel (1958) determined that a large part of blue crab fluctuations can be explained by variations in oceanographic and atmospheric conditions (VIMS 1981).

ECOLOGICAL ROLE

Blue crabs perform a variety of ecosystem functions and can play a major role in energy transfer within estuaries. At various stages in the life cycle, blue crabs serve as both prey and as consumers of plankton, small invertebrates, fish, and other crabs. They are important detritivores and scavengers throughout their range.

Zoeae are phytoplanktivorous (Darnell 1959), and readily consume dinoflagellates and copepod nauplii (Tagatz 1968). The omnivorous megalopa eats fish larvae, small shellfish, and aquatic plants (Van Engel 1958; Darnell 1959; Tagatz 1968). Cannibalism is common among all life stages of blue crabs (Hay 1905; Churchill 1919; Darnell 1959; Tagatz 1968).

Post-larval crabs are considered general scavengers, bottom carnivores, detritivores, and omnivores (Hay 1905; Darnell 1959; Adkins 1972). Food habit studies have shown that the predominant foods consumed vary greatly among localities. Some common items are dead and live fish, crabs, organic debris, shrimp, mollusks (including mussels, clams, oysters, and snails), and aquatic plants (Newcombe 1945; Darnell 1959; Williams 1965; Tagatz 1968; Seed 1980; Arnold 1984; Warren 1985). Truitt (1939) found that roots, shoots, and leaves of eelgrass (Zostera), ditch grass (Ruppia), sea lettuce (Ulva), and salt marsh grass (Spartina) were commonly eaten by crabs in salt marshes, tidal creeks, and other shallow estuarine areas. Darnell (1958) concluded that mollusks were the dominant food of crabs larger than 120 mm wide. Although predator-prey interactions are complex (West and Williams 1986), these relationships may be stabilized by predator avoidance mechanisms. For example, the periwinkle (Littorina irrorata) reduces injury and mortality rates caused by blue crab by climbing tall grass during high tides (Warren 1985). Some bivalves also escape predation as they develop thicker shells. Blue crab feeding on infaunal bivalves was found to be a function of prey availability and shell strength of the prey relative to predator strength (Blundon and Kennedy 1982).

Blue crabs are the prey of a variety of animals. Egg masses, carried by females, are often specifically attacked by some fishes (Adkins 1972). Larval stages are eaten by fish, shellfish, jellyfish, combjellies, and various other planktivores (Van Engel 1958). Juveniles are important prey of many fish such as spotted sea trout (Cynoscion nebulosus), red drum (Sciaenops ocellatus), black drum (Pogonias cromis), and sheepshead (Archosargus probatocephalus), as well as of shorebirds and wading birds (Fontenot and Rogillio 1970; Adkins 1972; Barrass and Kitting 1986). Barrass and Kitting (1986) showed that crabs less than 10 mm long respond to recorded vocalizations of laughing gulls (Larus atricilla) by fleeing or hiding; thus, the absence of visual cues in turbid waters apparently does not hinder the detection of avian predators by blue crabs. Juvenile and adult blue crabs are consumed by mammals, a variety of birds, and several fishes, including striped bass (Manooch 1973), American eel, Anguilla rostrata (Wenner and Musick 1975) and sandbar shark, Carcharhinus plumbeus (Medved and Marshall 1981).

The blue crab is host to several parasites and diseases, but many infections are temporarily eliminated during molting. After their last molt, adult blue crabs may serve as a lodging place for barnacles, bryozoans, and other sessile organisms (Darnell 1959; Williams 1965). The barnacles Balanus amphitrite and Chelonibia patula attach to the carapace but generally have little physiological effect on the crab (Darnell 1959; Williams 1965), although the stalked barnacle Octalasmis lowei may clog a crab's gills and gill chambers (Causey 1961) and sacculinid barnacles may prevent molting (Steele 1982). Infections by the protozoan Paramoeba perniciosa have been responsible for numerous crab mortalities along the eastern seaboard (Mahood et al. 1970).

Blue crabs have been implicated as carriers of strains of the bacterium Vibrio cholerae which are responsible for outbreaks of human cholera (Moody 1982; Welsh and Sizemore 1985; Huq et al. 1986). This Vibrio is apparently a natural part of the estuarine ecosystem and inhabits Chesapeake Bay and other major fishing areas (Greer 1981); however, these and other parasites pose no threat to humans if the blue crabs are properly stored, cleaned, and cooked.

ENVIRONMENTAL REQUIREMENTS

Temperature

Water temperature influences growth and survival of blue crabs. Williams (1965) found that larval crabs, reared at temperatures less than 21 °C, did not develop beyond the first zoeal stage and did not progress past the third zoeal stage when reared at 30 °C or higher. Blue crabs are more tolerant of low temperatures than are many species of fishes and shrimp (Music 1979). Their ability to burrow into the substrate apparently enables them to be insulated from cold water (Music 1979; Weinstein 1979). The upper incipient lethal temperature for juvenile blue crabs is 33 °C (Holland et al. 1971).

Leffler (1972) measured growth of crabs at four temperatures, starting with 22-mm crabs, and found the following mean carapace widths after 70 days: 56 mm at 34 °C, 48 mm at 27 °C, 40 mm at 20 °C, and 38 mm at 15 °C. The relationship between growth rate and water temperature was reported by Churchill (1919), Winget et al. (1976), and Leffler (1972). Growth rate was proportional to water temperature; growth and molting ceased below 15.5 °C (Churchill 1919) and below 13 °C (Leffler 1972).

Mortality was determined to be directly proportional to temperature within a range of 15-34 °C (Leffler 1972). Experiments by Holland et al. (1971) indicated that mortality increased at temperatures above 30 °C. Leffler (1972) noted that crabs also acclimated to 34 °C were hyperactive. Activity and aggression of crabs also decreased with temperature until at 13 °C almost no movement occurred.

Salinity

Blue crabs occupy water ranging from a near-ocean salinity of 34 ppt to freshwater in rivers as far as 195 km upstream from the coast (Tagatz 1968; Palmer 1974). Newcombe (1945) wrote that salinities of 22-28 ppt are needed for normal hatching of eggs and for normal development of zoeae, but survival and growth of megalopae and small juvenile crabs may be normal at salinities as low as 5 ppt. When salinity is very low, larvae may hatch prematurely and die in the prezoeal stage (Van Engel 1958). Gunter (1938) noted that post-larval blue crabs move into freshwater and may do so throughout the species' range. Specific salinity levels are not critical for postlarval crabs (Odum 1953; Costlow 1967; Adkins 1972; Palmer 1974), although the occurrence of mature males generally decreases with increasing salinity above 10 ppt (Music 1979). Holland et al. (1971) found that salinities within the range of 2-21 ppt had little effect on growth and survival of juveniles.

Temperature - Salinity Interactions

Optimal temperatures may vary with other environmental variables including salinity (Winget et al. 1976). Costlow (1967) found that survival of megalopae exceeded 70% at 20-30 °C when salinity was greater than 10 ppt, but never exceeded 50% at 15 °C. Larval development progressed normally at 25 °C when salinity was between 20.1 and 31.1 ppt, but did not progress normally beyond this salinity range (Williams 1965).

Habitat

The blue crab inhabits all areas of estuaries to some extent (Churchill 1919; Newcombe 1945; Palmer 1974; Music 1979). Weinstein (1979) found that shallow salt marsh habitats were important nurseries for juveniles. Mature males prefer creeks, rivers, and upper estuaries, but this may be a response to salinity rather than to other physical or biological features of the habitat such as refuge (Churchill 1919; Williams 1965; Music 1979). When not mating, mature females tend to remain in high salinity areas of lower estuaries and surrounding waters (Churchill 1919; Van Engel 1958; Palmer 1974; Music 1979).

The optimal habitat for small crabs is shallow estuarine water with bottoms of soft detritus, mud, or mud-shell (Adkins 1972). Larger crabs preferred deeper estuarine waters having harder bottom substrates.

Other Environmental Factors

Among the many stresses that affect blue crabs while they occupy nursery areas are pesticides, domestic and industrial wastes, alteration of currents, and destruction of marshlands (Adkins 1972). Blue crabs are adversely affected by a wide range of toxicants, including naphthalene (Pearson 1979; Sabourin 1982), dimethylnaphthalene (Mantel et al. 1985), methoxychlor (Bookhout and Costlow 1976), DDT (Commercial Fisheries Review 1946; Mahood et al. 1970), benzene (Saiff and Cristini 1982; Mantel et al. 1985), Kepone (Fisher et al. 1983), the organophosphate fenitrothion (Johnston and Corbett 1985), cadmium (Brouwer et al. 1984), and acid runoff (Livingston et al. 1976; Laughlin et al. 1978).

Effects from these toxicants range from sublethal responses, such as decreases in ion exchange efficiency at the gills (Sabourin 1982) and decreased growth (Mantel et al. 1985), to direct mortality (Commercial Fisheries Review 1946). Severity of the effects depends on the toxicant, concentration, time exposed, salinity, tidal cycle, age and molt phase of crab, and other variables. Many of the toxicants are bioaccumulated in blue crabs and passed to humans and other natural predators.

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16. Abstract (Limit: 200 words)

Species profiles are summaries of the literature on taxonomy, life history, and environmental requirements of coastal fishes and aquatic invertebrates. They are prepared to assist with impact assessment. The blue crab, Callinectes sapidus, occurs in lower reaches of freshwater rivers, estuaries, and coastal waters along the Atlantic seaboard and Gulf of Mexico, and the species supports the largest crab fishery in the United States. Chesapeake Bay provides the greatest production of blue crabs on the east coast. The blue crab's high abundance in estuaries, diverse feeding habits, and importance as prey for other marine animals indicate its important role in the structure and function of estuarine communities. Female blue crabs spawn in high-salinity lower estuaries of coastal areas; the resulting larvae are planktonic and develop into juveniles at 5 to 10 weeks of age. Juveniles gradually migrate into shallower, less-saline upper estuaries and rivers where they grow and mature at 1-2 yr of age. Mating occurs in the upper estuaries after which females migrate to areas having higher salinities. Growth and survival of blue crabs are strongly affected by water temperature and salinity, but tolerances vary with life stage. Larvae require temperatures of 20-30 °C and salinities of 10-30 ppt for proper development, but salinity and temperature tolerances are broad for advanced juveniles and adults. Blue crabs use nearly all areas within estuaries as nursery habitat, and crab populations are sensitive to changes in physical features of contamination of these areas.

17. Document Analysis a. Descriptors

Estuaries
Shellfish
Crustacea
Growth
Feeding
Spawning

b. Identifiers/Open-Ended Terms

Blue crab
Callinectes sapidus
Temperature requirements
Habitat requirements

c. COSATI Field/Group

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