A SUMMARY BRIEF FROM THE BLUE CRAB SPECIES TEAM

Ecosystem-Based Fisheries Management in Chesapeake Bay

Blue Crab

The blue crab, *Callinectes sapidus*, is a keystone species which plays an integral ecological, economic, and sociological role in Chesapeake Bay. The blue crab functions as both predator and prey in the Bay's complex estuarine foodweb and occupies a variety of critical habitats impacted by human activity. Blue crabs exhibit a complex life history, disperse between estuarine and marine habitats, and are particularly sensitive to fluctuations in environmental conditions. The robust fishery is intricate, divided between commercial and recreational sectors, a suite of fishing gear and effort levels, and several different markets. Concern over depressed population levels in 2008 resulted in Maryland and Virginia implementing a rebuilding strategy which includes limiting the fall harvest of migrating females, closing the winter female dredge harvest in Virginia, and extending the spawning season sanctuary. Following these new regulations, the female blue crab population increased by 200% from the period 2008 to 2009. While coordinated multi-jurisdictional, single-species management has been successful in recent years, fisheries researchers, managers, and policy makers recognize that blue crabs are particularly susceptible to ecosystem changes.

Figure 1. Blue crab (Callinectes sapidus). *Credit: Southeastern Regional Taxonomic Center, South Carolina Department of Natural Resouces.*

A holistic management framework which addresses the inter-relationships between the blue crab's foodweb, habitat, stock dynamics, and socioeconomics may yield a long-term strategy for managing blue crabs in an ecosystem context. The foundation of this approach is based on an understanding of the critical issues impacting blue crabs in Chesapeake Bay. As a critical first step for advancing EBFM for blue crabs, Maryland Sea Grant assembled a team of experts to develop detailed background and ecosystem issue briefs for five of the Bay's key species identified in the Fisheries Ecosystem Planning for Chesapeake Bay document, including the blue crab. The briefs describe how ecosystem issues impact the blue crab or the blue crab's ecosystem and recommends indicators which may be useful for management. Their findings are summarized here.

Stock Dynamics Issues and Drivers

Population Dynamics

The blue crab exhibits highly variable population dynamics, in part because of its complex life history during which different stages occupy very different habitats. Survival is unpredictable in the crab's early life stages and the species compensates for this by producing many offspring. Variable rates of disease, cannibalism, predation, and harvest, all contribute to natural adult mortality. Blue crab population dynamics are influenced by several critical factors in Chesapeake Bay, including: population connectivity, recruitment variability, a suite of environmental characteristics (drivers), natural mortality, and fishing exploitation. Understanding how these factors shape the population is integral to ecosystem management of blue crabs.

Population Connectivity

Different life stages are segregated among different habitats resulting in the formation of many subpopulations within the Bay (see Figure 2). Adult and juvenile blue crabs occupy estuarine habitats, but larval stages require warmer, saltier water; the last larval stage reinvades the estuaries to connect the two habitats. Two scales of population connectivity operate on blue crabs in the Bay: regional, which considers the potential for connectivity among the estuaries along the Atlantic coast of North America, and local, which considers the potential for connectivity among habitats within Chesapeake Bay. Data suggest that populations within each of the major estuaries along the Atlantic coast can be treated as distinct regional populations with minor larval exchange. As a result, the blue crab stock in Chesapeake Bay is managed as a distinct population. This population is considered well-mixed due to the larval oceanic phase of the life history. However, fidelity of juveniles to primary nursery habitats, their subsequent secondary dispersal from higher salinity settlement habitats to lower salinity habitats, and seasonal reproductive migration may all play an important role and impact spatial approaches to management.

Recruitment Variability

Recruitment connects generations within a population and is highly dependent upon the abundance of spawning females. Juvenile recruitment of blue crab in the Bay has been consistently low in recent years likely as a result of severe declines in reproductive females. Current management strategies targeting rebuilding of the spawning stock may elevate and stabilize juvenile recruitment, but these long-term effects have yet to be realized. At high levels of spawner abundance, cannibalism may play a greater role in regulating survival to the adult phase. However, while spawner abundance is low, the Chesapeake Bay blue crab population remains recruitment-limited.

Environmental Drivers of Recruitment

Seasonal variations in the physical oceanography of the system, stochastic environmental processes, and blue crab behavior all influence recruitment to Chesapeake Bay and play a key role in population dynamics. Larval retention in coastal waters and postlarval settlement depend upon seasonal oceanic flow and current patterns. Tidal influence, salinity, and other chemical cues may also impact larval settlement. Storm surges are thought to enhance recruitment by transporting large volumes of oceanic water into the Bay while slow moving storms may increase freshwater discharge and influence postlarval transport into the estuary. Because of the tight link to environmental factors, recruitment processes may be significantly altered by global climate change although to date, the potential impacts of this phenomenon are largely unexplored.

Juvenile and Adult Mortality

Predation, hypoxia, and disease represent the three biggest threats to blue crab survival. Habitat availability, loss, and fragmentation are associated with predator avoidance and survival in early blue crab life stages. Extreme hypoxia may trigger mass strandings of blue crabs. Several infectious diseases and parasites may limit blue crab fisheries in Chesapeake Bay; however, very little is known about quantitative impacts of disease on the blue crab population.

Fishery Impacts

Blue crabs are historically an important target species for Chesapeake Bay fishermen. However, the reliability of historical landings data impacts the ability of managers to fully understand the rate at which the commercial and recreational fishers are harvesting blue crabs in Chesapeake Bay. Recent declines in landings are likely explained by overfishing — specifically fishing pressure on the spawning stock — and fluctuations in ecosystem production due to regional hurricane activity. In 2009 the blue crab spawning stock was estimated to have increased by 200%, a success that may be attributed to the combination of management regulations designed to protect the female portion of the population and favorable environmental conditions.

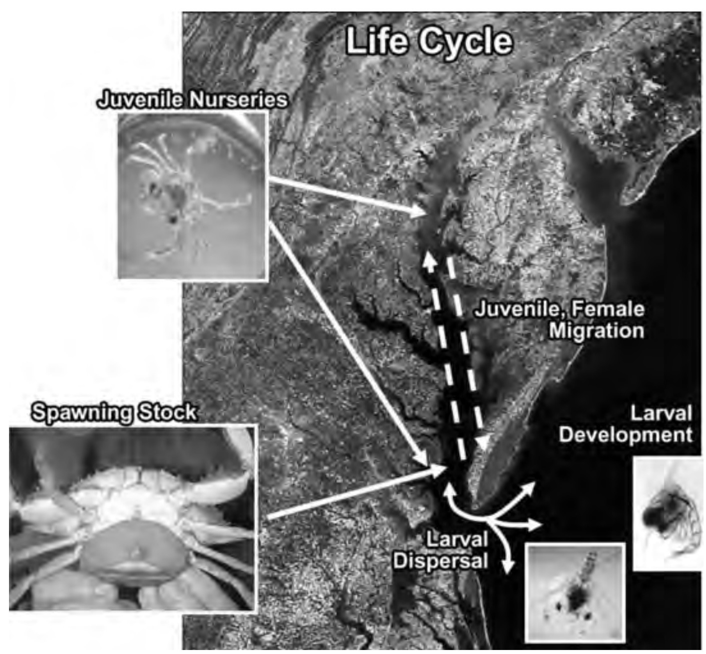

Figure 2. Complex migratory life cycle for the blue crab in Chesapeake Bay, showing the distribution of key life stages among the ecosystem distributed along the salinity and offshore gradients. Source: Hines et al. 2008.

Habitat Issues and Drivers

Climate Change Effects

Climate change is predicted to impact blue crab population in Chesapeake Bay in a variety of ways. These include direct effects on blue crab demographics, indirect effects on habitat and ecosystem attributes, and broad-scale weather effects on recruitment dynamics. In the Chesapeake Bay region, climate change may cause warmer winters and longer warm seasons which may result in more broods over the annual cycle. Additionally, the females may mature and mate earlier in response to climate change. However, small size at maturation increases vulnerability to predation and diminishes the number of offspring produced per brood. Further, predation and cannibalism on juveniles is also higher during warm seasons; therefore the juvenile portion of the population might also be negatively impacted by the extended warm temperatures predicted. Impacts to blue crab habitat may include changes in SAV species composition, loss of salt marsh acreage, oyster reef expansion, and increases in the extent and duration of areas with low dissolved oxygen.

Habitat Degradation

Hypoxia, habitat destruction, shoreline development, and chemical toxicants are all thought to be major issues impacting blue crabs and their habitat in Chesapeake Bay. Hypoxic and anoxic zones have been increasing, due in part to nutrient loading from agricultural runoff and an increase in impervious surfaces in the Bay watershed. Blue crabs avoid low oxygen by moving into shallower waters, which increases their susceptibility to fishing gear, predation, and agonistic interactions. Despite this avoidance, many may die during severe hypoxic events due to low oxygen levels. Seagrass loss resulting from deteriorating water quality limits its primary nursery habitat and may concentrate blue crab recruits into fewer nursery areas. This increases competition and cannibalism pressure and causes juveniles to disperse to less favorable habitats.

Fragmentation of seagrass patches has differential effects on predation, cannibalism, and survival of different age classes of blue crabs due to the high ratio of edge to interior area in small patches. Small patches support elevated densities and yield higher survival rates of juvenile blue crabs possibly due to more frequent recruitment encounters and food supply transport. However, smaller patches may also make juvenile crabs more prone to predation and cannibalism. Removal of natural marshes alters benthic communities and habitats in the nearshore subtidal zone. Residential and commercial shoreline development play a key role in this regard, replacing natural marsh habitat with inert structures including bulkhead and riprap used to stabilize shorelines. Blue crab prey and critical shallow water refuge are lost when natural marsh is removed resulting in lower abundances of juvenile blue crabs in the impacted areas.

Figure 3. Blue crab in submerged aquatic vegetation. Credit: Fish & Wildlife Service.

As benthic omnivores, blue crabs are particularly vulnerable to bioaccumulation of toxicants including heavy metals and chemical pollutants. There are a number of contaminants in Chesapeake Bay that impact blue crabs. Toxic effects include inhibition of digestion and nutrient uptake; retardation of growth, reproduction, and development; and impairment of nervous system functioning and endocrine disruption.

Collectively the impacts of habitat degradation may be minimized by limiting coastal development and controlling for agricultural runoff. Structured habitats for blue crab are comprised of various living resources including eelgrass, oysters, and salt marshes that are susceptible to disease. Wasting disease (eelgrass) and Dermo and MSX (oysters) are monitored by state agencies as part of restoration efforts for these species; however, there is no current monitoring program for salt marshes, which suffer from sudden wetland diebacks that impact crab foraging success.

Fishing Exploitation

Fishing pressure impacts living habitats by altering trophic interactions. Salt marshes may be threatened by a top-down trophic cascade spurred by the overharvest of blue crabs. Blue crabs are a key predator on marsh snails, which are the dominant grazers on salt marshes. Overharvesting may result in unchecked marsh snail grazing and a subsequent loss of salt marsh habitat. SAV and oyster reef habitat are two potential blue crab nursery areas. Both were recently jeopardized when cownose ray populations increased in response to predatory shark overharvest. Cownose ray excavations uproot eelgrass shoots and create bare patches, thereby increasing overall eelgrass edge habitat and fragmenting seagrass habitat. Finally, mobile fishing gears such as trawls and dredges reduce the complexity and refuge of blue crab habitats by reducing overall productivity and altering the diversity of infaunal benthic communities that serve as prey for blue crabs.

Foodweb Issues and Drivers

Fishing Exploitation

Fishing pressure also impacts predator-prey relationships within the blue crab foodweb. When the cownose ray population expanded, the impact yielded not only the habitat consequences discussed above, but more direct foodweb consequences. Rays both prey upon blue crabs and compete with them for clams and oysters. Finfish exploitation also changes the abundance of blue crab predators. Exploitation of blue crabs themselves decreases natural mortality resulting from density-dependent cannibalism. Finally, derelict or "ghost" crab pots which are lost in the process of fishing impose an unregulated fishing pressure on blue crabs as they continue to catch both blue crabs and finfish while untended in the water.

Predation

Predation is a limiting factor on blue crab population size in Chesapeake Bay and impacts population dynamics, survival, and reproduction. Predation varies seasonally, with latitude, and within and among habitats. The magnitude of predation impact on the blue crab population decreases with age and size — predation affects the smallest and earliest life history stages most greatly. The highest mortality from predation likely occurs during the pelagic phase of larval development when the larvae are targeted by a variety of planktivorous predators. Juvenile and adult blue crab mortality is contingent upon predation by a variety of finfish species including striped bass, particularly once intermolt crabs attain adult size as illustrated in Figure 4. Finfish predation appears to be most important in the higher salinity waters of the lower Bay where predator diversity and abundance is higher than in the upper Bay.

Cannibalism

Figure 4 highlights the significance of cannibalism by large crabs attacking small crabs, and by hard intermolt crabs attacking soft molting crabs. Stomach content analyses demonstrate that crabs comprise a significant portion of the diet of large blue crabs. Data suggest that 92% of juvenile blue crab mortality in estuarine habitats of upper Chesapeake Bay may be attributed to cannibalism. Shallow, nearshore waters and structurally complex habitats discussed previously provide refuge from cannibalism and are key nursery habitats for juveniles and important molting areas for adults.

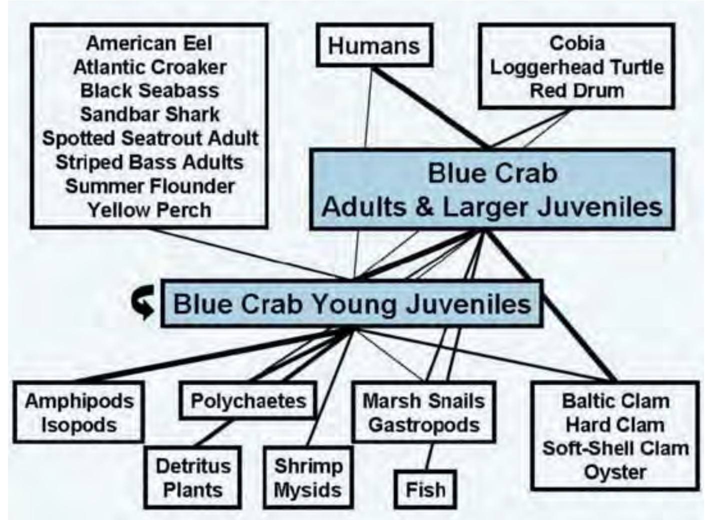

Figure 4. The blue crab foodweb illustrates that many predators consume blue crabs in nature. Cannibalism is a major source of natural mortality and several species of finfish also consume juvenile crabs. Adult and sub-adult blue crabs are preyed upon by only a small suite of predators, including humans. Source: EBFM Blue Crab Background and Issue Briefs.

Invasive Species

The Chesapeake Bay hosts a variety of non-native species that affect the blue crab through predation, habitat alteration, and competition. Blue catfish are of particular concern. Blue crabs are preyed upon by blue catfish and fishermen report that large portions of their catch from within the crab pots are consumed by blue catfish. At present the impact of blue catfish predation on the blue crab population is unknown. Three invasive crab species: the European green crab, the Japanese shore crab, and the Chinese mitten crab are highly effective competitors against blue crabs for prey resources and refuge habitat.

Two species of invasive flora, *Pragmites australis* and *Gracilaria vermiculophylla*, alter habitat although they have different consequences for the blue crab. *P. australis* may disrupt and alter marsh shoreline while *Gracilaria* may serve as alternative nursery habitat for juvenile blue crabs. Blue crabs also appear to limit the abundances of certain invasive species in the Bay such as the rapa whelk. It is hoped that blue crab predation may limit the down-stream spread of invasive zebra mussels should this species invade the Chesapeake Bay watershed.

Disease

There are numerous pathogens and parasites found in blue crab predators and prey in Chesapeake Bay — some of which cause significant mortality while others appear not to pose a threat. While parasitism in blue crab predators and prey likely impacts the blue crab population, these relationships are not well understood and likely vary both spatially and temporally. The extremely varied diet of blue crabs makes it difficult to predict the effect of a disease in a prey species, although a dramatic reduction in prey abundance may lead to a shift in blue crab diet composition.

Socioeconomics Issues and Drivers

Economic Value and Ecosystem Services

The blue crab is the most important fishery in Chesapeake Bay, providing livelihood and incomes for more fishermen than any other species. The blue crab is the major commercial fishery supporting local watermen incomes and is also the source of a major recreational fishery. Depending on the year, fishermen incomes may be 60% or more reliant on the blue crab. The fishery also supports a significant processing sector for crabmeat production. In Maryland, for example, there were 22 firms licensed to process crabmeat, producing a wholesale value of over $15 million. The role of the blue crab in providing other ecosystem services is probably most significant through its position in the food web and its reliance on other species such as SAV for nursery habitat and juvenile shelter.

Management Options and Models

The blue crab fishery in Chesapeake Bay is not managed via an overall harvest quota. Regulations are used to limit inputs in the fishery with the goal of limited harvests. Both Maryland and Virginia limit the number of licenses and the amount of gear that can be fished. However, these limits were set near the height of the fishery, so they are rarely binding. This is evidenced by the fact that both Maryland and Virginia engaged in license buybacks in 2010. Maryland will be conducting another buyback in 2011.

Equitable Management Alternatives

The blue crab fishery is not homogeneous throughout Chesapeake Bay. Fishing practices and the resulting harvest vary due to the complex ways crabs migrate and disperse throughout the Bay. Thus, harvest and input regulations that are either Baywide or statewide may impact fishermen in one area differently than in another area. For example, the crabmeat industry relies on the fall run of crabs in order to purchase them when the prices are lower than in the summer. They pasteurize or cryogenically freeze crabmeat to build inventory that will last to the spring when fresh crabmeat becomes available again. Thus, seasonal closures that cut days off the end of the season tend to be more costly to this industry segment compared with others. Developing regulations that protect the crab resource while not unduly creating a burden on one industry segment remains a difficult challenge. Management options should consider regional differences in crab availability, harvesting practices, and markets.

Competition with Imports

The globalization of seafood markets has had a significant impact on the Chespeake Bay blue crab fishery. Markets for Chesapeake Bay hard blue crabs have faced stiff competition over the last decade particularly from pasteurized crab meat imported from Asia and Latin America. There has been a marked increase in crabmeat imports in airtight containers into the Baltimore and Norfolk custom districts since 1995. Though of lesser quality in terms of taste, imported pasteurized crabmeat, used to make crab cakes, is less expensive, available year round, and has a long shelf life. As a result, the market for local hard crabs, particularly in the fall, has declined noticeably, even though crabs have been relatively abundant. Some of the downward pressure on domestic crab and crabmeat prices that would normally be exhibited due to the increase in imports has been ameliorated by significant market expansion, both geographically and through retail outlets. Nevertheless, a significant amount of imported product is sold in traditional domestic markets. The loss of market has forced watermen to shift harvesting to oysters earlier in the fall, thereby increasing pressure on that fishery.

Summary

Blue crabs are highly valued as a key predator, prey, and fishery within Chesapeake Bay. Ecosystem-based management of blue crab in Chesapeake Bay requires consideration of complex stock dynamics, habitat, foodweb, and socioeconomic issues as described in this brief (Table 1). Essential to the success of such a management shift is a theoretical framework from which to develop reference points for blue crab. Research that provides a detailed understanding of the compensatory ability of this species will provide the foundation for building a theoretical framework for ecosystem-based fisheries management for blue crab in Chesapeake Bay. Current efforts of the Ecosystem-Based Fisheries Management Project focus on enhancing single species management of blue crabs with ecosystem approaches and developing a long-term strategic ecosystem-based fisheries management plan.

Table 1. Critical ecosystem considerations for blue crab in Chesapeake Bay.

Ecosystem Stressor		Issues/Drivers/Stressors
1. Habitat	a. Climate Change	• Higher overall temperatures may promote blue crab growth rates as well as reduce crab size at maturity. • Less severe winters may yield increased winter survival of blue crabs and at the extreme, may allow crabs to grow and mature year round, increasing stock productivity. • Increased storm activity coinciding with larval settlement season may lead to increased settlement rates or major disturbances in juvenile dispersal patterns. • Loss of eelgrass and widgeon grass caused by high summer temperatures correlates with localized declines in juvenile blue crab abundance and survival. • Warming, high rainfall and stratification may increase extent and duration of hypoxia, reducing foraging resources and therefore distribution of blue crabs. • Warmer water temperatures may increase intertidal oyster abundance, restoring oyster reef habitat and providing additional blue crab food resources. • Sea level rise projections anticipate a loss of 161,000 acres of juvenile blue crab habitat in salt marshes by 2100.
	b. Habitat Degradation	• Hypoxia may alter blue crab distribution in the Bay, disrupting dispersal of all blue crab life stages throughout the estuary. • Habitat loss caused by hypoxic conditions leads to crowding and higher mortality rates due to increased potential for exploitation and predation on blue crabs. • Important seagrass habitat loss leads to increased resource competition and higher cannibalism rates. • Significant habitat alteration from shoreline development threatens blue crab populations via increased nutrient loading, the introduction of chemical contaminants and alterations to freshwater flow.
	c. Fishing Pressure	• Salt marsh communities may suffer from top-down trophic cascades if blue crabs are over harvested. • Annual gear loss (estimated 10-20%) results in ghost pots; derelict gear which remains in the water and actively traps blue crabs and finfish. • Trawl and dredge gear from other fisheries can reduce the complexity and refuge value of seagrass and oyster reef habitat for blue crabs.
	d. Disease	• Three critical juvenile blue crab habitats (eelgrass, oyster reef, and salt marsh) are diminished by disease.
2. Foodwebs	a. Predation	• Density-dependent cannibalism is a major factor affecting juvenile blue crab mortality. • Protecting nearshore waters and structural complexity of habitats may reduce cannibalism rates. • Finfish predation lowers survival rates of all life-stages of blue crab in the Bay.
	b. Prey	• Prey populations are destroyed during long periods of severe hypoxia. • Eutrophication, habitat alteration, and abundance of crab competitor species impact benthic prey abundance which may exert bottom-up control on blue crab populations.
	c. Fishing Pressure	• Fishery removals (predator removal) directly impact cannibalism rates due to increased relative abundance of all blue crab life stages. • Fishing pressure impacts blue crab and ecosystem level trophic dynamics as the blue crab is both a key predator and prey species in the Bay.
	d. Invasive Species	• Blue catfish may prey on blue crabs where the two populations overlap. • Some invasive flora may displace blue crab habitat while others offer alternative nursery habitats for juveniles. • Invasive crab species compete with blue crabs for prey resources and habitat but some are also prey species for blue crabs. • Blue crab predation is predicted to limit the down-stream spread of invasive zebra mussels.
	e. Disease	• Numerous pathogens and parasites found in blue crab predators and prey have differing impacts on blue crab populations.

Table 1, continued.

3. Stock Dynamics	**a. Population Dynamics**	• Blue crab genetic data indicate high diversity within population which makes quantifying and evaluating genetic exchanges among populations difficult. • Maintaining local connectivity for blue crabs within the Bay may require spatial management approaches.
	b. Recruitment Variability	• Declines in the reproductive spawning stock may have depressed juvenile recruitment in the Bay. • Changes in crab population size structure may impact recruitment as larger crabs are more important to reproductive output than smaller crabs.
	c. Environmental Drivers	• Stochastic environmental processes are major factors influencing inter-annual variation in the magnitude of blue crab recruitment to the Bay. • Hypoxia, temperature, and salinity conditions are significant drivers of blue crab mortality. • A variety of infectious diseases have been determined to contribute to blue crab mortality in the Bay.
4. Socioeconomics	**a. Ecosystem Services**	• Because of their significant place in the Bay ecosystem, blue crab may serve as an important indicator species for overall Bay health.
	b. Competition with Imports	• Large variability in commercial harvest rates creates uncertainty in the market, loss of local product contribution to the market and increased competition with imported product. • Increased understanding of factors contributing to catch variability would increase harvest efficiency and the ability to compete in the market.
	c. Equitable Management Options and Alternatives	• Spatial management options need to be developed further to ensure connectivity within the blue crab population is maintained. • Consideration should be given to many management options — including catch share programs, ITQs, community quotas, co-ops, and sector management — and how they may increase relative benefits to commercial and recreational fishermen, as well as the many part-time watermen that currently share resources with full-time watermen.

The Ecosystem-Based Fisheries Management (EBFM) Project for Chesapeake Bay *has been developed and coordinated by Maryland Sea Grant, working in partnership with the scientific community and the region's state and federal agencies (the Virginia Marine Resources Commission, Maryland Department of Natural Resources, Potomac River Fisheries Commission, Atlantic States Marine Fisheries Commission, District of Columbia Department of the Environment, NOAA, and EPA). The EBFM Project targets five key species identified in the Ecosystem Planning for Chesapeake Bay document, including striped bass, menhaden, blue crab, alosines, and oysters. The goals of the EBFM project are to build a sustainable mechanism for addressing ecosystem issues for fisheries within Chesapeake Bay and to develop ecosystem tools for use in ecosystem-based fishery management plans for the five key species (or group of species in the case of alosines). Currently the project involves 85 scientists, managers, and stakeholders from within and beyond the Chesapeake Bay region. For more information on Maryland Sea Grant's Ecosystem-Based Fishery Management Project please visit: www.mdsg.umd.edu/ebfm.*

Authors and Editors

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For More Information and References

Please visit our website for more information on the Blue Crab Species Team and all other information related to the Ecosystem-Based Fisheries Management Program at Maryland Sea Grant: www.mdsg.umd.edu/programs/policy/ebfm/

Further information and all references for primary literature can be found within the species briefs here: www.mdsg.umd.edu/programs/policy/ebfm/bioteam/bluecrab/

This publication was prepared by Alesia Read and produced by Maryland Sea Grant.

Publication Number
UM-SG-TS-2011-04

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A Maryland Sea Grant Publication
College Park, Maryland