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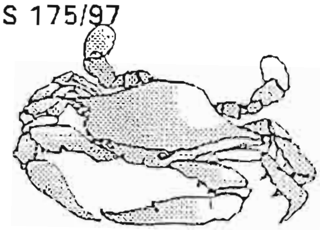
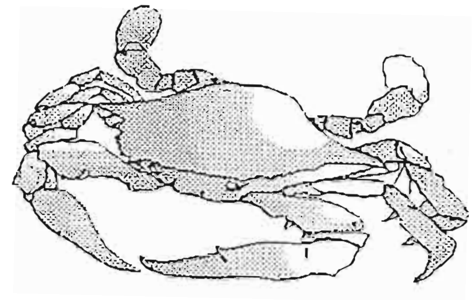


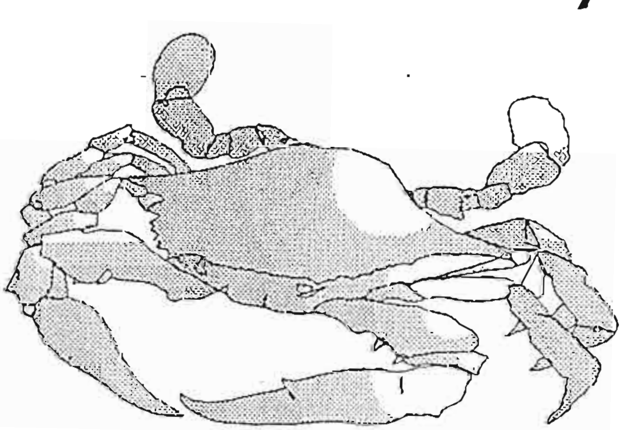


1997 Chesapeake Bay

BLUE CRAB

Fishery Management Plan

May 1997



Chesapeake Bay Program

FISHERY MANAGEMENT PLANS BACKGROUND

Chesapeake Bay fishery management plans (FMPs) are prepared under the direction of the *1987 Chesapeake Bay Agreement* and serve as a framework for conserving and wisely using fishery resources Bay fisheries traditionally are managed separately by Pennsylvania, Maryland, Virginia, and the District of Columbia. A Chesapeake Bay FMP provides a format for undertaking compatible, coordinated management measures among the jurisdictions. In addition, it creates a forum to specifically address problems that are unique to Chesapeake Bay. Habitat issues are particularly important. The goal of Chesapeake Bay FMPs is to protect the reproductive capability of a resource while allowing optimum harvest. The ecological, economic and sociological factors affecting the resource must be considered in the process. Objectives include:

* determine biologically appropriate levels of harvest;
* identify habitat requirements and develop necessary protection and restoration measures;
* monitor and assess the status of the resource using fishery-dependent and independent data;
* define management recommendations and identify effective enforcement procedures.

Development of a FMP is a dynamic, ongoing process. It begins with initial input by the FMP Workgroup, which is under the Chesapeake Bay Program's (CBP) Living Resources Subcommittee (LRSc). The FMP Workgroup consists of resource managers, scientists, stakeholders, and conservationists. They evaluate the biological, economic and social aspects of a particular resource; define problems and/or potential problems; and recommend strategies and actions to address the problems. Throughout development, FMPs undergo scientific and public review. The FMPs are adopted when signed by the Chesapeake Executive Council, the policy-making body of the CBP. Upon adoption, the appropriate management agencies begin implementing the recommended actions. In some cases, regulatory and legislative action must be initiated to fully implement a management action. In other cases, additional funding and staffing may be required. Progress of FMP implementation and status of the stock and fishery are updated annually for each FMP species. As the status of a stock changes, management strategies are changed accordingly. Amendments and revisions may be recommended by the FMP Workgroup (see Appendix A for FMP revision and adoption schedule).

1997
Chesapeake Bay
Blue Crab
Fishery Management Plan

Prepared by
Blue Crab Fishery Management Plan Workgroup
Living Resources Subcommittee
Chesapeake Bay Program

June 1997

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Chesapeake Bay Program

C H E S A P E A K E   E X E C U T I V E   C O U N C I L

ADOPTION STATEMENT
BLUE CRAB FISHERY MANAGEMENT PLAN

We, the undersigned, adopt the *1997 Chesapeake Bay Blue Crab Fishery Management Plan*. We agree to accept the *1997 Chesapeake Bay Blue Crab Fishery Management Plan* as a guide to conserving and protecting the blue crab resource for long-term ecological, economic and social benefits. We further agree to work together to implement, by the dates set forth in the Plan, the management actions recommended to address increased fishing effort, wasteful harvesting practices, stock assessment deficiencies, regulatory issues, and habitat degradation.

We recognize the need to commit long-term, stable, financial support and human resources to the task of managing the blue crab stock and addressing important research needs. In addition, we direct the Living Resources Subcommittee to periodically review and update the plan and report on progress made in achieving the plan's management recommendations.

Date June 4, 1997

CHESAPEAKE EXECUTIVE COUNCIL

FOR THE UNITED STATES OF AMERICA	Carol M. Browner
FOR THE STATE OF MARYLAND	Parris N. Glendening
FOR THE COMMONWEALTH OF PENNSYLVANIA	Tom Ridge
FOR THE COMMONWEALTH OF VIRGINIA	George Allen
FOR THE DISTRICT OF COLUMBIA	Marion Barry
FOR THE CHESAPEAKE BAY COMMISSION	W. Tayloe Murphy, Jr.

Acknowledgments

The *1997 Chesapeake Bay Blue Crab Fishery Management Plan* was developed under the direction of the Blue Crab Fishery Management Plan (FMP) Workgroup, which is under the Chesapeake Bay Program's Living Resources Subcommittee. The Blue Crab FMP Workgroup and Living Resources Subcommittee would like to acknowledge the following groups who significantly contributed to the development of this FMP:

- Chesapeake Bay Commission Bi-State Blue Crab Advisory Committee and its Technical Workgroup

- Chesapeake Bay Stock Assessment Committee and its Subcommittee

- Submerged Aquatic Vegetation (SAV) Workgroup of the Living Resources Subcommittee

- Habitat Objectives and Restoration Workgroup of the Living Resources Subcommittee

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FORWARD

This *1997 Chesapeake Bay Blue Crab Fishery Management Plan* serves four major purposes, and depending on interests, the reader may want to focus on the relevant sections. First, the Plan describes the nature and extent of the blue crab fishery on Chesapeake Bay. This is covered in the Background section, pages 7-14, and includes hard crab, as well as soft and peeler crab fisheries. Both commercial and recreational fisheries in the Maryland and Virginia portions of the Bay are described.

Second, the Plan provides a framework for state actions to manage the blue crab as a fishery. Stock status and analytical assessment, and concerns of the crab fishery are discussed on pages 14-23. The elements of management are spelled out in the provisions of the Plan on pages 52-74. Although the framework identifies a number of areas where changes in the fishery should result in management responses, no such actions would be triggered at this time from adoption of the Plan.

Third, the Plan incorporates an innovative effort to identify specific geographic areas that provide key habitat for the blue crab. Habitat requirements are identified on pages 5-7 in the Background section. Pages 27-29 describe Chesapeake Bay Program habitat protection and restoration goals and programs. Pages 69-74 of the management provisions of the Plan address habitat issues; and Appendix B details the decision matrix used to guide habitat recommendations. These habitat provisions are particularly important because, unlike other state and Federal fishery management plans, Chesapeake Bay plans are signed by the Chesapeake Executive Council on behalf of all applicable state and Federal authorities. This means that it is the responsibility of all executive agencies, not simply the fishery management agencies, to carry out and abide by the habitat protection and restoration provisions in the Plan.

Finally, the Plan outlines for the public the on-going scientific debate regarding the status of the blue crab stock, the life cycle, and the effects of management actions on both. Much of the discussion is related to studies still underway that are likely to be published in mid-1997. Once available, these reports will help expand the discussion on blue crab biology and management. The nature of the issues is outlined on pages 1-4 and 14-18 of the Background section; pages 29-31 regarding research needs; and pages 59-61 of the management section of the Plan, regarding stock status and fishery effort. As the policy implications of these scientific findings are analyzed, it may be appropriate to amend this fishery management plan to reflect any emerging consensus on currently unresolved issues.

EXECUTIVE SUMMARY

The blue crab stock behaves as one unit throughout Chesapeake Bay. A unified management approach among Bay jurisdictions was initiated with the development of the *1989 Chesapeake Bay Blue Crab Fishery Management Plan* (FMP). This FMP recognized the importance of the resource, identified areas of concern, and recommended strategies to stabilize fishing effort. Since 1989, new regulations have been implemented, commercial reporting has improved, and additional data have been collected. In 1996, a Baywide stock assessment was conducted and a targeting effort was initiated to define appropriate stock levels.

The *1997 Chesapeake Bay Blue Crab FMP* incorporates new information and management strategies. The overall goal has not changed substantially from the 1989 plan. The goal is: *to manage blue crabs in the Chesapeake Bay to conserve the baywide stock, protect its ecological value, and optimize the long-term utilization of the resource.* To achieve this goal, a sustainable and prudent level of spawning stock must be maintained; regulations must adequately protect the resource and optimize harvest; there must be fair allocation of the resource and minimal conflict among user groups; data must be collected to monitor and manage the fishery; research priorities need to be identified; submerged aquatic vegetation (SAV) should be protected and restored in lower Bay nursery areas; and water quality should be improved.

This Plan is flexible and responsive to new knowledge, changes in fishing mortality rates, and revised estimates of stock status. Major recommendations include: 1) restore and protect habitat and water quality; 2) maintain regulations designed to stabilize the fishery and modify them as necessary to achieve objectives of this Plan; 3) limit access to the fishery and lower the cost of harvesting crabs; 4) prevent an increased rate of exploitation; 5) design and implement a survey to estimate recreational catch and effort; 6) monitor the commercial fishery; 7) improve enforcement of regulations; and 8) develop socioeconomic data collection to assess the social and economic utilization of the blue crab resource.

A stock assessment conducted by the Chesapeake Bay Stock Assessment Committee (CBSAC), not yet published, indicates that stock abundance during the 1980s was high and has returned to average levels since 1991. Juvenile abundance has increased since the early 1970's, and additional studies in Virginia indicate this may be correlated with the recovery of submerged aquatic vegetation (SAV) in the lower Bay since the early 1980's. The blue crab fishery was characterized as fully exploited, based on an estimated rate at which crabs are removed by the fishery (fishing mortality rate) which allows for approximately 10% of the spawning stock (mature females) to escape harvest (measured as 10% of the spawning stock in the absence of a fishery). At present, there is no evidence of harvest exceeding sustainable limits (no recruitment overfishing). *This finding supports the need for caution. A fully exploited fishery should be managed to prevent any further increase in the rate of fishing mortality.* Since 1945, estimates of fishing mortality varied without significant trend; however, fishing mortality did increase from 1990 to 1994, then declined in 1995. The Baywide stock assessment supports the need for caution. In order to monitor trends and maintain the best possible understanding of the resource and the fisheries, the Baywide stock assessment will be updated in two years, and every five years thereafter. Additional studies will continue to be reviewed.

The CBSAC also evaluated effort in the Baywide commercial fishery. There has been a major increase in commercial fishing effort since 1945, coinciding with a decrease in catch-per-unit-effort (CPUE; example: crabs harvested per pot or yard of trotline). Most of this decrease occurred between 1945 and 1970. A decline in CPUE can indicate a declining stock. However, modeling efforts indicate that fishing mortality rates were stable over time and the decline in CPUE was not indicative of decreased crab abundance, but rather, catch was distributed among more pots as effort in the fishery continued to grow. Based on cumulative review of all the current information, this FMP strongly recommends caution, noting that gear and participation are currently at very high levels and any increase in fishing mortality could endanger the fishery and the resource.

Our understanding of the blue crab is far from complete. The massive transport of crab larvae out of the Bay and the subsequent return of variable numbers into the estuary may have uncontrollable effects on the availability of crabs from year to year. Crab abundance may also be affected by other environmental factors including the abundance of submerged aquatic vegetation (SAV) habitat. In addition, there is investigation underway exploring whether the level of harvest may be affecting the size distribution of crabs, resulting in a reduced total yield from the fishery (growth overfishing). This issue will continue to be revisited in the next update of the Chesapeake Bay Blue Crab Fishery Management Plan, the Baywide stock assessment and other investigations.

This plan sets forth general guiding principals based on the science as we know it today. The partners of the Chesapeake Bay Program, which include Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission, a tri-state legislative body; the U.S. Environmental Protection Agency (EPA), representing the federal government; and participating citizen advisory groups, will continue to work towards meeting the goals of this plan and furthering understanding of this complex animal. The plan is flexible and will be amended periodically as we learn more about the blue crab population dynamics and the fishery in Chesapeake Bay. The Chesapeake Bay Commission's Bi-State Blue Crab Advisory Committee (BBCAC), with diverse membership from Maryland and Virginia, will continue to be a valuable forum to assure complementary approaches to blue crab management among the jurisdictions and insure that research needs are identified and pursued so that actions are timely and based on sound science.

GOAL STATEMENT AND OBJECTIVES

The goal of the *1997 Chesapeake Bay Blue Crab Fishery Management Plan* is to manage blue crabs in Chesapeake Bay in a manner which conserves the Baywide stock, protects its ecological value, and optimizes the long-term use of the resource.

To achieve the *1997 Chesapeake Bay Blue Crab Fishery Management Plan* goal, the following objectives must be met:

1. Maintain the stock of mature adult males and females at a size that minimizes low reproductive potential (from harvest) as a cause of poor spawning success.

2. Maintain a clear distinction between conservation goals and allocation issues.

3. Minimize conflicts among user groups and between jurisdictions by coordinating management efforts throughout Chesapeake Bay.

4. Promote a program of education and public information to help the public understand the causes and nature of problems in the blue crab stock, its habitats and fisheries, and the rationale for management efforts to solve these problems.

5. Develop a Baywide regulatory process that provides adequate resource protection, optimizes the harvest, provides sufficient opportunity for recreational crabbers, and considers the needs of other user groups.

6. Promote harvesting practices that minimize waste of the resource.

7. Restore and improve habitat and environmental quality to increase growth, survival and reproduction of blue crab.

8. Identify and promote research to improve the understanding of blue crab biology, ecology and population dynamics.

9. Initiate and/or continue studies to collect necessary economic, social, and fisheries data to effectively monitor and manage the blue crab fishery.

SECTION 1
BACKGROUND

The blue crab, *Callinectes sapidus*, is a dominant bottom-dwelling predator in estuaries, lagoons and coastal habitats of the Western Atlantic, Caribbean and Gulf of Mexico (Williams, 1984). It is economically important throughout its range and has supported the largest single-species crab fishery worldwide over the past decade (FAO, 1990). The blue crab harvest from Chesapeake Bay accounted for over 50% of the national total during the late 1970s through the early 1990s (Orth and van Montfrans, 1990). It consistently outranks harvests from other shellfish species in Chesapeake Bay by weight and total dollar value. The recreational fishery also contributes to the economy of the region and is believed to be significant, though the value is currently unknown. Thus, the blue crab is an important natural resource requiring sound management to protect its long-term health and ecological, social and economic benefits.

Life History

Larval and Postlarval Phases

In Chesapeake Bay, larvae (zoeae) are released by mature females in high-salinity water near the mouth of the Bay (Van Engel, 1958; refer to life cycle in Figure 1). Larvae are transported to the continental shelf, where development proceeds for about 30-45 days, through seven or eight developmental stages (reviewed in Millikin and Williams, 1984; McConaugha *et al.*, 1983; McConaugha, 1988). Larvae feed on zooplankton and plant material (Truitt, 1939). High salinities in excess of 30 parts-per-thousand (ppt) are required for optimal development (Costlow, 1967). Physiologically, larvae are poorly adapted to undergo proper development at salinities much below 26 ppt, emphasizing the need for larval development in an oceanic environment.

Change to the postlarval (megalopae) stage occurs on the near-shore Atlantic shelf (Epifanio *et al.*, 1984). A retention mechanism has been postulated for blue crabs inhabiting western Atlantic estuaries such as Chesapeake Bay (McConaugha *et al.*, 1983). This process involves a southerly flow of water that traps and carries larvae south. At the same time, a counter-current and wind-generated surface flow move larvae in a northerly direction. The interaction between the southerly and northerly currents creates a circular pattern that prevent larvae from being swept too far from the entrance of Chesapeake Bay.

In many marine species, larval or postlarval abundance and settlement into nursery areas determines population size. Blue crab postlarval abundance, though highly variable in the Bay, generally follows a neap-spring tidal cycle, with brief periods of high abundance following spring tides by several days. Superimposed on this fortnightly pattern are peaks of abundance related to wind events that transport megalopae towards the coast and into Chesapeake Bay (Goodrich *et al.*, 1989). It is unknown if larvae hatched from adult females in adjacent coastal waters and nearby estuaries are swept into the Chesapeake Bay in significant numbers or how they may influence stock abundance. It is possible that weather events, such as hurricanes, may effect offshore currents and consequently impact the number and origin of crab larvae entering the Bay mouth during particular years.

Once within Chesapeake Bay, megalopae migrate vertically in response to light and tide. They utilize nocturnal flood tides to assist transport up the estuary to shallow estuarine nursery habitats (Olmi, 1993). During transport into the Bay, megalopae undergo physiological changes which prepare them for the metamorphic molt into the first juvenile instar (Lipcius *et al.*, 1990; Metcalf and Lipcius, 1992).

Settlement of blue crab postlarvae was assessed in the lower portion of Chesapeake Bay using artificial surfaces. Settlement occurs primarily between July and mid-November each year. It is characterized by episodic pulses during periods surrounding full and new moons (Orth and van Montfrans, 1987; van Montfrans *et al.*, 1990). The potential exists that these episodic settlement peaks, which account for more than half the annual total of blue crab postlarvae that enter into the Bay, may be the major determinants of adult population size. Low, but continuous, settlement over the summer and early fall and may also influence population size. Collection of postlarvae from surface water and near the bottom may provide a measure of planktonic abundance and postlarval settlement (van Montfrans *et al.*, 1990; van Montfrans *et al.*, 1995).

Early Juvenile Stages

Late premolt postlarvae settle in the lower Bay and utilize beds of submerged aquatic vegetation (SAV, also called Bay grasses) as nursery areas until approximately the fifth juvenile instar (Orth and van Montfrans, 1987; Pile *et al.*, 1996). Large juveniles migrate out of grass beds and are found in greatest abundance upriver, in lower bay tributaries. Eventually, they begin appearing in upper-Bay Maryland waters. This evidence suggests lower salinity areas are important for larger juvenile crabs, which ultimately grow and segregate by habitat. Large males generally occupy the upper reaches of tributaries and the Bay; whereas, females remain in higher salinity regions of the lower Bay and lower reaches of the tributaries (Hines *et al.*, 1987).

Adults and Reproduction

Blue crabs mature at approximately 12 to 18 months of age (Van Engel, 1958). Under current levels of fishing pressure, most crabs live from one to two years beyond maturity and the typical lifespan of a crab is up to 3 years. However, the maximum age may be as long as 5-8 years based on a few tag returns (Fischler and Walburg, 1962; Fischler, 1965; McConaugha, 1991; McConaugha, 1993; McConaugha, unpublished). Most mating occurs from May through October in lower- and mid-Bay habitats, where salinity preferences for males and females overlap. Female crabs molt preceding maturity at approximately 4.5 inches in carapace length (115 mm; measured from spine to spine; Knotts, 1989). The average size of an adult female is 6.1 inches (155 mm; Knotts, 1989; Hines *et al.*, 1987) and one hundred percent maturity is observed in female crabs 5.2 inches (130mm) and greater (Rothschild *et al.*, 1992). Growth of female crabs is believed to cease after the last molt preceding maturity (the terminal molt; Van Engel, 1958); however, there is evidence that some females may attempt to molt again (Havens and McConaugha, 1990; Rugolo *et al.*, unpublished). Adult female crabs found molting in the wild are rare. Documented specimen of mature female peeler crabs were preserved before molting was complete and is is not known whether those crabs would have survived to become hard crabs (Abbe, 1974; Casey, unpublished).

Male crabs "cradle" the females during the molt preceding maturity and guard them until the new shell hardens. Mating takes place while the female is in her soft-shell phase. After the pairs separate, males remain in lower salinities of the Bay and tributaries. Females migrate to higher salinities of the lower Bay, where they develop an orange, external egg mass beneath their aprons which may contain 750,000 - 8,000,000 eggs, depending on crab size (Prager *et al.*, 1990). The egg mass darkens over a two-week period as the orange yolk is consumed by the developing larvae. Larvae develop large, black eye spots as hatching approaches. Spawning is protracted and occurs over a period of one or two weeks. Spawning occurs from May to September, with a minor peak in June and a major peak in July and August (McConaugha *et al.*, 1983; Jones *et al.*, 1990). Individual females may spawn more than one time, depending on the amount of sperm transferred during mating (Jivoff, 1995; Prager *et al.*, 1990). Successive spawns may occur during the same year or females may overwinter before spawning again the following spring. Early reproductive females generally spawn prior to the coming winter; whereas, those maturing later spawn the following spring. Most males and many juveniles remain in lower salinities of the mid- to upper-Bay and tributaries and overwinter in the sediment. Females overwinter in the mid- and lower-Bay mainstem and at entrances of lower Bay tributaries.

Predator-prey Relationships

Blue crabs serve as both predator and prey in the benthic and planktonic food webs of Chesapeake Bay. Postlarvae in the water column (Olmi, 1993) are a food source for plankton feeders. Settled postlarvae and juveniles are eaten by eel, drum, spot, croaker, striped bass, sea trout and catfish. Some sharks and cownose rays feed on juveniles and larger crabs. The federally endangered species, Atlantic Ridley sea turtle (*Lepidochelys kempi*), migrates to the Bay every summer for its preferred food, blue crab. Cannibalism of young blue crabs by larger crabs is common (Mansour, 1992) and may regulate population abundance. Recent concern has been raised over the recovery of striped bass, which prey on blue crabs. Goshorn and Casey (1993) and Mosca *et al.* (1995) examined the relationship between striped bass abundance and blue crab landings in Chesapeake Bay and found no significant relationship. Instances where blue crabs are plentiful in the stomachs of striped bass are probably the result of opportunistic feeding (Booth and Gary, 1993), though the impact remains to be quantified.

Adult blue crabs feed on bivalves, crustaceans, fish, annelids, plants and detritus (Darnell, 1958; Tagatz, 1968; Alexander, 1986). Although the blue crab is an opportunistic predator that feeds on commonly occurring bottom dwellers (Laughlin, 1982; Mansour, 1992), recent research indicates that thin-shelled bivalves (e.g., *Macoma spp.* and *Mya arenaria*) are preferred food. Evidence suggests that blue crabs may control some bivalve populations (Lipcius and Hines, 1986; Eggleston, 1990; Eggleston *et al.*, 1992; Mansour and Lipcius, 1993). When bivalves become depleted, cannibalism on juvenile crabs increases (Mansour, 1992). Cannibalism may serve as a self-regulating control on crab populations, particularly during periods of high crab abundance or low alternative prey abundance (Mansour and Lipcius, 1993).

Biological Profile

Natural Mortality Rate	0.375 (Rugolo *et al.*, unpublished)
Fecundity	750,000 to 8,000,000 eggs per spawn, may spawn 2 to 3 times.
Longevity	Typical life span: about 3 years Possible maximum life span: 5 to 8 years

Egg and Embryonic Development

Egg Bearing Season	Females bearing external eggs ("sponges") occur May through September
Area	Egg bearing females are present infrequently in Maryland waters. Presence is limited at salinities of 15-20 ppt (e.g. between the mouth of the Potomac River and Wolf Trap Light), and most abundant in the lower Bay and the mouths of the Bay's southern rivers where characteristically higher percentages of females occur.
Embryonic Dev.	Hatching is limited between the mouth of the Potomac River and Wolf Trap Light, and increases substantially southward to the Bay mouth and slightly beyond. It may take up to 45 days at 16°C and 10-12 days at 26°C (60-79°F). The incidence of dark sponges, indicating late embryological stages, increases toward the Bay mouth.

Larval Development

Transport	Larvae are transported out of the lower Bay to the continental shelf where most larval development occurs.
Zoeal Development	Development of zoeae generally occurs from the southern end of the Bay out to 40 miles in the coastal ocean. The highest rate of growth and survival occur at salinities of 26 to 33 ppt and temperatures of 66-84°F (19 to 29°F). Survival is limited below 26°C and 20 ppt. Once transformed, the megalopa stage reinvades the Bay through wind generated transport, tides and changes in behavior.

Postlaryae and Early Juveniles

Recruitment	Generally occurs in the post-larval phase which invades estuaries from the coastal ocean thereby establishing the new year class.
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; late migration begins the following spring.

Biological Profile (continued)	
Subadults and Adults	
Location	Chesapeake Bay from Virginia Capes to tidal freshwater.
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 goal for selected Bay species, including blue crabs, is 5.0 mg/L monthly average; however, juvenile blue crabs are less tolerant than adult crabs and may need as much as 6.0 mg/L monthly average or more.

Habitat Requirements

Vegetated and Unvegetated Shallow Water Habitats

Submerged aquatic vegetation (SAV) and other shallow water habitats are utilized by blue crabs during postlarval settlement (Orth *et al.*, 1996), juvenile development (Orth and van Montfrans, 1987) and overwintering (Orth and van Montfrans, 1987; Montane *et al.*, 1994), as well as for protection during molting and soft shell phases of all size classes (Ryer *et al.*, 1990). Lower Chesapeake Bay SAV beds are most important for postlarvae and juvenile crabs (Heck and Thoman, 1981; Penry, 1982; Heck and Wilson, 1987; Orth and van Montfrans, 1987; Orth *et al.*, 1996; Wilson *et al.*, 1987; Montane *et al.*, 1994). SAV beds comprised of *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeon grass) fall within the salinity range of invading postlarvae. Orth *et al.* (1996) identified SAV beds within the range of postlarval blue crab settlement.

Several studies documented that postlarval and juvenile blue crabs prefer SAV and similar structural habitat over unvegetated shallow-water habitats (see Figure 15 for SAV bed locations). Field tests of postlarval response to mud, live oysters, and live eelgrass found a significant preference for eelgrass (Orth *et al.*, 1996). Samples taken over ten years from mud, sand, marsh creek, and SAV habitats found higher densities of blue crabs in SAV (Penry, 1982; Orth and van Montfrans, 1987; Montane *et al.*, 1994). Similarly, a study in Virginia's coastal lagoons found that densities of newly settled larvae in sunken mats of macroalgae (commonly called seaweed) are comparable to larval densities in lower Chesapeake Bay SAV beds (Brumbaugh, 1996). Small juvenile crabs are five times more abundant in SAV than in adjacent unvegetated habitats (Orth *et al.*, 1996). Calculations of the total areal coverage of SAV and unvegetated habitats in waters less than six feet (2 m) in depth were used to estimate juvenile abundance in each habitat. Total area covered by unvegetated bottom is approximately five times greater than that of SAV (Figure 2a). Juvenile crab density is approximately 30 crabs per square meter in SAV and only one crab per square meter in unvegetated habitat (Figure 2b). Despite significantly higher coverage of unvegetated bottom in Chesapeake By, more juvenile blue crabs were found in SAV (an estimated 2.7 billion crabs) than in unvegetated habitats (approximately 0.6 billion crabs; Figure 2c).

Postlarval and juvenile blue crabs prefer SAV and macroalgae over other available habitats because they provide structure where postlarvae and juvenile crabs can hide from predators. Studies in the lab and in the field show shallow water with no structural cover offers only partial refuge for small crabs (Dittel *et al.*, 1995). Predation rates of larvae in macroalgae mats are lower than in "unvegetated" or open habitat with no refuge and macroalgae may be an important settlement and refuge habitat in coastal areas (Brumbaugh, 1996). Predation of postlarvae and juvenile crabs in SAV habitat was documented (Orth *et al.*, 1996) and survival of young crabs was higher in SAV than in unvegetated habitats (Pile, 1993). Metcalf *et al.* (unpublished data; reviewed in Orth *et al.*, 1996) suggest that the high density of postlarvae and juvenile crabs in SAV habitat may insure that a greater proportion survive predation.

The geographic location of lower Bay SAV habitats offers another advantage to postlarvae as they enter the Bay estuary. SAV beds are situated in shallow water between marshy shores or creeks and deep open water. Grass beds are the first shallow-water refuges postlarvae encounter. The faster postlarvae can take refuge, particularly in areas where postlarval density is already high, the less likely they are to be preyed on.

Predation of juvenile crabs decreases with increasing crab size. Therefore, the faster crabs molt to larger size classes, the less likely they are to be preyed on. Research indicates that chemical cues from eelgrass are detected by postlarvae and induce molting to the first juvenile crab stage (reviewed in Orth *et al.*, 1996). In addition, molting frequency of juvenile crabs is higher in SAV than in adjacent marsh creek habitat (Ryer *et al.*, 1990). SAV probably provides the greater food availability needed by young, growing crabs (Orth *et al.*, 1984; Orth *et al.*, 1996).

Vegetative cover in much of the upper Bay is relatively sparse, when compared with the lower Bay. The Rhode River is a small tidal tributary on Maryland's lower western shore. Ruiz *et al.* (1993) found that adult blue crabs had significantly higher density in SAV beds in the Rhode River than in nearby unvegetated areas; however, there has been little SAV in the Rhode River in recent years. As juvenile crabs grow and disperse, they utilize other shallow-water habitats, as well as SAV. Tidal guts of small creeks and rivers in and around salt marshes provide shallow-water habitats for larger juveniles and mature crabs to feed and take refuge during molting (Orth and van Montfrans, 1987; Hines *et al.*, 1987; Thomas *et al.*, 1990). Coarse woody debris (pieces of wood over 2 centimeters or 0.8 inches in diameter) in shallow waters adjacent to forested riparian zones provide valuable shelter for large crabs, particularly during molting phases, when SAV is not present (Everett and Ruiz, 1993; Wolcott and Hines, 1989).

Habitat studies of American lobster, *Homarus americanus*, in Maine indicate that availability of larval settlement habitat is the factor that determines the population size. Habitat availability is even more important than larval entry into inshore waters, because larval entry is influenced by annual weather patterns (Wahle and Steneck, 1991; 1992). Young lobster prefer cobble bottoms, where they can hide from predators. They suffer high mortality in open habitats of sand and mud (Wahle and Steneck, 1991). Juvenile blue crabs may also require shelter to escape predation. Mortality of juvenile crabs is much higher in deep water and shallow water habitats devoid of vegetative cover offer only partial refuge. Based on current research, SAV is believed to be the primary structural habitat utilized by postlarvae and juvenile blue crabs in the lower Bay. Some investigation of the importance of oyster reef habitat for blue crab has been conducted; however, this habitat has been severely reduced in Chesapeake Bay due to overharvesting, poor water quality and disease (CBP, 1994a).

Dissolved Oxygen Content

Jordan *et al.* (1992; based on Funderburk *et al.*, 1991) recommended a monthly average dissolved oxygen content of 5 mg/L for target species in Chesapeake Bay, which included blue crabs. Blue crabs are tolerant of hypoxic (low oxygen) conditions; however, oxygen content less than 0.5 mg/L at 77° F (25° C) is lethal within 4.3 hours (Lowery and Tate, 1986). Crabs exposed to dissolved oxygen levels of 3.0 mg/L showed no mortality after seven days and less than 20% mortality after 25 days, at approximately 70° F (20° to 21° C); however, tolerance decreased with increasing temperature (deFur *et al.*, 1990). Figure 3 depicts Baywide distribution of areas where hypoxic and anoxic waters with a dissolved oxygen content of 3 mg/L or less frequently occurs (Chesapeake Bay Program monitoring data, 1985 to 1994).

Juvenile crabs may be less tolerant of hypoxia than adults (Stickle *et al.*, 1989). Juvenile mortality was 50% during 28 days of exposure to dissolved oxygen levels of 5.65 mg/L at 86° F (30° C) and juvenile crabs may require more oxygen than was recommended by Jordan *et al.* (1992) for other target species in Chesapeake Bay. Although dissolved oxygen tolerance limits for larvae and postlarvae are unknown, they are not as likely to experience episodes of low dissolved oxygen in the Atlantic Ocean or lower Chesapeake Bay.

Fisheries

Commercial Fisheries

The blue crab supports the largest single-species crab fishery worldwide in terms of landings (FAO, 1990). The crab catch has the highest value of any Bay commercial fishery and supports a recreational fishery of significant but undetermined value. Blue crabs are harvested as hard shell crabs, peeler crabs just prior to molting, and soft shell crabs immediately after the molt. Male crabs and immature female crabs are legal to harvest at 5 inches (127mm) in carapace width as hard crabs. No size limits exist for mature female crabs. The minimum size for peeler crabs in Maryland and the Potomac River is 3 inches; Virginia has no size limit on peeler crabs. Soft crabs must be a minimum size of 3 ½ inches (88mm) in Virginia, Maryland, and the Potomac River.

Hard Crab Fisheries

The hard crab fishery represents the largest commercial component of the crab fishery in Chesapeake Bay, both in terms of total dollar value and quantity landed. Annual commercial hard crab landings average 46 million pounds in Maryland (MDNR unpublished data, 1981 to 1995; Figure 4; preliminary landings for 1996, 36.1 million lbs.) and 40 million pounds in Virginia (VMRC unpublished data, 1981 to 1995; Figure 5; preliminary landings for 1996, 32.5 million lbs.), for a baywide total of 86 million pounds. Recently, Chesapeake Bay landings have fluctuated from a low of 53 million pounds in 1992 to a high of 107 million pounds in 1993. Baywide landings in 1995 were below average (68 million pounds), and landings in 1994 were only slightly below average (75 million pounds). Commercial reporting in Virginia and Maryland became mandatory for all commercial harvesters in 1993 and 1994, respectively. Comparisons of the new and old reporting system in Maryland give similar estimates of landings (MDNR unpublished data, 1994 to 1995). Virginia's voluntary reporting system provided landings estimated to be between 40 to 50% below actual landings (Vance, 1982; Rhodes and Shabman, 1994). Because Virginia's new reporting system is mandatory and collects data from all harvesters, it is believed to be more accurate (VMRC unpublished data, 1993 to 1995).

Principal techniques for commercially harvesting hard crabs include trotlines, crab pots and dredges. The crab pot is the most widely used gear throughout Chesapeake Bay and harvests approximately 60% of hard crabs landed in Maryland and over 80% of hard crabs landed in Virginia. Crab pots catch both male and female crabs; male crabs represent a greater proportion of the harvest in the upper portions of tributaries and upper Bay mainstem and female crabs represent a greater proportion of the harvest in southern Maryland and Virginia. Female crabs comprise approximately 40% of hard crab landings in Maryland (MDNR unpublished data, 1981 to 1995) and approximately 60% of hard crab landings from the crab pot fishery in Virginia (VMRC unpublished data, 1993). Nearly all mature females are fertilized and carry eggs either internally or during later stages as an external sponge. Sponge crabs represent a portion of the crab pot harvest in the lower bay in Virginia during summer months and make up a very small percentage of the population in Maryland, where they are illegal to harvest. In 1996, Virginia placed restrictions on the harvest of late stage sponge crabs bearing brown and black eggs. Early stage sponge crabs bear orange then yellow eggs.

Trotlines harvest approximately 40% of hard crab landings in Maryland (MDNR unpublished data, 1981 to 1995), where commercial crab pots are prohibited in tributaries. The Maryland trotline fishery primarily targets larger males in tributaries, though some females are harvested in the lower reaches of tributaries. In Virginia, crab pots are permitted in tributaries and trotlines are not commonly used.

The winter dredge fishery occurs exclusively in Virginia, in limited areas of the lower and middle Bay mainstem. Dredges target hard crabs that overwinter in deeper water and the harvest is estimated to consist of between 85% and 98% mature, inseminated female crabs (Van Engel, 1962; Schaffner and Diaz, 1988). The baywide winter dredge survey found 53.5% of adult female crabs overwintered within commercial dredge boundaries in 1993 (see Volstad *et al.*, 1994). Total harvest by the winter dredge fishery is small compared with the hard crab pot fishery. Dredge harvest averages approximately 7 million pounds and accounts for less than 20% of hard crabs landed annually in Virginia (VMRC unpublished data, 1981 to 1995); whereas, crab pot landings average approximately 32 million pounds (VMRC unpublished data, 1981 to 1995) and are comprised of approximately 60% female hard crabs (VMRC unpublished data, 1993).

Dockside values for hard crabs have increased over recent years (Figures 4 and 5). Dockside values in Maryland ranged from $18.0 million to $36.1 million during 1990 to 1995 (MDNR data; preliminary value for 1996, $25.2 million). In Virginia, the dockside value of hard crabs doubled between 1993 and 1995. Dockside values in Virginia range from $9.1 million to $30.6 million during the period 1990 to 1995 (VMRC unpublished data). Male crabs bring a higher price per pound than female crabs. The average dockside value of large male hard crabs (#1 males) in Maryland has increased from $0.73 per pound in 1990 to $1.29 per pound in 1995. As a result of their greater value over female crabs, male crabs have experienced higher fishing pressure, particularly in Maryland where they are most abundant (Casey *et al.*, 1991). However, the price of female crabs also has increased over recent years. In 1990, the average dockside value for female hard crabs in Maryland was $0.23 per pound; prices steadily increased to $0.71 per pound by 1995 (MDNR data). Price increases may be due to the discovery of Asian markets, which prefer egg-laden crabs and the increasing demand for female crabs in live markets, where male crabs have been priced out of many customers' range. Historically, the primary market for female crabs has been picking houses where crabs are steamed and the meat is picked and processed for container sale.

Soft and Peeler Fisheries

Annual landings of soft and peeler crabs average 2 million pounds in Maryland and 1 million pounds in Virginia (Figure 6; MDNR unpublished data, 1981 to 1995; preliminary 1996 landings in Maryland, 1.8 million lbs.; VMRC unpublished data, 1981 to 1995; preliminary 1996 landings in Virginia, 1.7 million lbs.). Available data suggest that landings of soft and peeler crabs have increased since 1987. Virginia, however, relied on a voluntary data reporting system prior to 1993. Virginia's mandatory reporting system, in place since 1993, has produced a more complete record of landings data and soft and peeler landings have averaged 1.6 million pounds through 1995 (VMRC unpublished data, 1993-1995).

Dockside values for soft and peeler crabs in Virginia also increased significantly in 1993 (Figure 6). Total dockside values from 1990 to 1992 averaged $1.7 million; from 1993 to 1995, total dockside values averaged $3.6 million (VMRC unpublished data, 1990 to 1995). Dockside values for soft and peeler crabs in Maryland have varied without trend and ranged from $1.6 million to $4.7 million during the period 1990 to 1995 (Figure 6; MDNR unpublished data, 1990 to 1995). However, the average price per pound for soft and peeler crabs steadily increased from $2.34 per pound in 1990 to $2.81 in 1995 (MDNR unpublished data, 1990 to 1995). Although soft and peeler crabs are a high value product, the process of holding crabs in shedding tanks is labor intensive and overhead costs are greater than for the hard crab fishery.

Scrapes, peeler pots and peeler pounds/traps are used for the capture of soft crabs and peeler crabs for the soft-shell and bait industries. Peeler crabs are also harvested as bycatch when they enter hard crab pots. Peeler pots are the primary gear in Virginia, however, harvest by peeler pots versus hard crab pots is unknown in Maryland. Virginia established a separate license for peeler pots in 1994. Peeler crabs are harvested throughout spring and summer and peak harvest occurs in the spring during "peeler runs" in both Maryland and Virginia. Crabs stop feeding when they are close to molting; however, unbaited peeler pots are attractive refuge sites for molting crabs. A common practice is to bait peeler pots with a live male "jimmy" crab to attract female crabs just prior to their molt before maturity. Baited trotlines and hard crab pots also attract male hard crabs cradling female peeler crabs. Soft and peeler crab harvest is not reported by sex, however, harvest is believed to be largely immature female crabs. The impact of this fishery on the blue crab population is difficult to assess due to inadequate reporting methods in the past. Peeler crabs held in shedding tanks after their initial harvest may suffer high mortality, if not cared for properly, and the extent of this mortality is currently unknown.

Commercial Fishing Effort

Baywide

Commercial fishing effort was estimated Baywide from 1945 to 1995 (Rugolo *et al.*, unpublished). Early data was obtained from *Fisheries Statistics of the U.S.* (Bureau of Commercial Fisheries and NMFS, 1945 to 1989), and later estimates were derived from fisheries statistics collected by the states (MDNR unpublished data, 1981-1995; VMRC unpublished data, 1973-1995). Effort was standardized to crab pots by dividing calculated values of catch per pot into the total harvest by all gears to give estimates of nominal effort baywide. Baywide, nominal effort increased five-fold from an estimated equivalent of 100,000 commercial crab pots at the start of the time series, to a range of 500,000 to 600,000 commercial crab pots in the last decade (Figure 7).

Maryland

Maryland has collected data on commercial fishing effort since 1981 and has seen increases in commercial effort, particularly since 1992. The average number of pots during any given month of the season in Maryland waters has grown from approximately 94,400 in 1991 and 1992, to approximately 130,000 in 1993 and 1994. The cause of this recent increase is seen in Maryland's commercial reports, where harvesters record the number of pots in the water each month. In 1991, most harvesters reported fishing 101 to 200 pots per person. In 1994 (the first year pot limits were in place in Maryland), more people reported fishing 201-300 pots and greater (Figure 8).

Increase in total gear fished and high effort extended over a greater portion of Maryland's crabbing season may explain the exceptional harvest in 1993 and the average harvests in 1994 and 1995. These high harvests were in spite of reduced abundance since 1991, as indicated by fishery-independent trawl and dredge surveys (Rugolo *et al.*, unpublished). Another possible shift in effort that has not been investigated is the movement from part-time and seasonal participants to full-time harvesters dependent solely on blue crab harvest. As alternative fisheries closed or became less profitable, license-holders may have shifted their efforts to harvesting blue crabs.

Three major license categories for commercial crabbing in Maryland currently exist. They include the Limited Crab Catcher License (LCC), which permits the use of trotlines and up to 50 crab pots; the Crab Harvester License (CB3), which allows for the use of trotlines and up to 300 crab pots; and the Tidal Fish License (TFL), which is a consolidated license for the harvest of finfish and shellfish, including blue crabs with trotlines and up to 300 crab pots. Both CB3 and TFL licensees may purchase additional allocations for the use of up to 600 pots (1 allocation) or up to 900 pots (2 allocations), with the assistance of one or two unlicensed crew members, respectively. Of the 6,646 commercial licenses issued in 1995 which permit crabbing, 73% (4,863) were LCCs, 3% (205) were CB3s, and 24% (1,578) were TFLs. TFL license-holders landed the largest portion of blue crab harvest in 1995. More specifically, TFL licensees permitted to fish up to 900 pots landed 44% of the total blue crab harvest. The second largest portion of blue crab harvest in 1995 was by LCC licensees (23%); CB3 licensees landed only 5.1% of the total blue crab harvest (Figure 9).

LCC license-holders are largely part-time crabbers. Recreational crabbers are not allowed to sell their catch or harvest more than one bushel per day for personal use. If a crabber wishes to sell any portion of the catch, then that person must purchase an LCC or other commercial license Some recreational crabbers who wish to harvest more than one bushel per day for personal use also hold LCC licenses. Harvest by CB3 license holders in Maryland with no allocations for additional crab pots was less than 10,000 pounds per person (average). The low harvest is an indication of part-time participation by a significant portion of license-holders (Table 1). When averaged, harvesters with a TFL license with no allocations harvested more than 10,000 pounds per person, indicating that a greater portion of these participants are full-time crabbers (Table 1). Licensees with one and two allocations in both CB3 and TFL license categories harvested significantly more per person and reflects greater full-time participation by licensees in these categories (Table 1).

In 1994, Maryland law prohibited the sale of commercial licenses after April 1, 1996, after which, a maximum allowable number of licenses must be determined. Depending on what level commercial licenses are capped at, no new licenses will be issued unless the number of valid licenses falls below the limit. Commercial licenses at the end of April, 1996, totaled 6,942 (4,872 LCC; 237 CB3; and 1,833 TFL). Despite the license moratorium, there is still potential for growth in the commercial blue crab fisheries. Across all license categories, only 60% of commercial license holders reported actually crabbing in 1995 (see Table 1 for participation by license category). This indicates that 40% of licensed commercial crabbers did not participate in the fishery. Non-participating license-holders represent a potential avenue for future growth. In addition, many license-holders authorized to fish up to 600 and 900 pots are not taking full advantage of their gear allocations. For example, during peak months of the crabbing season in 1995 (June through August), 420 TFL and CB3 licensees were authorized to use up to 900 crab pots. However, only 96 licensees reported actually using more than 600 pots in June; 81 in July; and 80 in August. Maryland's limited entry legislation expires in 1999 and if not renewed, the fishery will return to open-access with a two-year delayed-entry program.

Table 1. Participation and average harvest by license category for commercial crabbers in Maryland for 1995.

License Type	% of license holders who reported harvest	Average Lb./person
LCC	61%	2,659
CB3	58%	8,627
+1 allocation	72%	13,364
+2 allocations	67%	33,156
TFL	57%	10,917
+1 allocation	80%	24,087
+2 allocations	83%	52,053

Virginia

Virginia requires all commercial fishermen to purchase a Commercial Registration license for $150, prior to obtaining a license for a specific gear. The Commercial Registration license went into effect January 1, 1993, and a two-year delay process was also established for new entrants to the commercial fisheries. The Commercial Registration license identifies the commercial fishermen and facilitates the operation of the mandatory reporting system. In 1993, 3,837 commercial registration licenses were issued, 3,066 were issued in 1995, and 3,070 were issued in 1996 (VMRC unpublished data, 1993 to 1996).

Crab pots are currently the principal commercial gear for catching crabs in Virginia tidal waters and account for 80-90% of the hard crabs harvested (VMRC unpublished data). In 1996, 1,741 crab pot licenses were issued in Virginia, compared to 1,642 crab pot licenses in 1995 and 1,574 crab pot licenses in 1994 (Figure 10; VMRC unpublished data). Mandatory reporting data from 1993 to 1995 reveal that 50% of licensed commercial crabbers in Virginia use 100 crab pots or less per person (includes hard crab pots and peeler pots; VMRC unpublished data, 1993 to 1995). A 1992, socioeconomic study of Virginia's crab pot fishery estimated that 32.6% of licensed crab potters derived no income from crabbing and utilized their license privileges for personal use only (Rhodes and Shabman, 1994). Rhodes and Shabman characterized Virginia's crab pot fishery as, "...an extremely diverse fishery, with vessel ages ranging from new to over 60-years-old and with numbers of pots fished ranging from one to 600. The average boat length is 24 feet, demonstrating the small scale of most license holders. There is a relatively small group (about 16% of license holders) who are large scale operators, but general indications are that this is not a capital intensive fishery, with much high-tech equipment and many big operators." From 1993 to 1995, 20% of Virginia crab potters fished between 150 and 200 pots, 16% fished between 250 and 350 pots, and only 5% of crab potters fished between 400 and 500 pots.(VMRC unpublished data, 1993 to 1995).

In 1996, Virginia adopted restrictions on the sale of crab pot and peeler pot licenses, thereby limiting effort in the crab pot fisheries. A commercial peeler pot license was established in 1994; 506 licenses were issued and sales increased to 585 in 1995 and 739 in 1996 (VMRC, unpublished data). The Commercial Registration license fee discouraged some participants in Virginia's crab pot fishery and many participants purchased a recreational license in place of the commercial license. Figure 10 shows an apparent decline in the number of crab pot licenses in Virginia; however, when the amount of peeler and recreational pot licenses are included, as they were prior to 1994, the amount of pots used to harvest crabs is, in fact, still on the rise.

In 1993, a limited entry program was established for the Virginia crab dredge fishery. The 1993/94 dredge season was designated as a window of opportunity for anyone who wanted to participate in the fishery. Consequently, the number of licenses sold during this dredge season slightly increased. Beginning with the 1994/95 season, no crab dredge licenses will be issued to any new applicant until the number of licenses drops below 225. Licensees must be actively engaged in the fishery in order to retain their license. The number of crab dredge licenses sold in 1996 declined to 287, from a high of 375 in 1994 (Figure 11; VMRC, unpublished data, 1994-1995).

Other types of gear used to commercially harvest crabs in Virginia include trotlines, crab scrapes and crab traps (Figure 12). In 1996, only 20 commercial trotline licenses were sold, indicating that trotlines are not an important commercial gear in Virginia. Crab scrape license numbers have declined from a high of 447 in 1992, to 193 in 1995 and 205 in 1996 (VMRC, unpublished data, 1992-1995). Likewise, crab trap numbers have steadily declined from 3,023 in 1980, to 1,787 in 1995 and 1,849 in 1996 (VMRC, unpublished data, 1995). This decline in gear designed to target peeler crabs has apparently been redirected to the use of peeler pots, which have been increasing

Recreational Fisheries

Recreational gears include baited hand lines, mesh rings, collapsible traps, crab pots, trotlines and dip nets. The Maryland General Assembly is considering a bill during the 1997 Session that would require recreational crabbers to purchase a license, though a license would not be required to recreationally crab with handlines, dipnets, or crab pots from private property. Revenues would fund an extensive survey of the recreational crab fishery. From 1989 to 1993, Maryland required a license for noncommercial crabbers to harvest more than one bushel per day and no license was required to harvest up to one bushel per day. Noncommercial license-holders could not sell their catch but were permitted to use more gear than unlicensed sport crabbers. In 1993, 15,378 licenses were issued for noncommercial recreational crabbing in Maryland, more than double the number of licensed commercial crabbers (6,489). Reported landings by licensed noncommercial crabbers in 1993 totaled 6.1 million pounds. Maryland surveyed licensed and unlicensed recreational crabbers in 1990 and estimated 500,000 recreational crabbers made 2.5 million trips and harvested approximately 11 million pounds of crabs (Stagg *et al.*, 1992). Prior to the 1990 survey, Maryland contracted the National Marine Fisheries Service (NMFS) to include crabbing questions in the Marine Recreational Fishery Statistics Survey (MRFSS) during 1983 and 1988 (Table 2). The 1990 survey and the two MRFSS surveys were a combination of access intercept (where crabbers are interviewed in the field) and random telephone surveys. Estimates from the 1990 survey were calculated differently and may not be comparable to previous surveys.

Table 2. Results of recreational crabbing surveys in Maryland.

Year/Survey	Number of Participants	Number of Recreational Crabbing Trips	Recreational Harvest
1983/MRFSS		5.1 million	41.2 million pounds
1988/MRFSS		3.6 million	21.5 million pounds
1990/MDNR	500,000	2.5 million	11.5 million pounds

Historical estimates of recreational harvest in Virginia are not available. A recreational crab pot license was adopted in Virginia in 1993 which allows the use of up to five crab pots and unlimited harvest for noncommercial purposes. Recreational crab licenses may also be purchased for trotlines and one crab pound per person. Licensed recreational crabbers are required to report their catch to VMRC. Numbers of recreational crab licenses issued in Virginia from 1993 to 1996 are given in Table 3 (Figure 10 and 12; VMRC data). In addition to licensed recreational crab pot activity, anyone can use two crab pots in Virginia tidal waters with no license to take as much as one bushel of hard crabs and two dozen peeler crabs per day.

Table 3. Recreational crab licenses issued in Virginia, 1993 to 1996 (VMRC unpublished data).

Year	Crab pot license	Trotline license	Crab trap (pound) license
1993	361		55
1994	394	--	
1995	418	57	
1996	383	57	89

Stock Status

Abundance

Blue crab landings can widely fluctuate with changes in market conditions as well as changes in resource abundance. Crab abundance may, therefore, not always be adequately indicated by the level of landings. In lieu of fishery-dependent based assessments of resource conditions, fishery researchers have increasingly relied on data obtained from surveys independent of the fishery to monitor the resource. Fishery-independent surveys have been used to monitor the Chesapeake Bay blue crab population since 1956. The surveys use the same sampling protocol and effort is relatively consistent from year to year.

Virginia Trawl Survey

The longest-running survey for blue crabs in Chesapeake Bay is the Virginia trawl survey (VIMS/W&M data, 1955 to present). The survey is conducted in the James, York, and Rappahannock Rivers and Chesapeake Bay by dragging a trawl net. The survey has been conducted annually from April through November, since 1955. An index of crab abundance, expressed as the number of crabs caught per tow, is generated annually. Indices are generated by life-history stage from different segments of the data. For example, the adult female index is based on trawls during late summer and fall months. Effort in the Virginia trawl survey changed when the gear was made more efficient in 1972 (a tickler chain was added). To correct for this and make data from the two gear-types comparable, gear comparisons were used to generate a conversion factor.

Preliminary analysis of survey indices corrected for gear changes over time tracks what may be a long-term shift in the blue crab stock (Lipcius, unpublished). From 1956 to 1970, juvenile blue crab abundance in Virginia was high and fell in the early 1970s. Since 1975, juvenile crab abundance has shown a gradual and increasing trend back to pre-1970 levels (Lipcius, unpublished). Scientists from Virginia speculate that this trend in blue crab abundance is correlated with damage to lower Bay SAV habitat and thin-shelled clams (*Macoma spp.* and *Mya arenaria*), which blue crabs prey on, when Tropical Storm Agnes affected the region in 1972 (Lipcius *et al.*, 1995). Increasing juvenile crab abundance in Virginia appears to track recovery of lower Bay SAV beds in the years after Agnes. Adult female abundance from 1955 to 1970 in Virginia followed the same increasing trend as juvenile crabs and also declined after 1970.

However, indices have shown no increasing trend since 1972 and adult female abundance has remained low through 1995 (Lipcius *et al.*, 1995). Lipcius *et al.* (1995) suggest either intense natural mortality or fishing pressure is preventing crabs from entering the spawning stock. Catch statistics for the Virginia commercial dredge fishery, which harvests primarily mature females, also show a decline in winter harvests after 1972 (Figure 13a)..When commercial dredge landings are compared with adult female indices from Virginia's trawl survey, they correlate highly (Figure 13b) The winter dredge fishery is preceded by the fall crab pot fishery in Maryland and Virginia, which also harvests primarily mature females as they migrate down the Bay to overwintering sites (MDNR unpublished data, 1981 to 1995; VMRC unpublished data, 1993). Declining harvest by the winter dredge fishery (Figure 13a), despite increased effort (Figure 11), may be evidence that females are not surviving to complete their migration down the Bay, possibly due to earlier harvest in summer and fall, or that spawning stock abundance is at a lower level since the passage of Tropical Storm Agnes (Lipcius, unpublished).

Maryland Trawl Survey

A trawl survey was also initiated in Maryland in 1975 (MDNR unpublished data, 1975 to 1995). The Maryland trawl survey samples lower portions of the Chester, Choptank, and Patuxent Rivers, Eastern Bay, and Tangier and Pocomoke Sounds. Abundance patterns from Maryland's trawl survey, which is conducted May through October, often differ from Virginia. Survey indices in Maryland indicate that adult blue crab abundance (>119mm or 4.8 inches carapace width) was relatively high in 1977, low from 1978-1982, and was relatively high from 1983 to 1987. Since 1987 (1988-1995), crab abundance in Maryland has been moderate with the exception of 1992, which was low. Abundance of juvenile crabs (<60mm carapace width or <2.4 inches) in Maryland was low from 1978 to 1982 and fluctuated between high and moderate levels from 1983 to 1994, with the exception of 1987, which was low. Juvenile abundance in 1995 was low overall, however, surveys in late 1995 and the first two months in 1996 found unusually high numbers of juveniles (MDNR unpublished data, 1977 to 1996). There is speculation that the extraordinarily high abundance of juvenile crabs in several coastal states during this period was the result of tropical storms and hurricanes in the Atlantic which influenced nearshore ocean currents nearshore.

Chesapeake Bay Winter Dredge Survey

A third survey, the Chesapeake Bay Winter Dredge Survey, randomly samples the entire Chesapeake Bay and tributaries during winter months when crabs are inactive. A commercial-style dredge is used to dig into the Bay sediments where crabs overwinter. Because the dredge survey monitors the entire Bay, it provides an important and consistent way to measure Bay trends since it uses one method baywide. The Virginia and Maryland trawl surveys provide additional information on regional trends. However, the dredge survey only began in 1990, and the short data set does not show long-term trends in crab abundance. The blue crab population in Chesapeake Bay was estimated from the winter dredge survey by Rothschild and Sharov (1996). Numbers of crabs per meter sampled were extrapolated to estimate the crab population for the entire area of the Bay. The total population (all sizes and sexes) during the winter of 1995 was estimated to be 770 million crabs, of which 336 million were crabs one-year-old or greater

(>60mm carapace width; or >2.4 inches). These estimates are thought to be conservative when compared with total baywide landings.

Exploitation rates calculated from Virginia trawl survey data and crab pot survey data from Calvert Cliffs, Maryland (Abbe and Stagg, 1996), have also been used to back-calculate estimates of population size (Rugolo *et al.*, unpublished). In 1995, the population (reported as biomass) of crabs greater than 60 mm (2.4 inches) was estimated to be between 400.81 million crabs (169.43 million pounds) and 438.14 million crabs (185.12 million pounds). Since 1968, the average estimated population size from the same two surveys was 420.9 million crabs (181.10 million pounds) to 467.62 million crabs (201.91 million pounds) and the range was 236.74 million crabs (97.98 million pounds) to 678.65 million crabs (288.52 million pounds).

Mortality and Exploitation

Fishing mortality (F) is a measure of the *rate* at which blue crabs are removed from the population by the fishing activities of man. If F is constant over time, harvest will be greater during times of high abundance and less during times of low abundance. Generally, F is not directly measured. First, total mortality (Z) is evaluated and then natural mortality (M) is subtracted, leaving F (F=Z-M). Estimates of mortality are derived from evaluating changes in abundance over time, as measured by fishery-independent surveys. Fishing mortality may also be estimated from commercial landings. Exploitation (u) is related to estimates of mortality and is the *fraction* of a population that is removed by harvest (accounting for any concurrent natural mortality) over the course of a year (Ricker, 1975). Exploitation and rates of mortality may also be expressed as a percentage of the population (non-technical discussion in Wallace *et al.*, 1994).

Blue crab fishing mortality is estimated using various surveys in Chesapeake Bay. Rothschild *et al.* (1992) analyzed Baywide winter dredge survey data and commercial harvest. Estimated values of M ranged between 0.17 and 0.37 and F was as high as 4.5 (exploitation = 92% to 95% for given range of M). Rothshild *et al.* considered estimates of F between 1.6 and 2.0 likely (exploitation = 70% and 82% for given ranges of M and F). Utilizing the same data, Volstad *et al.* (1994) calculated exploitation rates of 50% to 92% for crabs over 2 inches (50mm) carapace length. Neither Rothschild or Volstad included commercial soft and peeler crab harvest or recreational harvest, which would increase estimates of F and u. Analysis of Maryland summer trawl survey data by Casey *et al.* (1991) estimated M between 0.1 and 0.5 and F between 1.3 and 2.0 (exploitation = 70% to 73%). The above estimates of mortality were made by evaluating changes in abundance between presumed year classes (based on observed size classes) and may be biased where age of the animal is not well defined.

Chesapeake Bay Stock Assessment

In 1996, the Chesapeake Bay Stock Assessment Committee (CBSAC), of the Chesapeake Bay Program, conducted a baywide stock assessment for blue crab (Rugolo *et al.*, unpublished). Forty years of data from four fishery-independent surveys were analyzed; these include the Maryland Trawl Survey, the Virginia Trawl Survey, the Baywide Winter Dredge Survey, and a crab pot survey off Calvert Cliffs, MD (1968-1995; Abbe and Stagg, 1996).

Mortality

Fishing mortality rates were calculated based on crab length frequencies from fishery-independent surveys (length measured from spine to spine). Length-based estimates for Z ranged from 0.875 to 1.54 (A = 58% to 78%) over the 40-year data series. Subtracting M (0.375; 20% to 25% annually when Z = 0.88 to 1.54) provided estimates of fishing mortality rates (F). Since 1956, fishing mortality rates appear to have varied without trend (range. 0.50-1.16; exploitation rate = 33%-59%), despite a five-fold rise in fishing effort in the commercial fishery since 1945. A slight increase in fishing mortality was noted in the early 1990s, however, there was a drop in 1995. Fishing mortality rates in recent years (1990 to 1996) have been around 0.9 to 1.0 (exploitation rate = 51% to 54%).

The CBSAC stock assessment found no indications of recruitment overfishing. Indices of abundance from the four surveys were expressed as the number of crabs caught per unit of effort (i.e. crabs per trawl, crabs per square meter sampled). Indices of abundance from surveys indicate that the blue crab population was high in the late 1980's through 1991 and, since 1991, has returned to levels typical during years prior to the 1980s. Juvenile recruitment indices in the 1990s have been increasing, further indicating that recruitment overfishing is not occurring. Given the steady state of exploitation and recruitment for 40 years, it appears that the blue crab has been able to withstand annual exploitation rates up to 59% (F = 1.16).

Threshold Limit for Fishing Mortality

The blue crab fishery was characterized by the CBSAC stock assessment as fully exploited. This description is based on a threshold limit fishing mortality rate that allows for at least 10% of the spawning stock (measured by weight) to escape the fishery to reproduce ($F_{10\%}$; measured as 10% of the spawning stock in the absence of a fishery). The target rate should be set at a safer level. The selected $F_{10\%}$ of 1.2 (exploitation rate = 60%) should be a maximum limit. Results indicate that fishing mortality rates for blue crab in Chesapeake Bay have remained at or below the estimate of $F_{10\%}$.

Stock assessment is an analytical process that incorporates understanding of the life history of the species and historical performance of the fisheries. The status of "fully exploited" includes the assumption that the maximum attainable age of the blue crab species in the absence of fishing pressure is eight years and that female crabs cease spawning at age six years (based on present estimates of reproductive ability). Changes to these variables produce results that are less protective of the resource. Selection of the maximum age of eight for blue crab produces higher estimates of fishing mortality rates at $F_{10\%}$. The selection of age eight is based on the results of a historical blue crab tagging study (McConaugha, 1991; 1993) which resulted in several recoveries of crabs age five and six-years-old and one recovery in 1995 corresponding to a 7.5 year-old crab. Calculations based on previous estimates of maximum age at six and four years produced higher estimates of threshold mortality rates at $F_{10\%}$. These previous estimates would produce management practices that are less protective of the resource. Although corresponding estimates of actual fishing mortality rates were also higher, the assumption of a shorter life span implied that the stock could withstand a higher level of fishing mortality than had been measured in the recent past.

Fishing Effort and Gear Efficiency

Since 1945, deployment of more gear has not resulted in any proportional increase in fishing exploitation rates. This has been explained by the catchability (q) of the crab pot (the ability of the gear to catch crabs or the catch efficiency of the gear). A crab pot is capable of attracting crabs presumably within some constant radius (i.e. crabs beyond a certain distance will not be attracted to the bait) and, of the crabs within range of the gear, some will not be attracted to it for various reasons. Crab pots and trotlines are static gears which require that crabs approach the gear voluntarily (as opposed to active gears such as trawls and dredges, which actively capture animals and prevent them from escaping). Some crabs may choose not to approach a pot or trotline because they are not searching for food or they may avoid pots saturated with crabs, which can be cannibalistic. Crab pots within close proximity may compete with each other. Also, a certain portion of crabs may be able to escape the gear. Small-scale studies in Maryland, where blue crabs were marked and left abandoned in pots, found that some crabs were able to find their way out of the gear over time, depending on the time of year (Casey and Wesche, 1981).

Catchability (q) measures the average *portion* of a fish stock that a unit of gear (i.e. one crab pot) is capable of catching (i.e. the mortality rate, F, per unit of fishing effort) and should not be confused with CPUE. CPUE measures the *number or weight* (biomass) of crabs caught per unit of gear (for example, Figure 7 is expressed in pounds per pot). CPUE may be influenced by changes in crab abundance (for example, higher abundance means more crabs are available to be caught); whereas, catchability measures the portion of a stock that will be captured, regardless of abundance. CPUE can also be influenced by catchability. Increased effort in a fishery can affect catchability in one of three ways: 1) catchability may remain the same and more gear will result in a greater total harvest; 2) catchability may increase as the probability of crabs encountering the gear increases, also resulting in a greater total harvest; or 3) catchability may decrease as the gear competes with each other to catch the same portion of crabs, resulting in stable harvest in spite of increased effort. In scenario one, CPUE would only fluctuate as a result of changes in stock abundance and could be used as an indicator of stock health. In the second scenario, CPUE may increase regardless of stock abundance and can give a false indication that the stock is healthy. In scenario three, CPUE may decrease and give a false indication that the stock is declining. The CBSAC stock assessment estimated nominal fishing effort in the Chesapeake Bay blue crab fishery. Nominal fishing effort (f) is the unit of effort measured in time (days fished) and number of gear units. Since 1945, nominal fishing effort has risen fivefold; whereas, catchability (q) has declined. This has resulted in decreased CPUE (Figure 7) and the steady state of fishing mortality (F).

Economic Implications

Although the results of the stock assessment are positive for the current status of the blue crab resource, they do indicate that the resource is not being harvested in the most economical manner. Prior to 1994, blue crab fisheries in Maryland and Virginia were open access and had only limited obstacles to obtaining a license to participate in the commercial harvest of blue crabs. Rising numbers of participants since the 1940s has resulted in increased competition between participants and overcapitalization of the commercial fishery. As competition for the same number of crabs has intensified, the catchability of the gear has decreased and CPUE declined. In its current state, participants in the fishery are deploying more gear and working harder to catch an equivalent portion of the available stock.

Problems and Concerns

Fishing Pressure

Maximum Sustainable Yield (MSY) is defined by Ricker (1975) as *the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.* In effect, it is the greatest poundage of blue crabs that can be removed from the bay without reducing the capacity for the crabs to replenish the population to the same level for harvest in future years. When MSY is exceeded and stock replenishment is at risk, the resource is said to be recruitment overfished. Larkin (1977) argued MSY is not attainable on a sustainable basis. Often, MSY is modified for optimum yield (OY) by factoring in economic, social or ecological issues and OY is frequently used as justification for harvest exceeding MSY (National Academy Press, 1994). The collapse of certain fish stocks has been attributed, in part, by Ludwig *et al.* (1993) to management based on MSY estimates.

In addition to Ricker's (1975) definition of MSY, he notes that for species with fluctuating recruitment, the MSY is dependent on yearly abundance. The size of the blue crab stock is initially controlled by entry and settlement of blue crab postlarvae in nursery habitats (i.e., the survivors of the larval phase) and abundance can fluctuate annually. To prevent recruitment overfishing of stocks with variable abundance, as has occurred in many other exploited species (Holmes, 1994), it may be necessary to take fewer fish in some years. For managers to apply such a method, abundance must be predicted with confidence prior to the harvest season. Given the past failures of MSY (Ludwig *et al.*, 1993; Larkin, 1977) and the scientific uncertainty of some parameters used in the current stock assessment of blue crab (Rugolo *et al.*, unpublished), a conservative approach to blue crab management in Chesapeake Bay is recommended.

Growth Overfishing versus Recruitment Overfishing

Two types of overfishing, growth and recruitment overfishing, are defined by this management plan. Growth overfishing occurs when the losses in weight (biomass) from harvest and natural mortality exceed the gain in weight due to reproduction and growth. Hence, there is a net loss of biomass from one year to the next (NMFS, 1993) which is characterized by a decreasing proportion of older and larger individuals in the catch. Growth overfishing may continue without any visible effect on the number of individuals in a stock (i.e. reproduction remains high enough to replace individuals removed by the fishery); however, if fishing pressure is too high, it can result in recruitment overfishing. Recruitment overfishing is the rate of fishing above which recruitment to the exploitable stock is reduced and is characterized by a reduced spawning stock and generally very low production of young year after year (NMFS, 1993).

The decline in the blue crab population in Chesapeake Bay in the early 1990s, along with increased fishing effort and decreased CPUE in the commercial fishery since 1945, were believed to be symptomatic of a stock in the process of being recruitment overfished. However, the decline in CPUE occurred between 1945 and 1970 and fishing mortality rates since 1945 vary within a relatively constant range and appear to be stable (Rugolo *et al.*, unpublished). When long-term trends were analyzed, blue crab abundance was unusually high in the 1980s and the reported decline from 1990 to 1995 was a return to average levels of abundance. Abundance of juvenile crabs during this same time period has been increasing and indicates that recruitment overfishing is not occurring. In the case of blue crabs, greater effort has produced stable landings and no increase in the portion of the stock being removed by the fishery (fishing mortality).

In addition to threshold harvest limits ($F_{10\%}$), the level of F at which the greatest yield per recruit is seen from the fishery (F_{max}) was estimated for Chesapeake Bay (Rugolo *et al.*, unpublished). Yield per recruit refers to the size or weight per crab harvested and larger crabs generate a higher yield per recruit. Current levels of F between 0.8 and 1.0 exceed the estimated F_{max} of 0.64. Currently, there is not consensus among Bay scientists surrounding the implications of growth overfishing. The debate is complex and combines the concerns of economic stability of the fishery and the biological well-being of the resource. A recent analysis by Abbe and Stagg (1996) cites growth overfishing as the probable cause for an observed and gradual decline in the mean size of male crabs 5 inches and greater from 1968 to 1995. Although the decline is reported to be statistically significant ($p=0.001$), there is also a high level of variation in mean size over time ($r^2=0.356$). Given the variation, mean lengths of legal size male crabs in this study decreased by approximately 10 mm (0.4 inches) over the time period. Rugolo *et al.* (unpublished) acknowledge that, while current levels of F are in excess of F_{max}, evidence of growth overfishing (i.e. decreasing size) should be coupled with an increase in fishing mortality rates over time. Results of the baywide stock assessment did not detect any increasing trend in F from 1956 to 1990 and the rise in F seen between 1991 to 1994 did not exceed $F_{10\%}$. Furthermore, from a management perspective, the present level of effort and participation in the fishery would have to be reduced to levels measured in 1956, or less than one-sixth of current levels, before an increased yield from the fishery could be obtained.

From a risk-averse perspective, there is concern that current levels of F not only exceed F_{max}, but are approaching the recruitment overfishing threshold ($F_{10\%}$). Measured attempts to scale down effort could provide a buffer against recruitment overfishing, in addition to improving the performance of the fishery. Because there is no current danger of stock collapse at present levels of fishing mortality, this could be done gradually, over time, and in consultation with the industry. Adopting a target fishing mortality rate such as F_{max} as a reference point would move the fishery further away from the recruitment overfishing level, providing a buffer for errors in estimates of limiting levels of exploitation, while simultaneously providing yield per recruit benefits. The debate surrounding growth overfishing is constructive and the issue will continue to be revisited in upcoming years as the baywide stock assessment is updated and additional studies become available.

Target Setting Task Force

In addition to the CBSAC stock assessment, the Chesapeake Bay Program (CBP) formed a Target Setting Task Force to develop methods for measuring the progress of efforts to protect, restore, and enhance selected Bay species. Targets can help define the status of the stock and its probable status under alternative management strategies. Blue crab targeting efforts focus on an exploration of two areas: environmental factors that affect stock size and recruitment; and the spatial and temporal patterns of blue crab by life history stage. The results are anticipated to provide indices and life history models that are region-specific and sex-specific and explore stock-recruitment relationships. The target setting exercise for blue crab should be complete in 1998 and will provide managers with another tool to monitor stock status trends and respond with management measures which are effective for protecting the resource and the fishery.

Female Harvest

The number of crabs recruiting to Chesapeake Bay in any given year relies, in part, on the size of the spawning stock from which the young originated. The spawning stock includes all females that survive natural and fishing mortality to reproduce. It is not limited to those crabs possessing an egg mass, nor to those mated females that do not show eggs. Except during molting, when crabs are vulnerable to predation, juvenile females larger than 80-100 mm in carapace width (approximately 3.2-3.9 inches) suffer relatively low natural mortality and should reproduce if they are not removed by the fisheries.

Portions of the potential spawning stock are removed from the population by different segments of the fishery. When regulating harvest and effort, due consideration should be given to the fisheries and their respective harvest of potential spawning stock. The crab pot fishery lands the greatest portion of female hard crabs (MDNR unpublished data, 1981 to 1995; VMRC unpublished data, 1993). The extent of female harvest by the soft and peeler fishery is unknown.

Male Harvest

Insemination rates of female crabs and the amount of sperm they receive from male crabs during mating may be dependent on the abundance and size of male crabs in the population. Insemination rate is the proportion of females in the population that successfully mate during their terminal molt to maturity. The sperm that a female receives at the time of mating, which is during the maturation molt, is stored for many months in paired storage vesicles (spermathecae) until they produce broods of eggs during the spawning season. If female blue crabs mate only one time and with only one male, as published by Van Engel (1958), the amount of sperm she receives must last for her lifetime of brood production. If females fail to find a suitable mate at the time they are ready to mate, they are thought to be unable to contribute to the spawning stock. In addition, a small male may not be able to transfer enough sperm for the female to fertilize all of the eggs she is capable of producing.

Research indicates that fishing pressure has probably not affected insemination rates of female blue crabs, which are generally high (>95%) in Maryland and Virginia portions of Chesapeake Bay, South Carolina, and Florida (Wenner, 1989; Jivoff, 1995). However, in the upper Chesapeake Bay, the amount of sperm that mated females receive is highly variable among individuals and among years, with large proportions of newly mated females having spermathecae which were only partially full (range 20-100% full) during 1990 to 1994 (Jivoff, 1995). Controlled laboratory and field experiments show that variation in the amount of sperm received by a female blue crab is regulated by male size, sex ratio, and short-term mating history (Jivoff, 1995). Small males transfer less sperm than large males, and females receive less sperm when small males are over-represented in mating pairs (Jivoff, 1995; in press). More sperm is transferred to females in crab stocks with a sex ratio dominated by males than when males are proportionately less abundant (Jivoff, 1995). Recently mated males are less willing to mate again and, when they do re-mate, they transfer less sperm than males that have not mated recently (Jivoff, 1995; in press). Exploitation of male crabs in other fisheries has demonstrated effects on the amount of sperm that females receive (Paul and Paul, 1992; Sainte-Marie and Lovrich, 1994; Sainte-Marie *et al.*, 1995). Consequently, it is important for managers to consider not only the impact of harvesting mature female crabs, but, also, the influence on males in the population. Male reproductive capacity can have a significant effect on the lifetime reproductive success of females.

Wasteful Harvesting Practices

Harvesting practices are identified as wasteful when they decrease economic yield from the fishery or make crabs unavailable for future harvest. For example, buckrams, which are crabs that have recently shed but have not yet grown into their new shell, are light weight and yield less meat than fully developed hard crabs. Small size limits in the soft and peeler fishery results in a greater number of crabs harvested per pound of meat. Small crabs contain less meat and, although they have high market value, their harvest may not maximize yield from the resource. The consumer preference for large softshell crabs shipped into Maryland demonstrates a market demand for large softshell crabs (Uphoff *et al.*, 1993). Increased size limits could make Chesapeake Bay's product more competitive.

Blue crabs are cannibalistic predators and sublegal-sized crabs retained in crab pots with larger crabs experience high mortality rates (Eldridge *et al.*, 1979). Cull rings installed in the mesh of a crab pot provide a circular opening that allows undersized crabs to escape. In South Carolina, Eldridge *et al.* (1979) tested 2.4 inches and 2.5 inches diameter cull rings in standard crab pots for small crab escape efficiency. Pots with two 2.4 inches rings reduced sublegal crab catch by 62% and pots with two 2.5 inches rings reduced sublegal catch by 76% when compared with no cull rings. Raynie and Casey (1992) investigated the use of one to three cull rings, 2.25 inches in diameter, in crab pots for practical use in Chesapeake Bay. No legal-sized crabs escaped through the rings and pots retained 83%-89% less sublegal crabs than pots with no cull rings. These results are slightly higher than Eldridge *et al.* (1979) found in South Carolina. The South Carolina study employed greater numbers of pots and is considered more statistically sound.

Commercial watermen have expressed concern for the potential loss of small peeler crabs and mature females that are legal to harvest. Virginia investigated the loss of small, mature females from cull rings and found that a cull ring with a 2 3/16 inches diameter allowed only minimal losses (VMRC unpublished data, 1995). Self-culling crab pots reduce injury to sublegal crabs and save time because crabs do not need to be culled by hand.

Crab pots lost to storms or left abandoned at the end of the fishing season, often called ghost pots, are attractive refuge sites for blue crabs. Crabs and fish trapped inside abandoned pots die and attract other animals into the pots (Guillory, 1993). This process of self-baiting is a problem in many other pot fisheries including lobster, king crab, snow crab and black cod. As a cannibalistic species, blue crabs may be attracted by dying crabs impounded in abandoned traps. In Louisiana, Guillory (1993) found 55% mortality of impounded crabs. A similar study by Casey and Wesche (1981) examined 40 unbaited pots on a weekly basis in Sinepuxent Bay, Maryland, from July through December. A total of 1,033 crabs were impounded; 33% of the impounded crabs were unable to escape and subsequently died. Pots abandoned during winter months in Chincoteague Bay, Maryland, caught fewer crabs than pots abandoned during warmer months, but mortality increased to 100% in the winter months. Such high mortality may have been due to decreased water temperature and a crab's inability to bury in sediments (Casey and Daugherty, 1989).

Watermen interviewed from the Chesapeake Bay region estimated 10-30% of pots are lost each year (Casey, 1990). The lobster fishery in New England (New England Fish. Mgt. Counc., 1983) proposed developing biodegradable escape panels. Casey (1990, 1992) studied materials for degradability in Chesapeake Bay. Escape panels made of jute decayed within two months. This may not be accepted by watermen who would have to replace them frequently throughout a season. Cotton twine escape panels were unreliable and decay rates varied. Materials that degraded in six to nine months also proved impractical. Fouling tended to clog escape vents as panels degraded. Other options included nongalvanized wire mesh over a portion of the pot or burning off galvanizing with a torch in a section chosen for escape. Nongalvanized wire rusts and weakens over time. Variability in the degradation times of escape vent materials under different environmental conditions needs thorough examination before a recommendation can be made.

International Trade and Implications for the Chesapeake Bay

The United States is one of the largest exporters of crabs and crab products worldwide in terms of dollar value. In 1994, United States exports of crabs and crab products totaled $347 million (NMFS, 1995). Chesapeake Bay blue crab harvest has accounted for over 50% of national landings since the 1970's (Orth and van Montfrans, 1990), though growing crab fisheries in the South Atlantic and Gulf states have been increasing their contribution to the national harvest. Crab fisheries are developing worldwide, particularly for crabs of the genus *Portunus*, which are similar in appearance and marketability to blue crab (Petrocci and Lipton, 1994).

In addition to being one of the world's largest exporters of crabs, the United States was the second largest importer of crab and crab products in 1993, outranked only by Japan (Petrocci and Lipton, 1994). Venezuala, Mexico, Indonesia, Thailand, South Korea, and China are the largest source of crabs imported to the U.S. . Imports in 1993 were worth over $150 million (Petrocci and Lipton, 1994). As more countries develop crab fisheries and processing techniques, the crab supply worldwide will continue to grow. From 1982 to 1991, worldwide landings of crab species increased by almost 60%. Petrocci and Lipton (1994) provided recommendations for the Chesapeake Bay product to remain competitive in the domestic and international market. In particular, they stressed the importance of distinguishing the Chesapeake product as one of superior quality and taste. The development of value-added products that stimulate and maintain consumers' desire for the region's product was also suggested.

Petrocci and Lipton (1994) assessed Asian crab fisheries and production and predicted Asia would grow in international importance for crab harvest and productivity. Asian resources are reportedly abundant and underutilized, which makes the product inexpensive. Worldwide landings of *Portunus* have increased from 56,400 metric tons (mt) in 1982 to 227,100 metric tons in 1991. Worldwide landings of blue crab increased during the same time period (99,900 mt to 111,700 mt), though not as rapidly as for *Portunus*. However, the fisheries for *Portunus* include numerous species; whereas, the blue crab fisheries harvest a single species. Petrocci and Lipton (1994) stressed the importance of acknowledging the potential for competition from abroad and the relationship between the long-term health of the resource and the ability to compete in an international market. In the Chesapeake region, Petrocci and Lipton warned of the effects of overcapitalization, high levels of fishing pressure, and competition that drive the product price up. Limited access to the fishery was recommended to prevent overcapitalization, increase productivity, and lower the cost of harvesting crabs. To remain competitive in the global market, managers and the industry are urged to focus on the health of the resource, rather than short-term availability from one season to the next. Petrocci and Lipton's (1994) conclusion is in accordance with the goal of this management plan and the recommendation that limited entry and stabilization of fishing effort be implemented Baywide as a management strategy.

Parasites and Disease

Diseases and infections in the blue crab population can bring about wide and varied effects, both actual and perceived, on the blue crab and its industry. Even the perception of disease and pathogens, once shared with the public, can have considerable effects on the industry and on management. A variety of pathogens can affect crustaceans, including viruses, bacteria, fungi, protozoans and helminths. Some cause unattractive necrotic lesions on the shell or black pigmentation in the meat, rendering affected crabs unmarketable. Other pathogens may reduce fecundity, while still others are documented to cause significant mortalities. The parasitic dinoflagellate, *Hematodinium perezi*, was first described by Newman and Johnson (1975) from blue crabs in coastal areas of North Carolina, Georgia and Florida. In recent years, the parasite has been detected in blue crabs from coastal bays of Maryland and Virginia (Messick, 1994) and crab mortalities have been associated with the parasite.

The relationship between stress and disease is a well documented phenomenon. Sindermann (1989) found that the occurrence of disease was higher in stressed populations. In a number of instances, degraded water quality has been implicated in blue crab disease (Engel and Noga, 1989; McKenna *et al.*, 1990). Because many infections are contagious to other crabs and may be an indication of stress in a population, existing diseases and parasites, such as *Hematodinium*, should be actively monitored in both Maryland and Virginia.

Water Quality

Worldwide, estuaries are experiencing water quality problems as a result of human activities in coastal areas. Chesapeake Bay, one of the world's largest estuaries, has experienced deterioration of water quality from nutrient enrichment, sediment inputs, and high levels of contaminants. Declines in living resources are attributed to degradation of water quality (Horton and Eichbaum, 1991).

Excess Nutrients and Anoxia

High levels of nitrogen and phosphorus in the Bay's mainstem and tributaries lead to favorable conditions for explosive algae blooms. Phytoplankton in the water column are so abundant during such blooms that they block sunlight to underwater Bay grasses and plankton deeper in the water column. Grasses and plankton subsequently die and decompose. This decomposition uses oxygen at an accelerated rate, causing water oxygen levels to drop. Lowered dissolved oxygen inhibits Bay grass respiration and limits the amount of area suitable for many forms of aquatic life. Anoxic (no oxygen) and hypoxic (low oxygen) conditions kill benthic food organisms.

During the months of May to September, deeper waters of the mid-Bay mainstem, from Baltimore to the mouth of the Potomac River, are subject to anoxic conditions (Officer *et al.*, 1984; Taft *et al.*, 1980; see Figure 3). The anoxic portion of the Bay varies from year to year. Although low dissolved oxygen levels are, in part, a result of natural conditions in the Bay, the anoxic portion has been increasing in size and duration in recent years. Dissolved oxygen depletion was first documented as hypoxic areas, or areas of reduced oxygen content. Over the years hypoxic conditions have worsened to anoxic conditions (Officer *et al.*, 1984). Historically, the affected area was limited to a narrow strip of the deep channel in the Bay. In some years, anoxic conditions now cover a much wider area, with fringes of hypoxia stretching across almost the width of the Bay and down to the Bay mouth (Officer *et al.*, 1984). Cross-current winds and low pressure storms often push anoxic water into shallow areas.

As winter approaches, decomposition of organic matter slows down and oxygen supplies are replenished with greater mixing of fresh and saltwater layers (diminished halocline) in the Bay mainstem. The depletion of filter feeders in the Bay, particularly oysters, may aggravate the situation. Oysters filter feed on phytoplankton suspended in the water column, and, unlike other phytoplankton feeders, overwinter in the Bay. Spring warming stimulates feeding early in the season. Today, a large portion of the spring phytoplankton bloom goes ungrazed (Newell, 1988), adding to organic accumulations later in the season and potentially further contributing to anoxia.

Toxics

Blue crabs that overwinter in sediments are exposed to accumulations of toxic substances. Their preference for feeding on bottom-dwelling organisms, such as filter feeding bivalves, also make them likely candidates for toxics bioaccumulation. However, because blue crabs are migratory and have a short life span, toxic accumulation has not been a problem. Crabs examined in the two most polluted areas of Chesapeake Bay, the Elizabeth River (Norfolk, VA) and Patapsco River's Baltimore Harbor (MD), were highly tolerant of toxic environments. Minimum amounts of contaminants were found in muscle tissue; higher levels of some contaminants were accumulated in the hepatopancreas (Garreis and Murphy, 1986). Blue crab larvae may be sensitive to contaminants in the water. Sublethal doses of toxics slow larval development (Epifanio, 1984). Van Heukelem (1991) summarized literature on contaminants to blue crabs. Contaminants included petroleum hydrocarbons, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, kepone, mirex, malathion, halogenated compounds, chlorine and chlorine-produced oxidants, and heavy metals including cadmium, chromium and mercury. No literature was found on the effects of arsenic, copper, lead, mercury, nickel or zinc.

Submerged Aquatic Vegetation

One of the major factors contributing to the high productivity of Chesapeake Bay has been the historical abundance of submerged aquatic vegetation (SAV, also called Bay grasses). SAV provides important habitat for settling postlarvae (Orth and van Montfrans, 1987) and molting crabs (Ryer *et al.*, 1990). SAV growth is restricted to shallow water areas and is limited by light availability. Therefore, water quality is of utmost importance for successful re-establishment of SAV.

Nutrient and sediment effects

A Baywide decline of all SAV species in Chesapeake Bay occurred in the late 1960's and early 1970's (Orth and Moore, 1983; 1984). The decline was attributed to increasing amounts of nutrients and sediments in the Bay (Kemp *et al.*, 1983; Twilley *et al.*, 1985). Soil runoff increases as the wetlands and forests are lost to development and agriculture. Without forest or grass buffers and wetlands, eroded soil and nutrients enter water bodies (Schlesinger, 1991). Nitrogen and phosphorus from agricultural and urban landscape fertilizers enter the Bay as runoff or as dissolved ions percolated into groundwater. Atmospheric nitrogen oxide from the burning of fossil fuels is deposited on the water's surface via rain or dry deposition.

Suspended sediments and excess nutrients in the water have impacted SAV in varying ways, primarily through light-related perturbations. Sediments from surrounding uplands or resuspended from bottom deposits can severely limit light penetration through water. Nutrients enhance the growth of phytoplankton in the water column and epiphytic algae that grow on SAV leaf surfaces. Phytoplankton and epiphytes block light that would normally reach SAV leaves, reducing photosynthesis. The spectral character of the light may also be changed, placing additional stress on SAV growth and survival.

Researchers believe that recent efforts to improve water quality, through nutrient input reductions and managed shoreline development, have influenced the recovery of SAV in Chesapeake Bay. Although recent restoration efforts have led to an improved status of SAV in the Bay, there are still only approximately 60,000 acres of SAV in the Bay and its tributaries. Chesapeake Bay Program scientists estimate that historically 400,000 to 600,000 acres of SAV might have existed. It is believed that most of the major SAV declines in Chesapeake Bay have occurred outside the primary settlement and nursery areas for the blue crab (Orth *et al.*, 1995). However, these vegetated habitats are of such vital importance to maintaining historically high population abundances of crabs that they should be recognized and preserved (Orth *et al.*, 1996). Figure 14 shows areas of particular importance to postlarval settlement and juvenile development. Outside of the primary settlement areas for blue crab postlarvae, SAV beds are also important refuge sites during molting and soft-shell phases. Figure 15 displays potential SAV habitat for blue crabs baywide. Baywide, SAV beds are an important component of the Chesapeake Bay ecosystem and, as such, indirectly impact the blue crab population by supporting communities of prey items and regulating water quality.

Effects of physical disruption

Human activities in coastal areas and on the water reduce the area of shallow water available for crabs and SAV and physically disrupt SAV in shallow water habitats. Shoreline structure, such as bulkheads, revetment and breakwaters, increase wave energy near shore and reduce shallow water habitat suitable for bay grasses. Grasses sliced at the base by dredging for commercial fisheries must recover before they can offer refuge to blue crabs. The effects of heavy crab scrapes dragged through grass beds to collect soft and peeler crabs are unknown. Areas of high frequency scraping may be scarified the same way high frequency propeller contact scars grass beds, often resulting in permanent alteration of the habitat (Fonesca *et al.*, 1992). Large boats are being utilized more by crab scrapers, and the crab scrape fishery is expanding as more watermen drop out of the oyster fishery and outfit their boats and power rigging for the crab fishery. The use of power winders to haul scrapes has not been investigated for the potential to damage SAV habitat. Virginia limits the size of scrapes and prohibits mechanized hauling of crab scrapes. Hand pulling limits the weight of scrapes that can be hauled. Clam dredging may also cause local SAV destruction via physical disruption (Hurley, 1991).

Chesapeake Bay Program Efforts

Nutrient Reduction[1]

The *1987 Chesapeake Bay Agreement* (Chesapeake Executive Council, 1987), signed by the jurisdictions of Maryland, Virginia, Pennsylvania, and the District of Columbia, established a goal of reducing controllable sources of nutrients to the Bay by 40% from 1985 levels by the year 2000. Controllable sources include runoff from agriculture, urban and suburban areas; shoreline erosion, and point sources such as sewage treatment plants. It was estimated through analysis of computer models that achieving the 40% reduction goal would reduce anoxic conditions in the Bay by 20 to 25% in an average year. The same model also estimated that anoxic conditions would increase by 15 to 20% over a ten-year period if no nutrient reduction occurred. From 1984 to 1992, phosphorus concentrations in the Bay declined by 16% and nitrogen levels held steady with no decline. Effects of nutrient reduction efforts take several years before results are visible (Kunishi, 1988) No consistent pattern of improvement in the Bay's dissolved oxygen or a reduction of algae has been noted to date (CBP, 1995b).

Uncontrollable sources of nutrients not included in the 40% reduction goal, most notably, atmospheric deposition, add significant amounts of nitrogen to the Bay. Atmospheric nitrogen deposited directly into the water may account for 10% of the nitrogen load to the Bay. Furthermore, accounting for atmospheric nitrogen deposition in the entire Bay watershed increases the estimate to 40%. Nitrogen released to the atmosphere from the burning of fossil fuels is regulated on the federal level by the Clean Air Act. The federal Act mandated a 2 million ton reduction in nitrogen oxide emissions by the year 2000, however, it does not establish a cap for total nitrogen oxide emissions to compensate for future growth and fossil fuel demand. The Clean Air Act also requires automobiles built after 1993 to have 60% reduced nitrogen oxide emissions. Although this mandate is expected to reduce nitrogen emissions, the result will be much less than 60%, due to the growing demand for automobiles and the continued use of vehicles manufactured prior to 1994. Studies by the Maryland Department of the Environment and the U.S. Environmental Protection Agency concluded that future growth will cancel out much of the reduction of atmospheric nitrogen resulting from the Clean Air Act. By the year 2010, the net result may only be about a 5% reduction.

Minimum Dissolved Oxygen Requirements

Action 6.1.2 of this Plan recommends minimum standards for dissolved oxygen in Chesapeake Bay waters for blue crabs. Achieving the minimum standards depends on four factors.

1. The Bay jurisdictions should continue to work towards the goal of 40% reduction in controllable nutrient sources.

2. Without capping nutrient loads, the minimum dissolved oxygen requirements recommended by this plan can not be maintained. The jurisdictions should continue to

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[1] Reviewed in: Chesapeake White Paper. 1993. Nutrients and the Chesapeake: Refining the Bay cleanup effort Alliance for the Chesapeake Bay. Baltimore, MD; Richmond, VA, Harrisburg, PA.

work towards capping nutrient loads to the Bay, once the 40% reduction is accomplished, as agreed on in 1992 (Chesapeake Executive Council, 1992).

3. The Bay jurisdictions should continue to study the cost and benefits of going beyond the federal Clean Air Act. The Bay jurisdictions are leaders in resource conservation and have set major precedents for watershed management. A stronger commitment to reducing atmospheric pollution would be of great benefit to Chesapeake Bay, set precedent for air quality as an integral part of watershed management, and provide new leadership for regional watershed management.

4. The Bay jurisdictions should work cooperatively with outside jurisdictions that impact the Chesapeake Bay airshed.

A fifth possible mechanism for nutrient reduction is through biological control. Oyster repletion efforts in the Bay are underway with a revised management plan with progressive new strategies (CBP, 1994a). However, disease and parasites are affecting oyster recovery and repletion goals are long-term. Other Bay species are also considered beneficial for their uptake and removal of nitrogen, though it is unknown what quantity of nutrients is reduced by biological means.

SAV and Wetland Protection and Restoration

Action 6.2.1 of this Plan outlines the Chesapeake Bay Program directive for SAV restoration (CBP, 1993; see Figure 15). The goals are supported and reinforced by this Plan. The success of SAV restoration and protection is most dependent on nutrient reduction, as discussed earlier. In addition, protection of existing SAV and future restoration efforts is dependent on efforts to reduce sediment loads to the Bay. Wetland and riparian buffer protection and restoration benefits SAV by preventing shoreline erosion, trapping sediments and absorbing nutrients before they can enter the water. The Chesapeake Bay Program's *Riparian Buffer Directive* (CBP, 1994c) seeks to protect and restore riparian buffers. A 1996 riparian forest buffers initiative furthers the Bay Program's commitment to improving water quality and enhancing habitat with the goal of increasing riparian buffers on 2,010 miles of stream and shoreline in the watershed by the year 2010 (Chesapeake Executive Council, 1996). In 1988, the Chesapeake Bay Program also established a "no net loss" policy for wetlands in the Chesapeake Bay watershed with a long-term goal of net gain (CBP, 1988).

The Chesapeake Bay Program has identified threats to SAV from physical disturbance and provides guidelines to protect existing and restored SAV habitat (CBP, 1995a). The highest priority is to protect shallow water habitat that supports existing or potentially restored SAV down to the one meter depth contour from physical disruption. The Chesapeake Bay Program also recommends protection of shallow water habitat to the two meter contour. Shallow water habitat is important to blue crabs and protection of shallow water habitats and SAV is of direct benefit.

Protection and restoration of SAV and water quality is most important for blue crab in areas where postlarval settlement and juvenile development occurs. Priority areas for SAV restoration that specifically benefit the critical postlarval stage of blue crab have been identified (Figure 14; Action 6.2.2, Table 4). Water quality monitoring results from segments within

Chesapeake Bay and its tidal tributaries that were within the likely range of postlarval blue crab settlement, as defined by Orth *et al.* (1996), were identified by the Chesapeake Bay Program's SAV Workgroup Segments were classified into four categories by comparing SAV survey data (from Orth *et al.*, 1995) and water quality data (CBP, unpublished data, 1984-present). Actions are recommended for each category, based on two assessments: 1) the present amount of SAV compared to the maximum extent mapped from 1978 to 1991; and 2) recent water quality measurements in each segment in comparison with median water quality standards that support SAV growth in different salinity zones within the Bay (Batiuk *et al.*, 1992; Dennison *et al.*, 1993; see Appendix B for decision matrix used to make recommendations in Action 6.2.2). In general, SAV in a segment starts to increase when about 80% or more of the water quality habitat requirements are met in that segment, especially when they have been met for several years in a row (see Batiuk *et al.*, 1992, for water quality requirements for SAV).

Toxics Reduction Strategy

In 1994, the Chesapeake Executive Council of the Chesapeake Bay Program adopted the *Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy* (CBP, 1994b). The goal of the toxics strategy is:

> *"a Chesapeake Bay free of toxics by reducing or eliminating the input of chemical contaminants from all controllable sources to levels that result in no toxic or bioaccumulative impact on the living resources that inhabit the Bay or on human health."*

The strategy commitments go beyond point-source control, and begin to address the more difficult tasks of controlling stormwater runoff and atmospheric deposition. Implementation of efforts to identify the origin of nonpoint source toxics will be used to develop strategies to reduce contaminants from those sources in the future.

RESEARCH NEEDS

Three categories for research needs can be identified for blue crabs: 1) biological data; 2) economic profile data; and 3) data needs for management. The first two are directly related to the third, data needs for management. Biological data needs include age and growth for more precision and accuracy in stock assessments; a better understanding of life history, such as factors that affect settlement and recruitment; and the effects of changes in habitat quality and quantity. Economic profile data includes a characterization of the people of various segments of the fisheries (commercial and recreational) and their practices. Both sets of information are valuable for assessing the impact and effectiveness of various management strategies such as limits on fishing effort, harvest restrictions, and limited entry. Other data needs that directly impact management decisions include accurate fishery statistics and gear design studies. Priority research needs are listed below:

1. Develop an accurate method and determine criteria that may be used to assess the age of blue crabs and use these data to determine the age structure of the population and longevity of the species.

2. Develop criteria that would define overfishing, its potential effects on the adult and juvenile portions of the stock, and methods for recovering the stock should it become overfished. Set stock targets and indicator triggers that will signal potential problems.

3. Determine annual estimates of spawning stock size and size of the recruiting year class and examine their relationship and factors that affect their relationship.

4. Determine the level of spawning stock which would conserve reproductive potential in a range of environmental conditions and develop prudent targets for the size of that stock.

5. Develop Chesapeake Bay-wide estimates of catch and effort by life history stage, year class, sex, and gear type in the commercial and recreational fisheries.

6. Quantify the carrying capacity of habitats for different sizes and sexes of blue crabs to identify critical areas of habitat which provide maximum blue crab productivity.

7. Obtain basic information pertaining to the reproductive biology of blue crabs and stock-recruitment relationships.

8. Develop analytical models and supporting databases to evaluate the social and economic conditions in the fishery and the effects of management and actions on those conditions.

9. Support fishery independent surveys to augment or refine collection and compilation of fisheries data and improve and fully utilize the winter dredge survey, the only Baywide sampling program.

10. Study the relationship between laws, regulations, and enforcement and the status of the stock.

11. Encourage studies of atmospheric and aquatic environments of the continental shelf, their effects on the blue crab larval and megalopal populations, and their relationship to stock size of the blue crab in Chesapeake Bay.

12. Evaluate sources of natural mortality (including predation mortality rates) at various life history stages of the blue crab.

The blue crab is a complex animal with a complex life cycle. Although understanding of this species has grown, there is still much that is unknown. Research needs will continue to be identified through the Bay Program, and in particular through the Chesapeake Bay Commission's

Bi-State Blue Crab Advisory Committee. This committee has a Technical Workgroup (comprised of leading crab scientists and economists from around the Bay region) which advises them on research needs and management issues There is a strong working relationship between the Bi-State Blue Crab Advisory Committee and the partners in the Chesapeake Bay program that will ensure that expanding knowledge of the blue crab and its fishery is incorporated into the Chesapeake Bay Program's Fishery Management Plan and the fishery and habitat management programs of the jurisdictions.

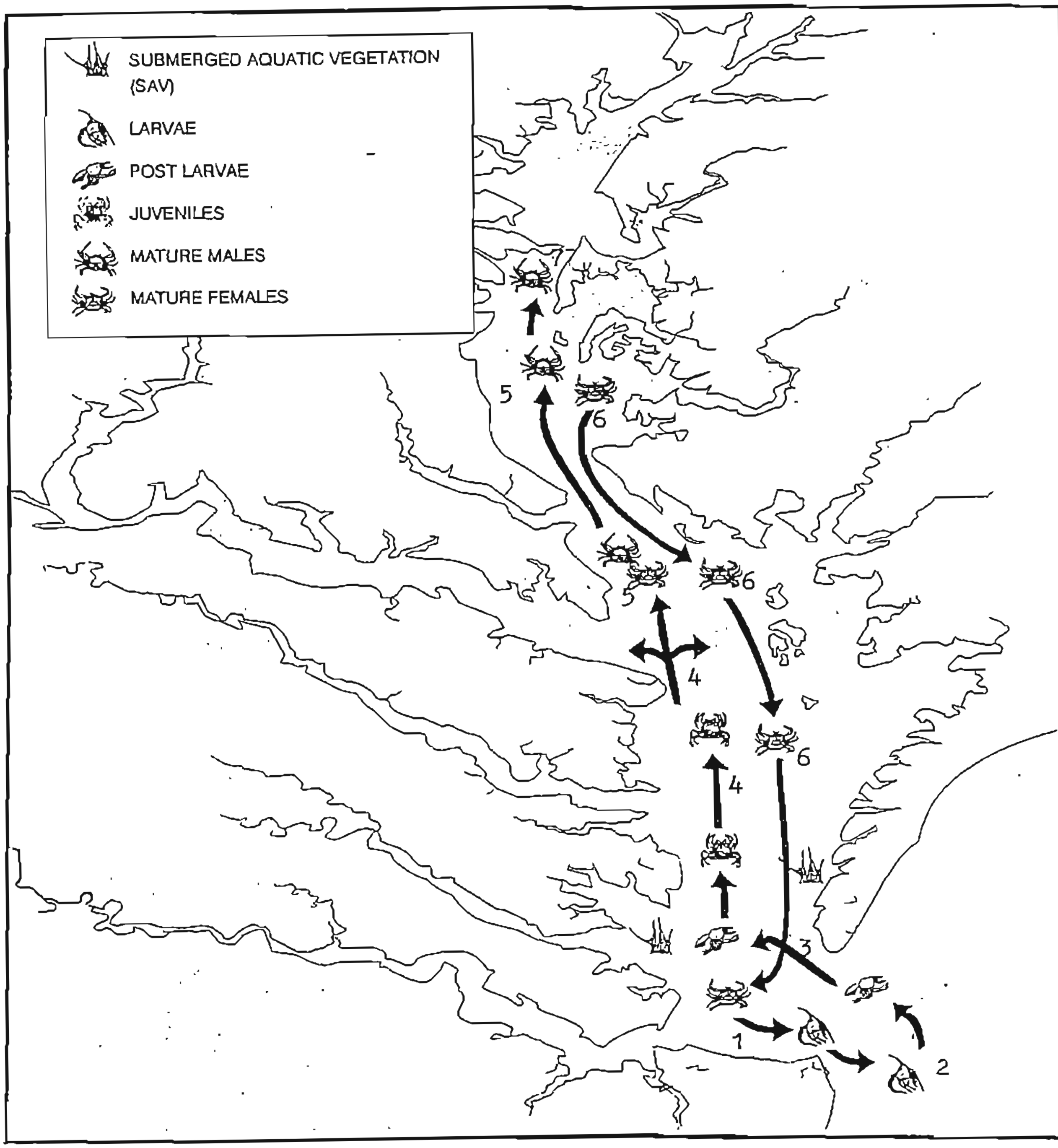
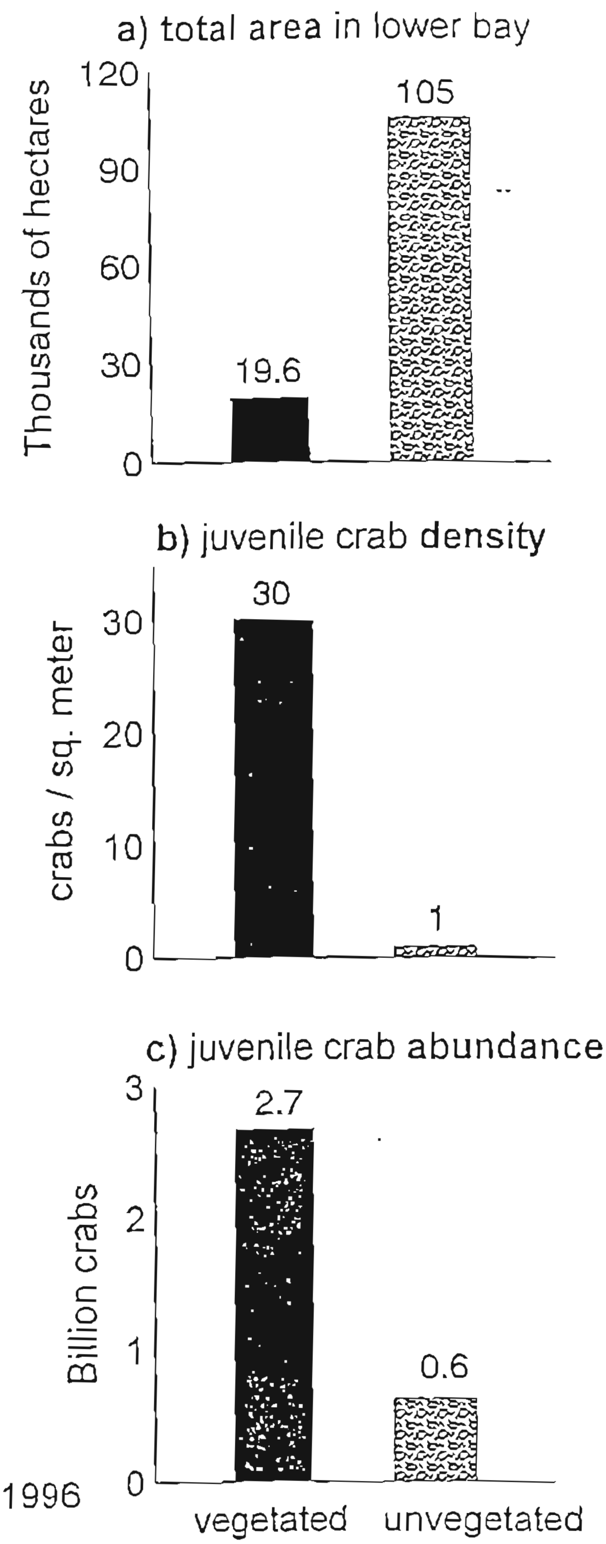


Figure 1. Life history of blue crab in Chesapeake Bay.

1. Larvae are hatched in lower Bay and exit into adjacent coastal waters.
2. Larvae develop and re-enter the estuary as postlarvae.
3. Postlarvae settle in lower Bay, particularly in beds of SAV, and develop into juvenile crabs.
4. Juvenile crabs disperse into tributaries and up the Bay.
5. Mature males and females mate in mid-salinity waters.
6. Females migrate to high salinity waters in the lower Bay, develop eggs, and spawn.
7. Males move into lower salinity waters up tributaries and in the upper Bay.



From Orth *et al.*, 1996

Figure 2. Estimates of the total number of blue crabs, based on bay-wide sampling throughout the middle/lower Chesapeake Bay. Figure *a* denotes the total area of vegetated and unvegetated bottom in the middle/lower Bay which is less than 2 meters in depth. Figure *b* represents the mean density of juvenile crabs in vegetated and unvegetated areas of the middle/lower Bay. Figure *c* shows the resulting estimate of juvenile crab abundance in vegetated and unveoetated middle/lower Bay habitats occurring in less than 2 meters of water.

Figure 3

Dissolved Oxygen Limitations for Blue Crabs

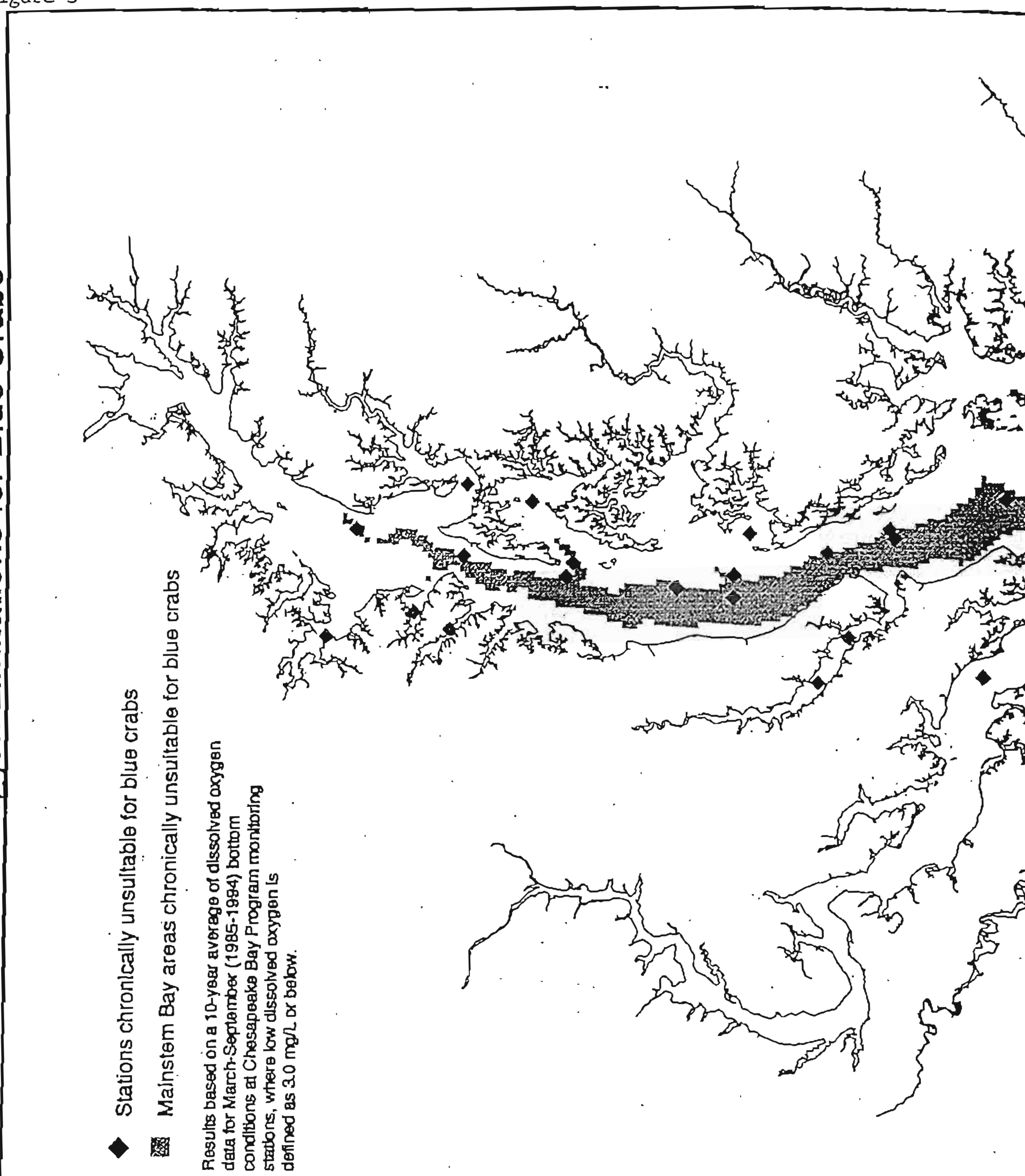
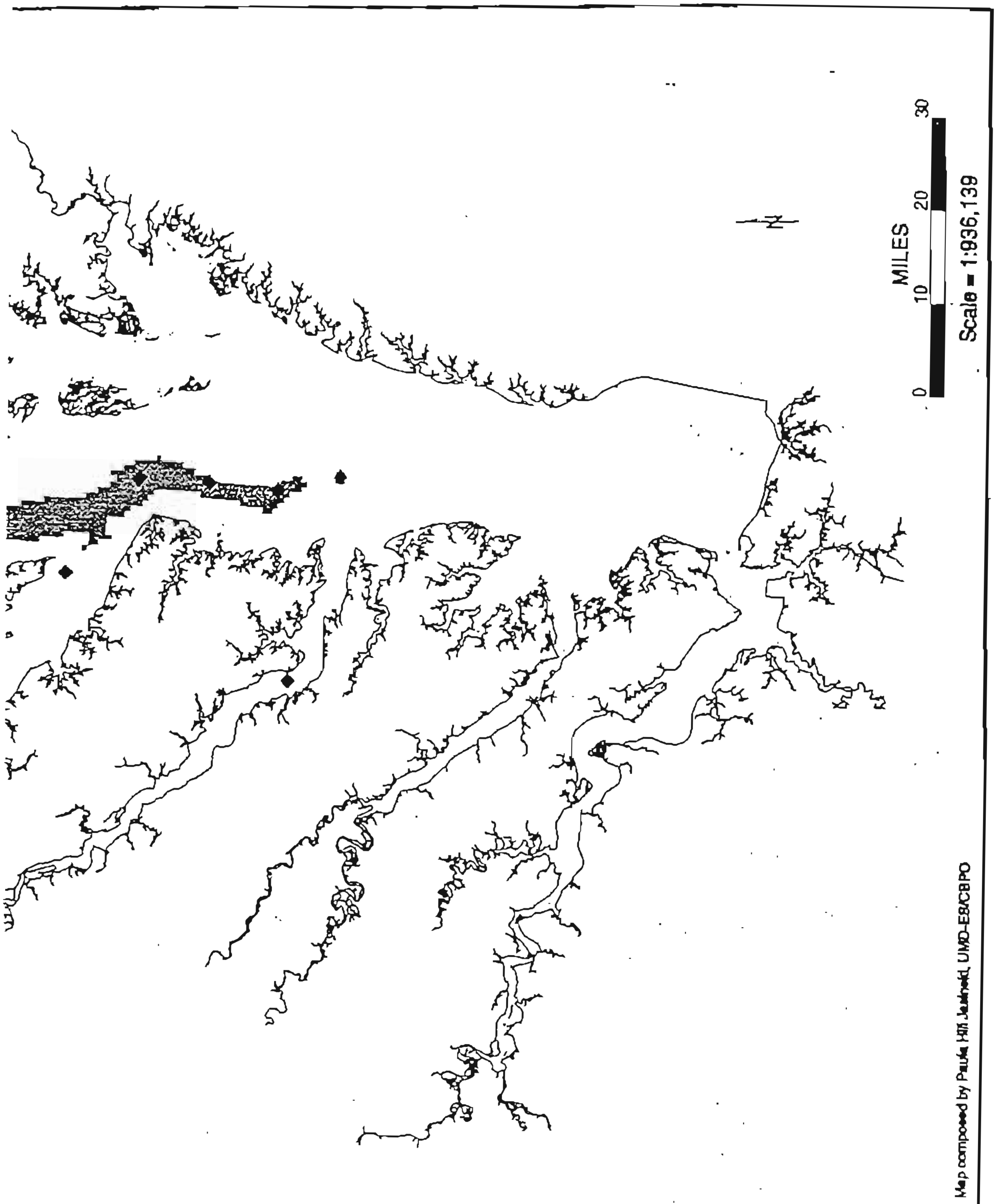


Figure 3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Map composed by Paula Hill Jasinski, UMD-ES/CBPO

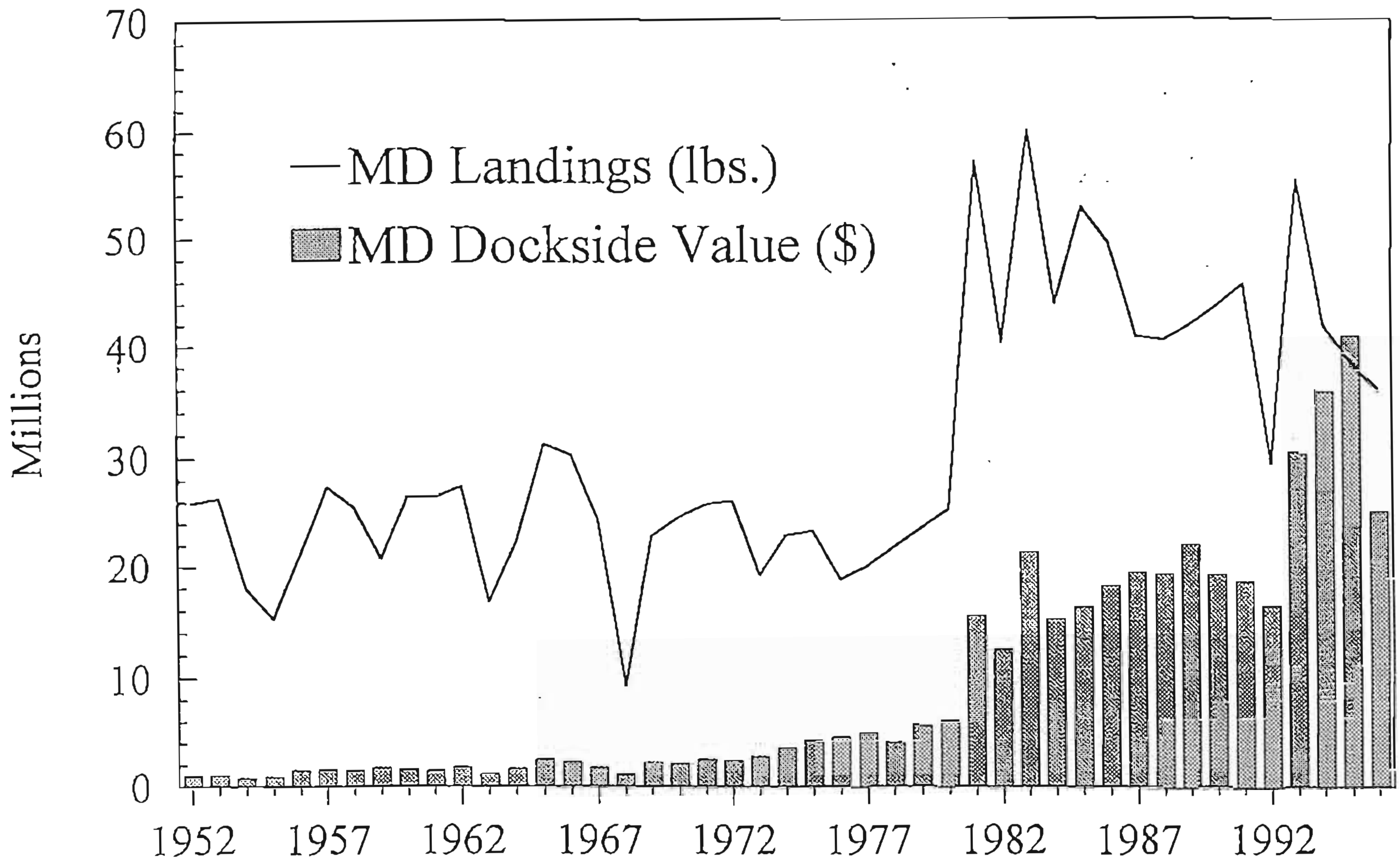


Figure 4. Maryland hard crab landings and dockside value.

Source:
MD - 1952-79, NMFS; 1980-95, MDNR; 1996 value preliminary.

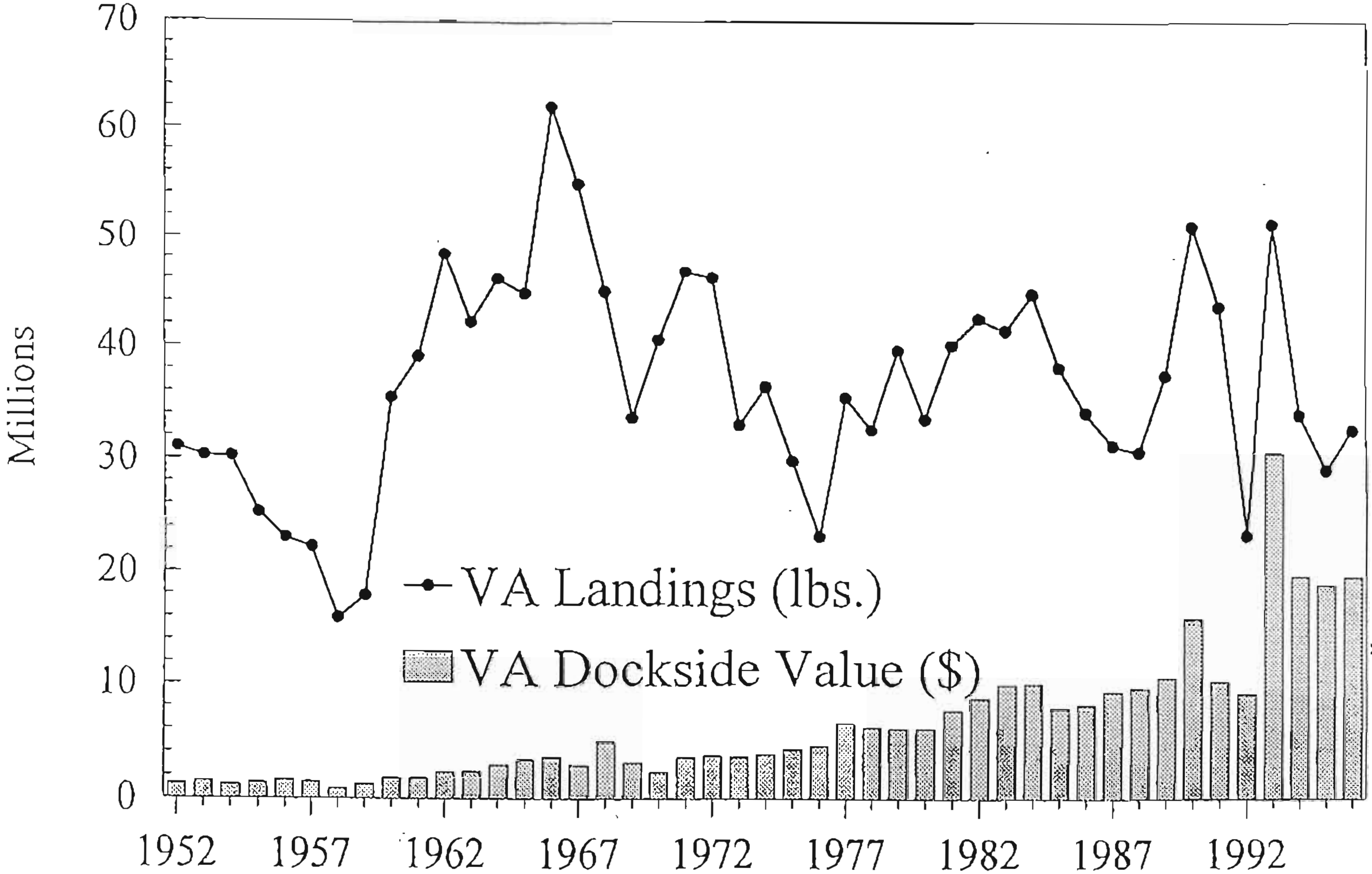


Figure 5. Virginia hard crab landings and dockside value.

Source:
VA - 1952-72, NMFS; 1973-95, VMRC; new reporting system implemented in 1993. 1996 value, preliminary VMRC data.

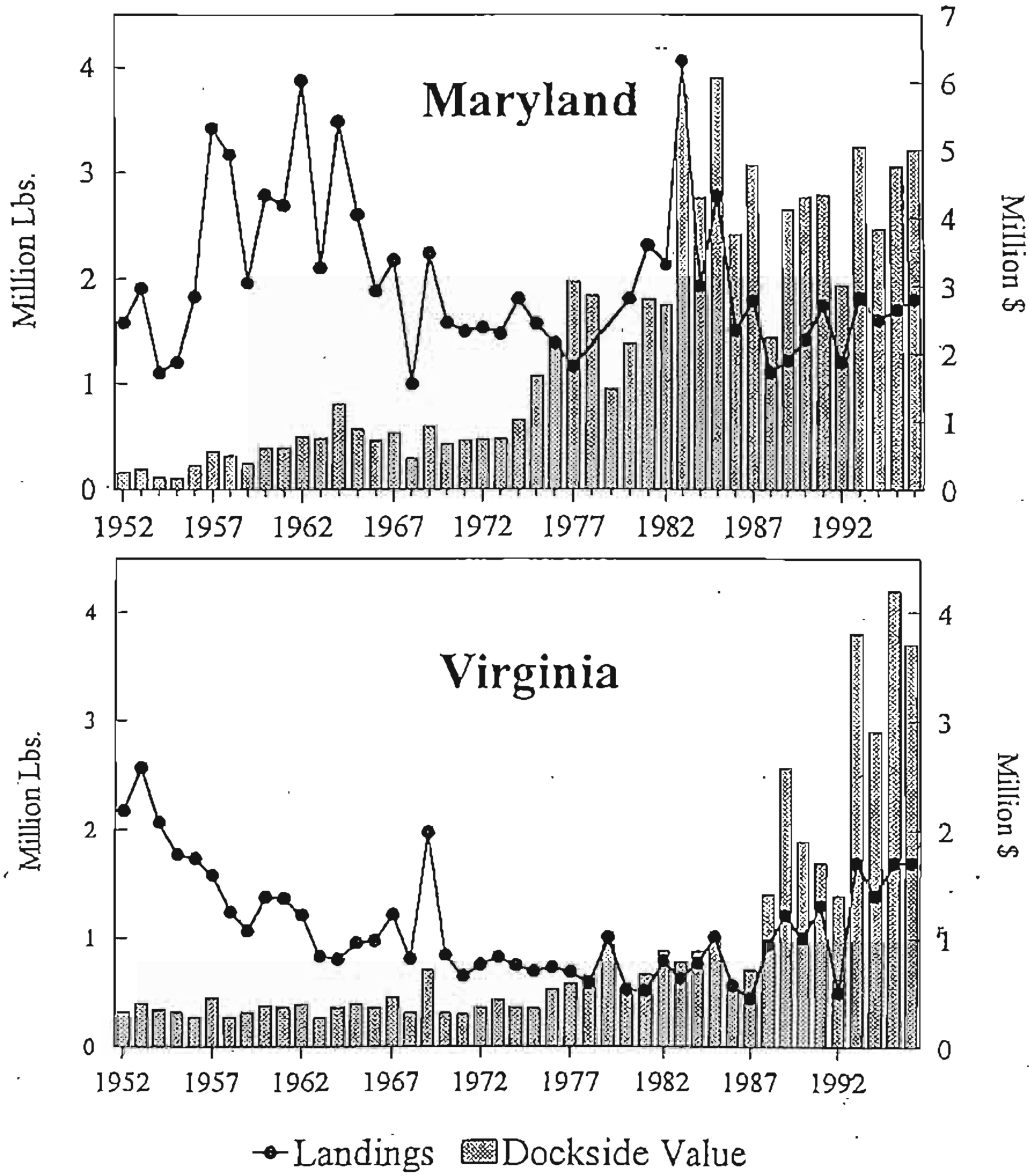
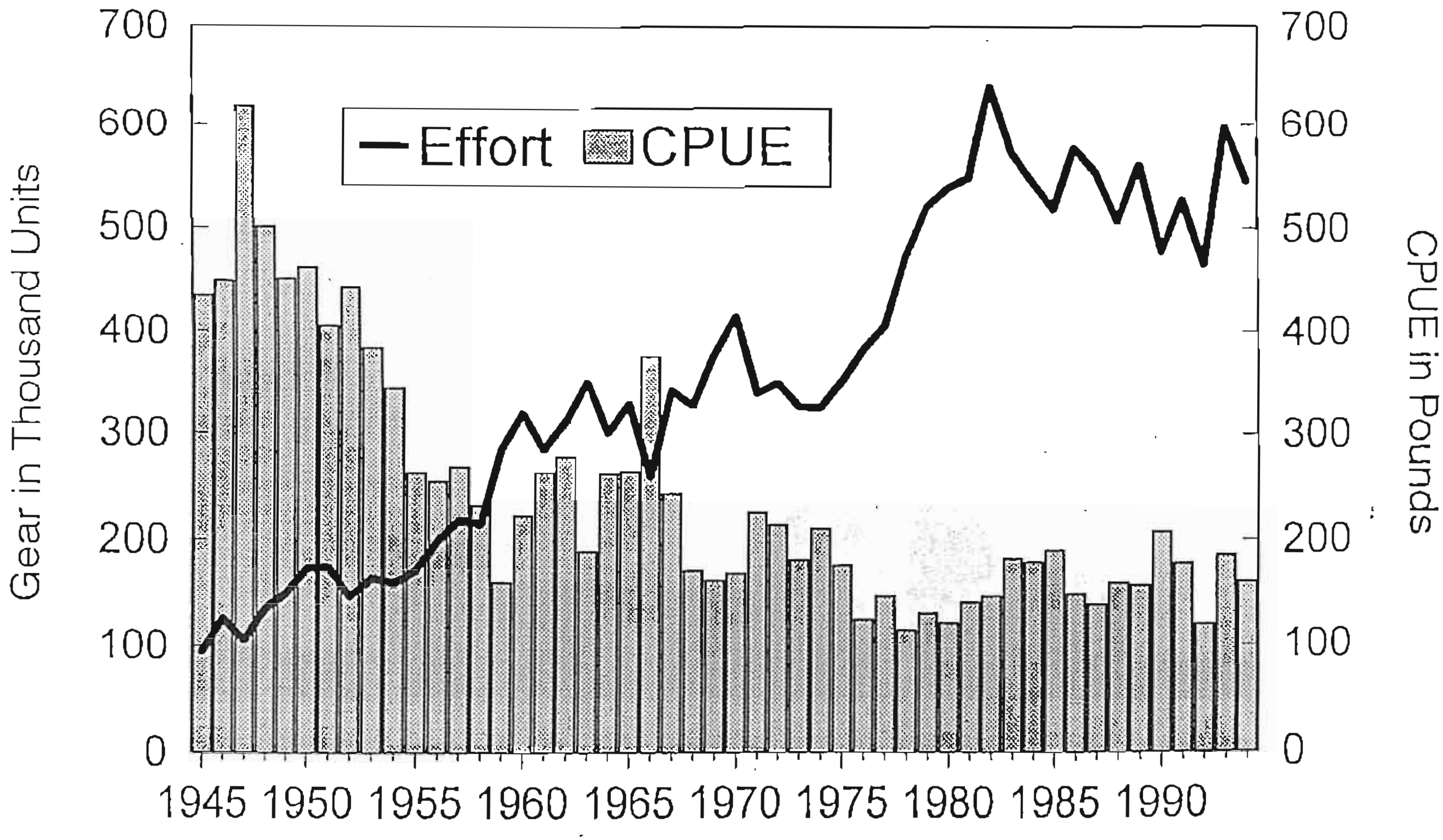


Figure 6. Soft and peeler landings and values in Chesapeake Bay.

Source:
VA - 1952-72, NMFS; 1973-95, VMRC; new reporting system implemented 1993.
MD - 1952-79, NMFS; 1980-95, MDNR

Figure 7. Fishing Effort and CPUE

Chesapeake Bay Blue Crab Fishery



From CBSAC Stock Assessment (Rugolo et al., unpublished).
Effort - Nominal based on crab pot CPUE expanded to total catch.
Catch - CPUE based on crab pot effort, Bay only.

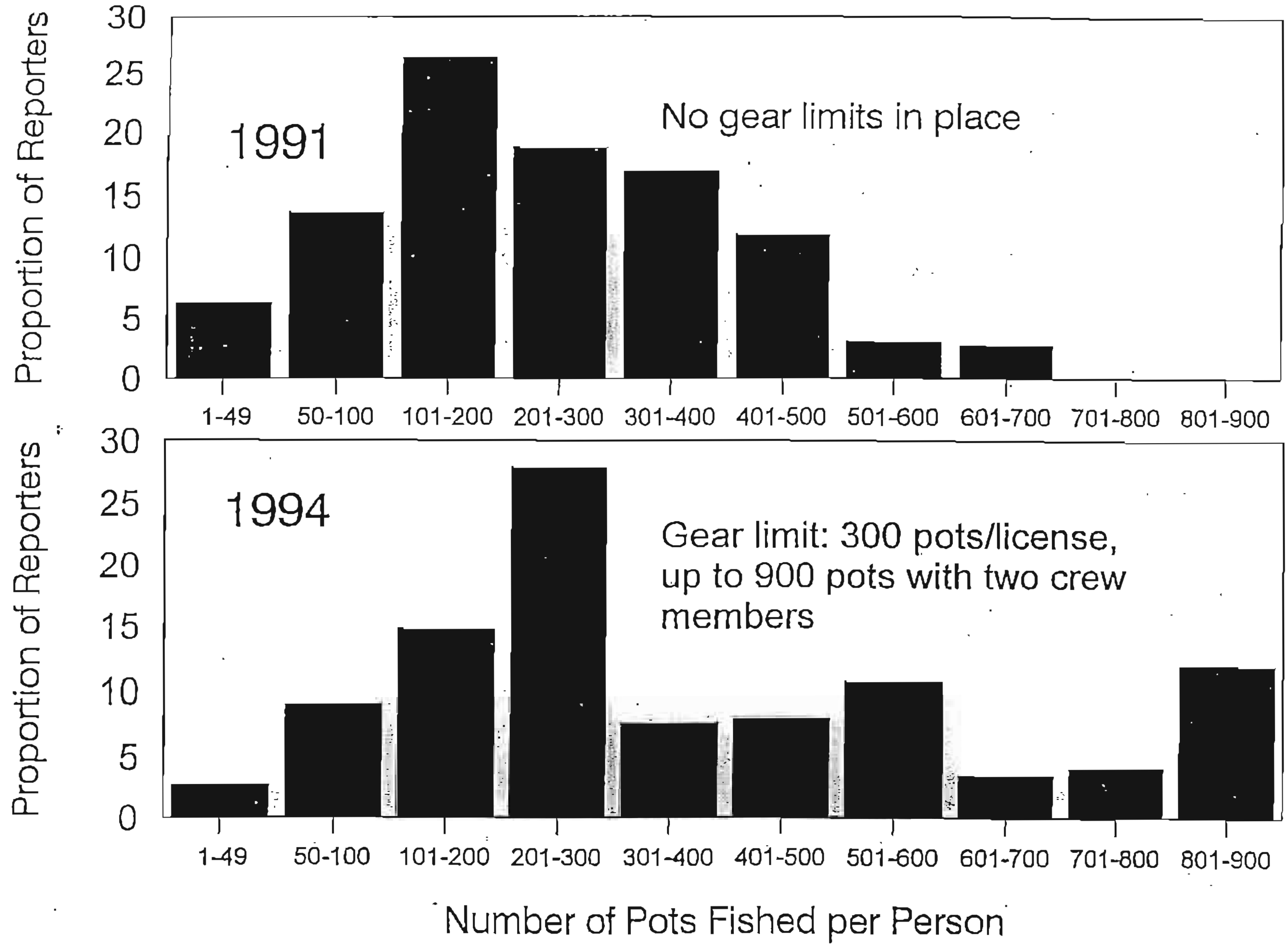


Figure 8. Distribution of crab pot usage per person in Maryland. MDNR data.

*Lcc licensees are limited to 50 pots/person and are not included in this figure.

Figure 9. Maryland License Structure, 1995

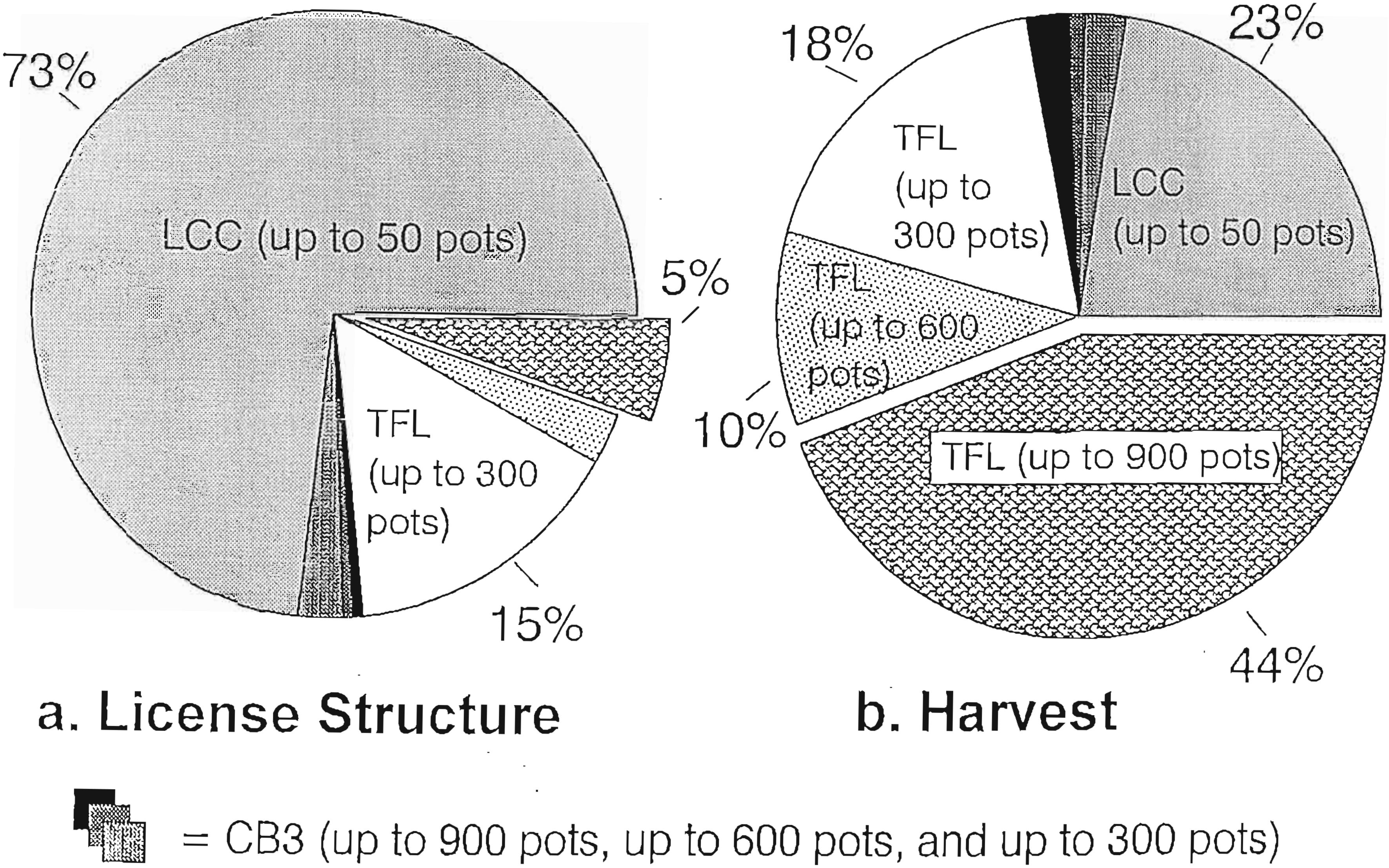
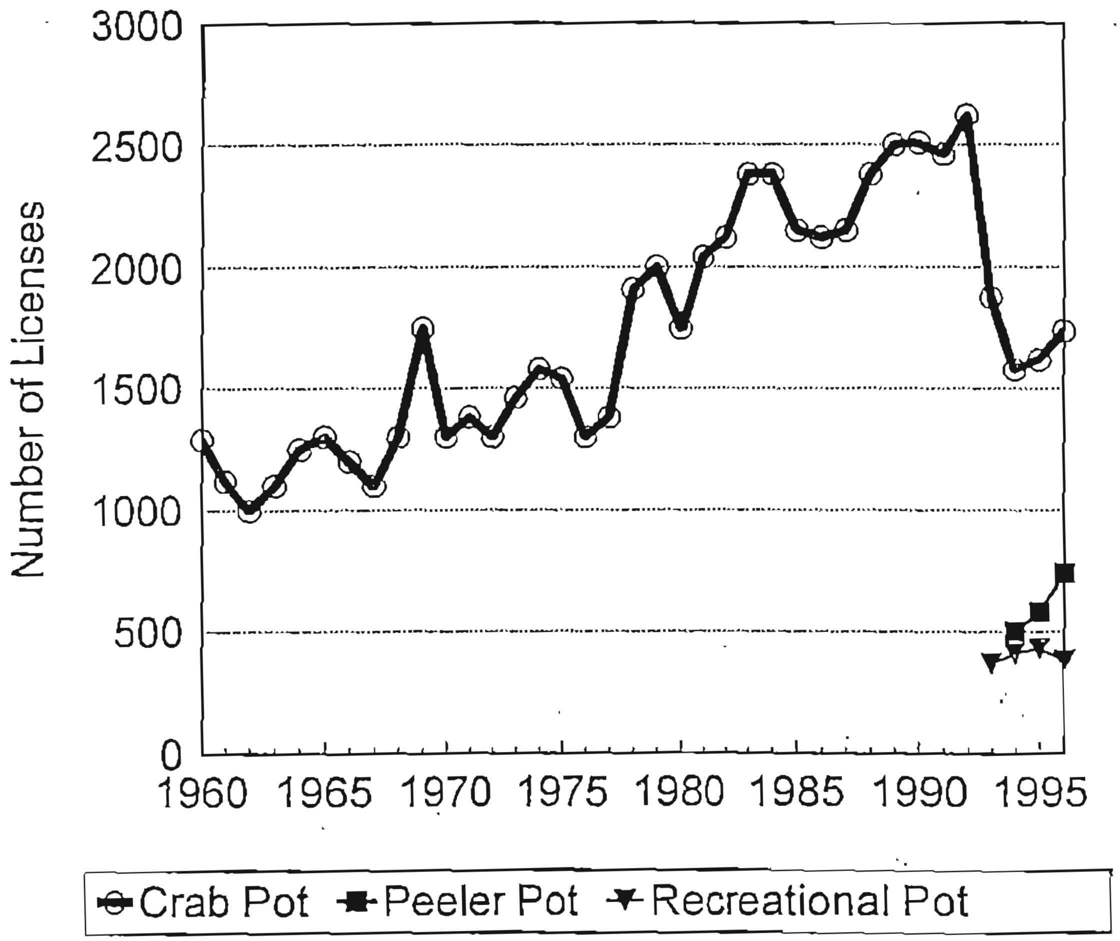
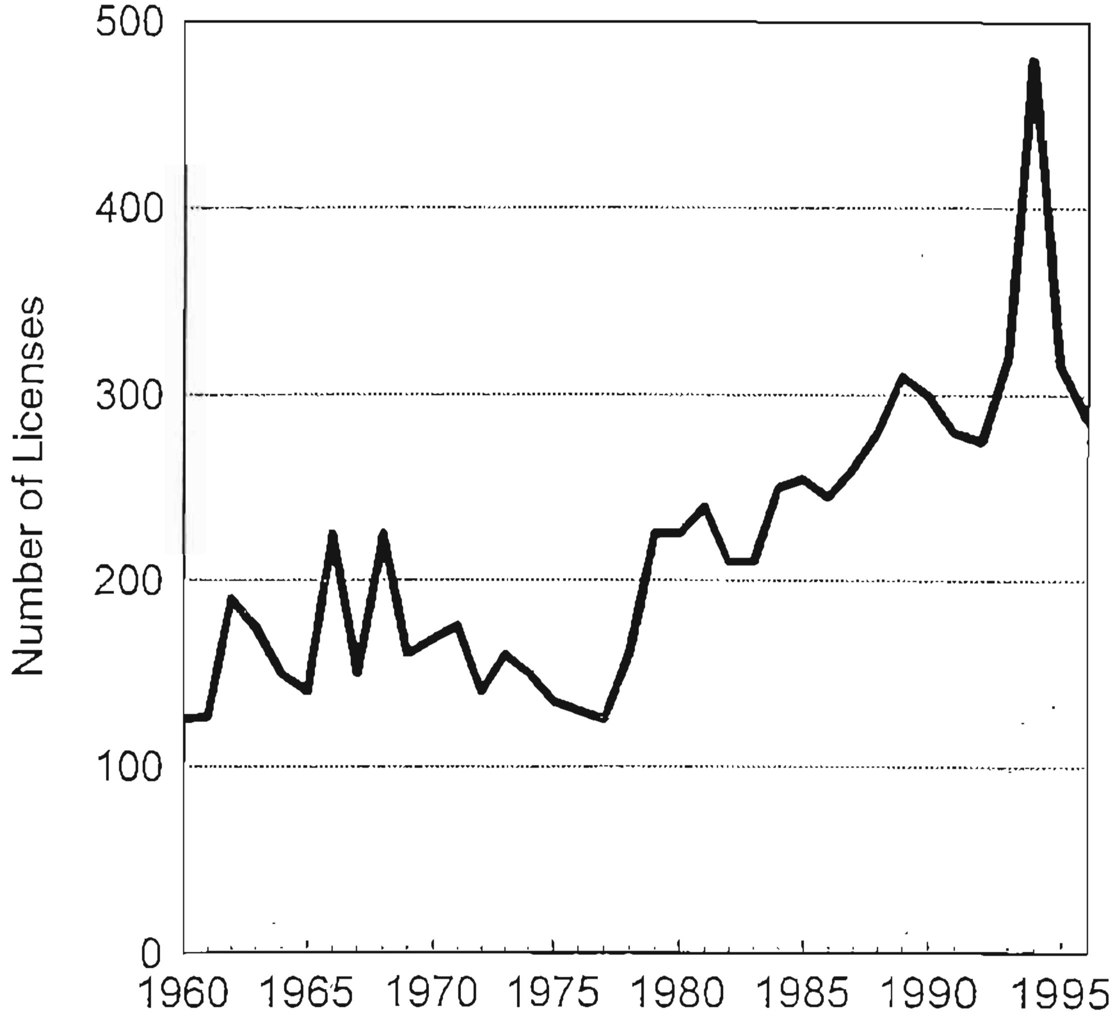


Figure 10.
Virginia Crab Pot Licenses



1993: New recreational pot license and commercial registration license
1994: New peeler pot license

Figure 11.
Virginia Crab Dredge Licenses



Limited entry window 1993/94 season.
VMRC Plans & Statistics

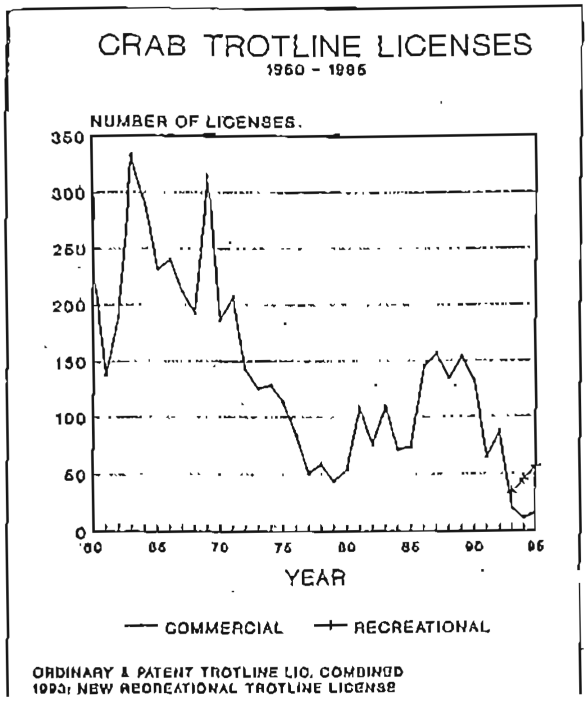
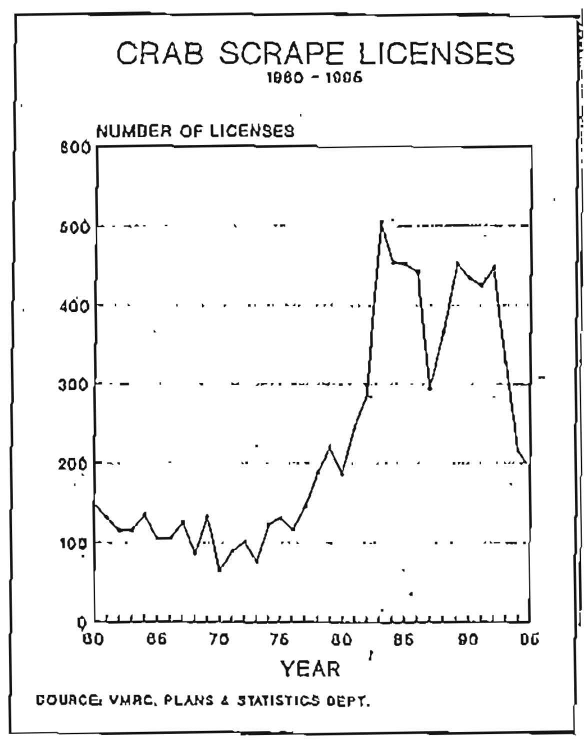
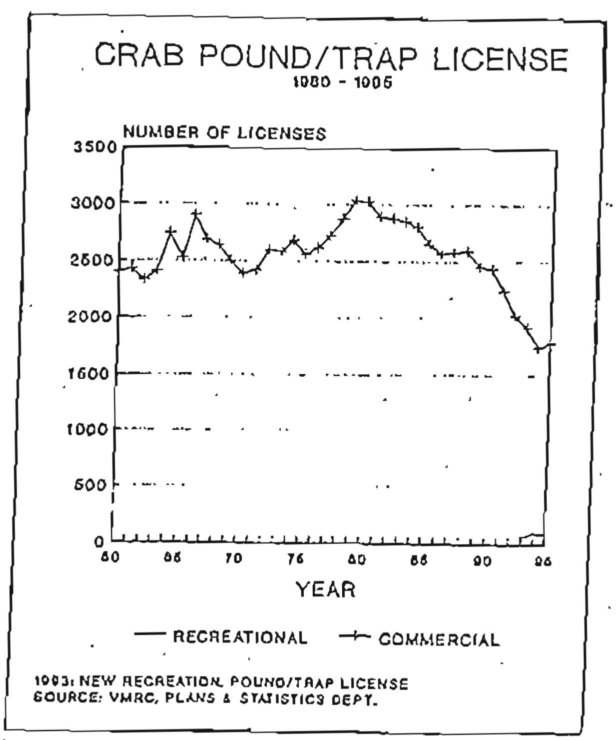


Figure 12. Virginia trotline, scrape and crab trap licenses.





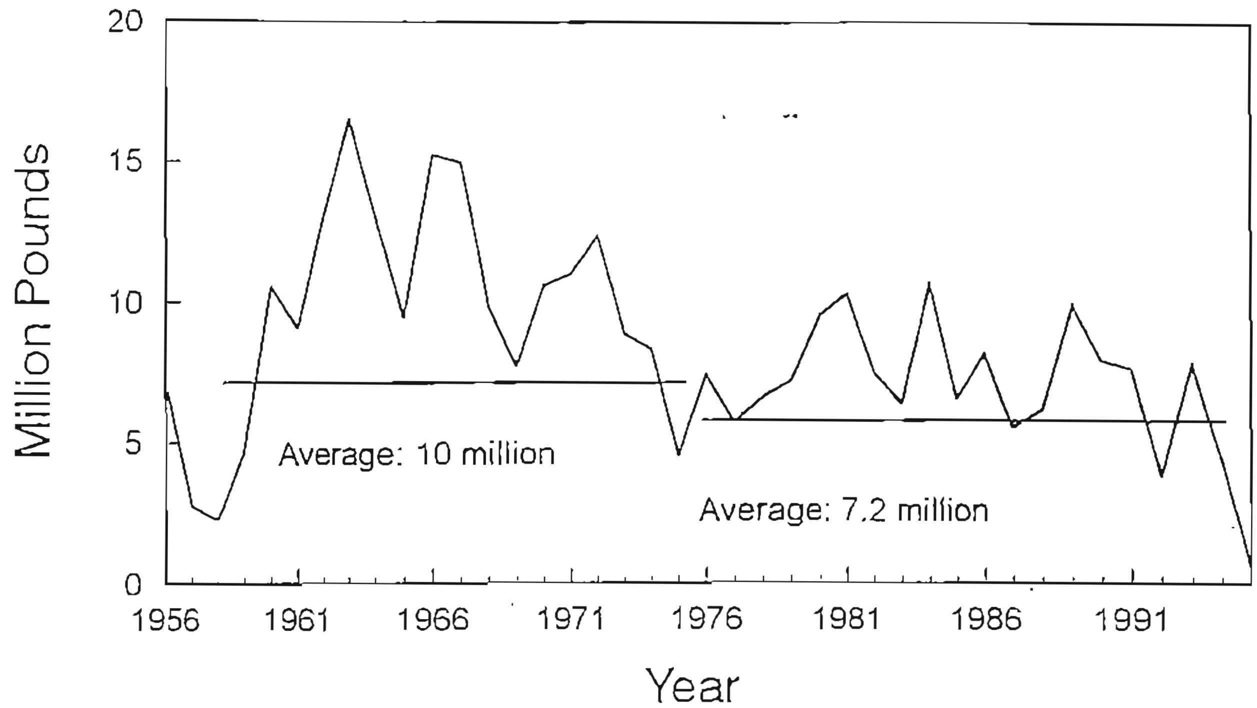


Figure 13a. Landings from Virginia's commercial dredge fishery and average landings for the periods indicated. NMFS and VMRC data.

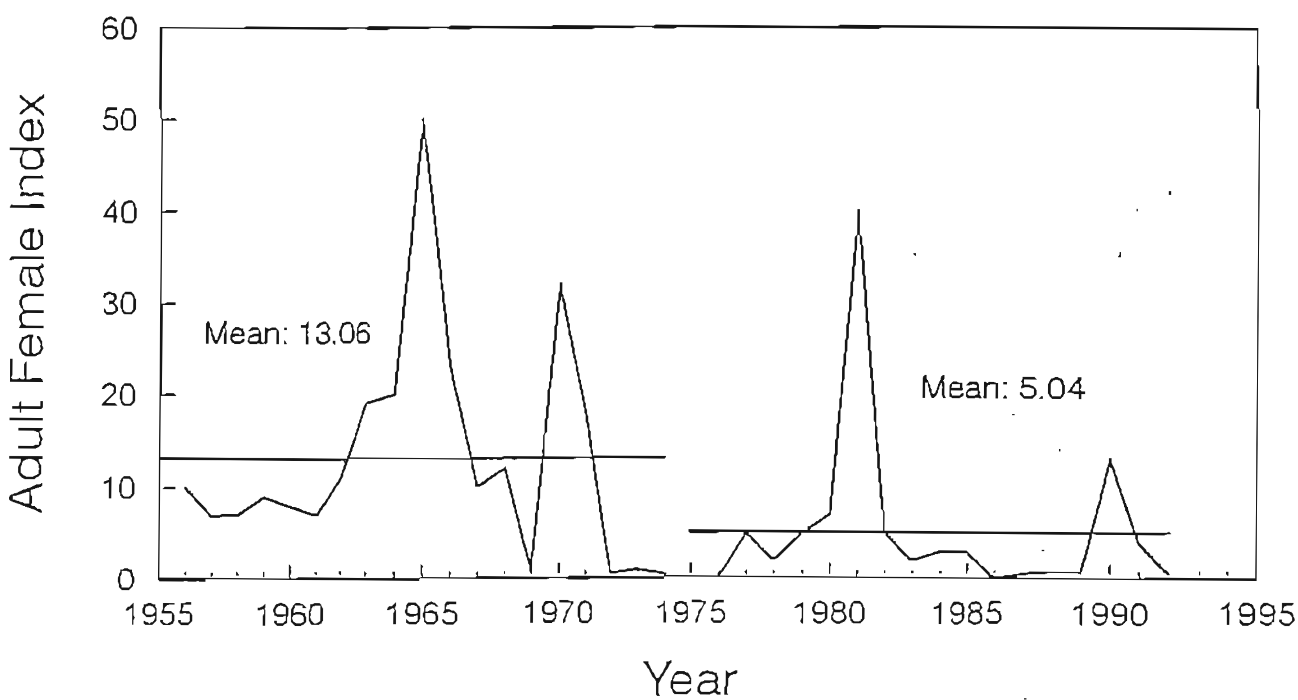
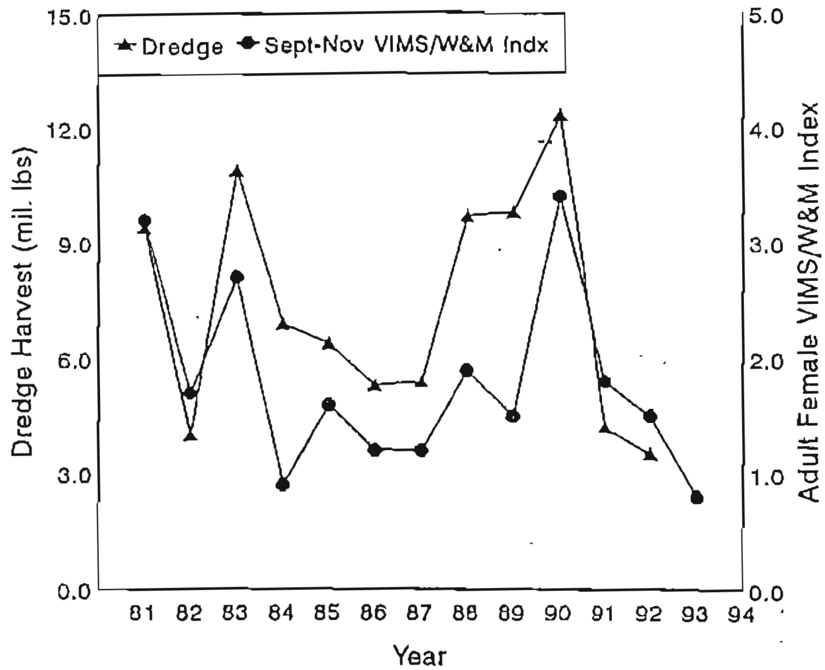


Figure 13b. Adult female crab abundance (catch per unit effort) from VIMS/W&M trawl survey by year for 1956-1992. Note the relatively low level of abundance during the past two decades. Dashed lines indicate means for each period shown. Survey areas were the York, James and Rappahannock Rivers.



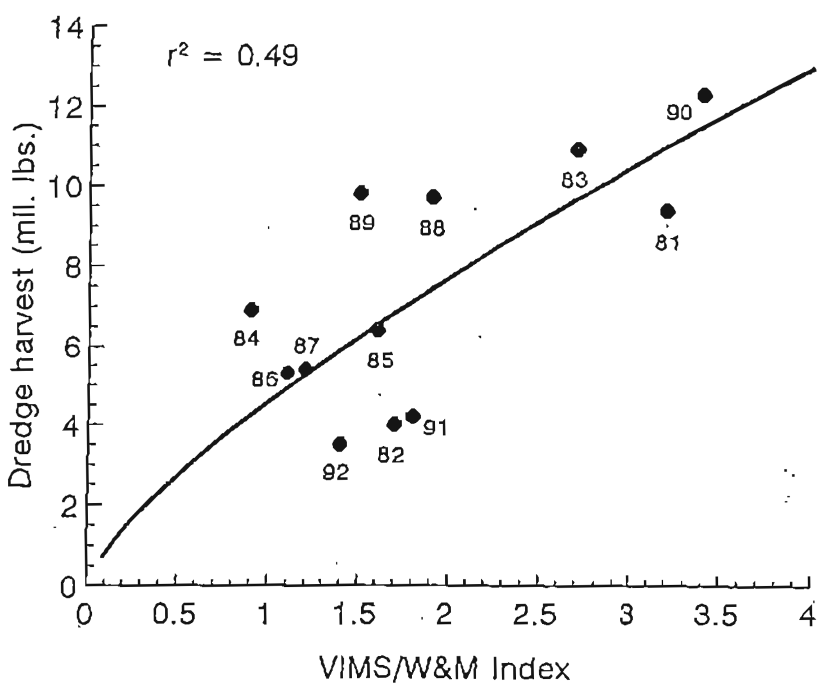


Figure 13c Indices of stock abundance (catch per unit effort) for 1981-1993. Shown are the commercial dredge harvest and the adult female index from the VIMS trawl survey. The lower plot is the resulting regression of dredge harvest on adult female index, with years indicated.

Figure 14

SAV Recommendations to Benefit Blue Crab Postlarval Settlement

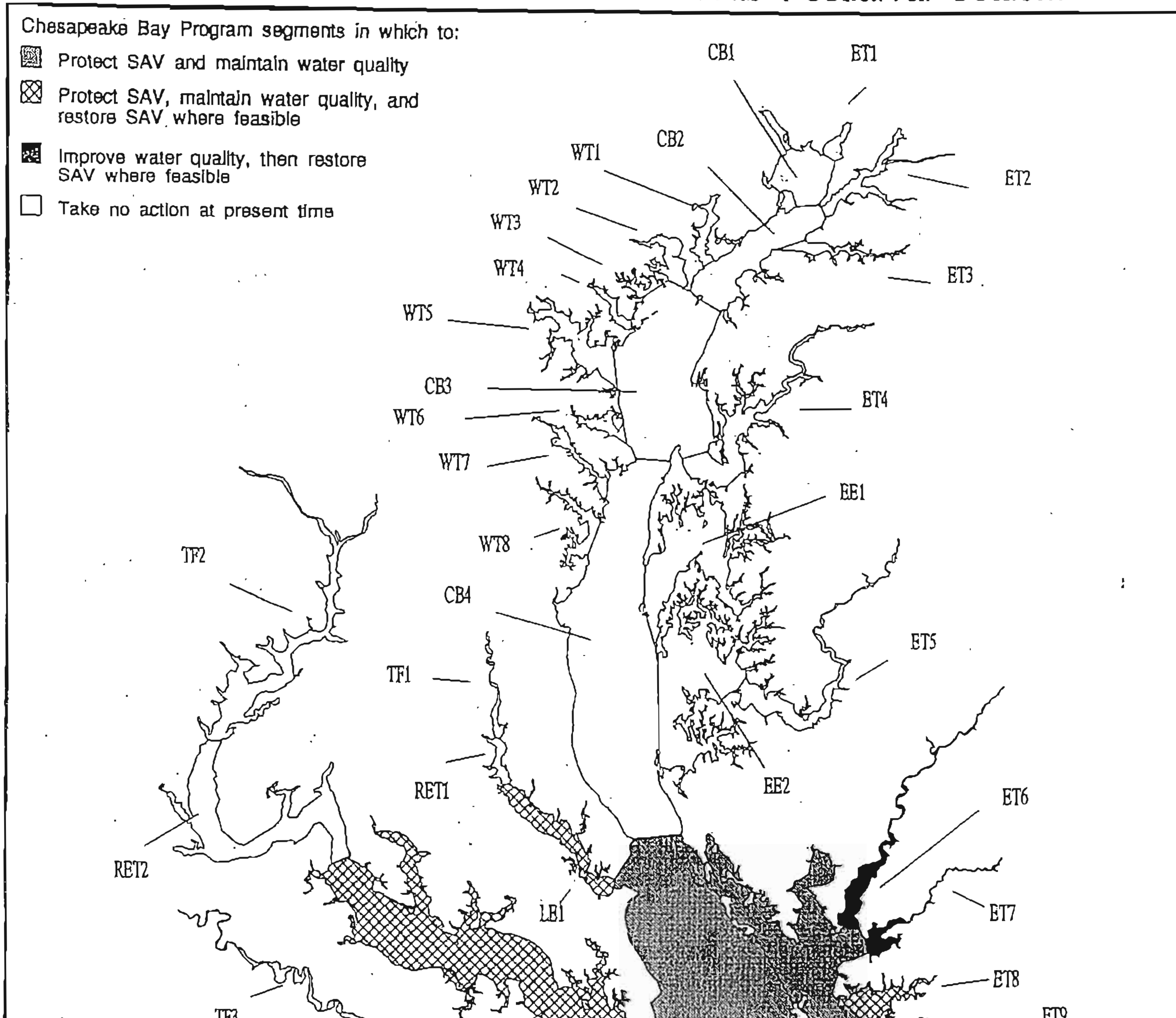
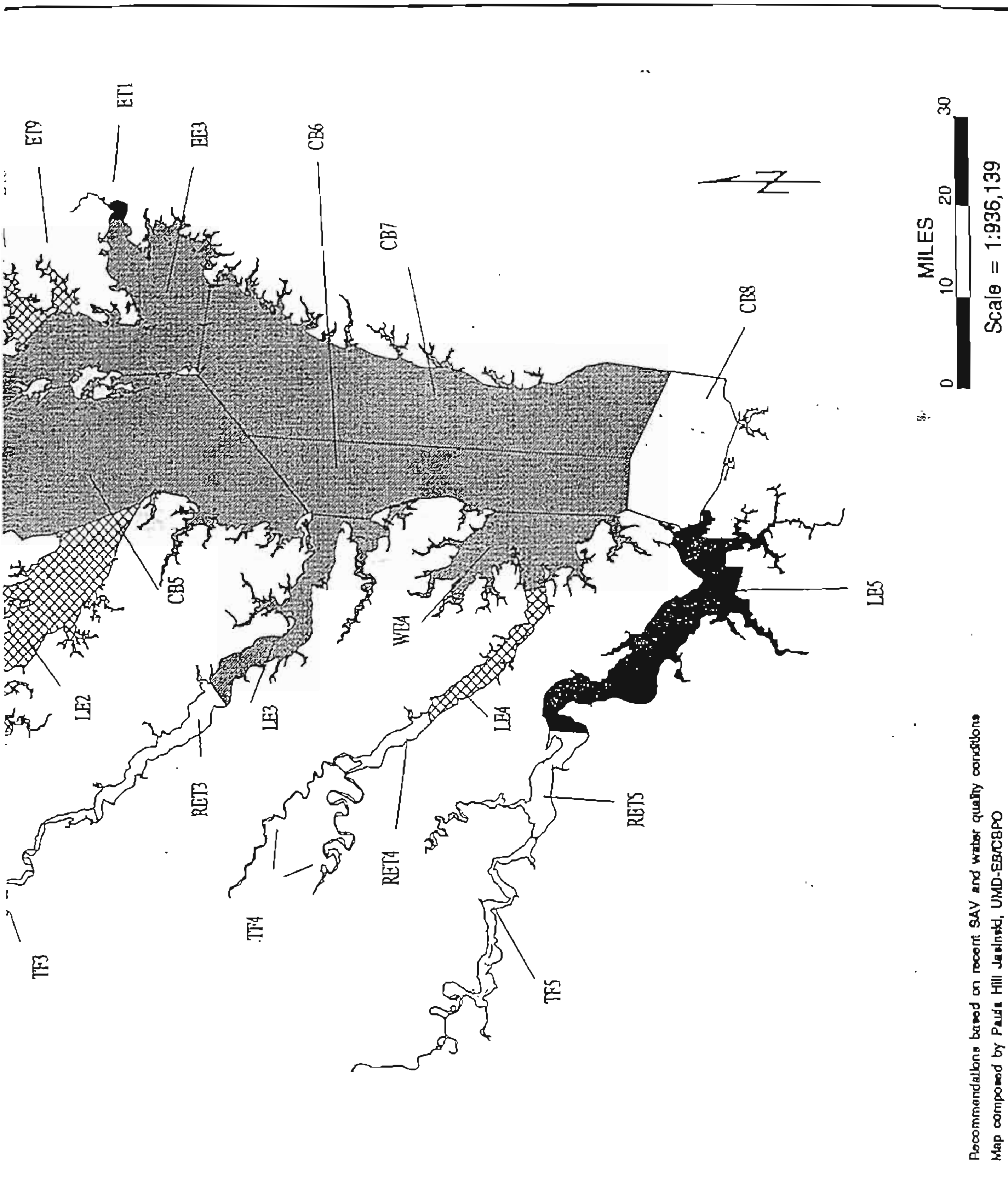
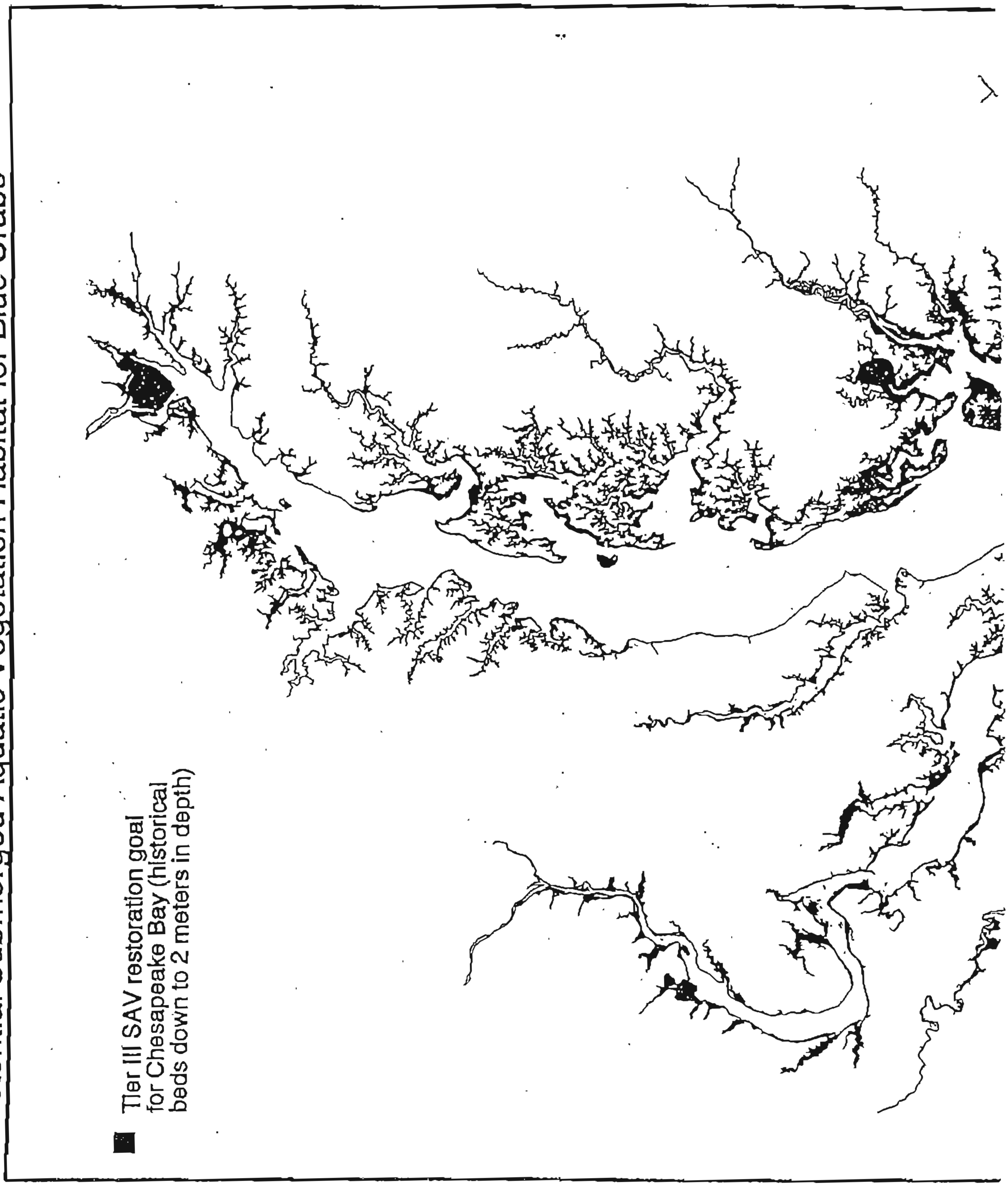


Figure 14



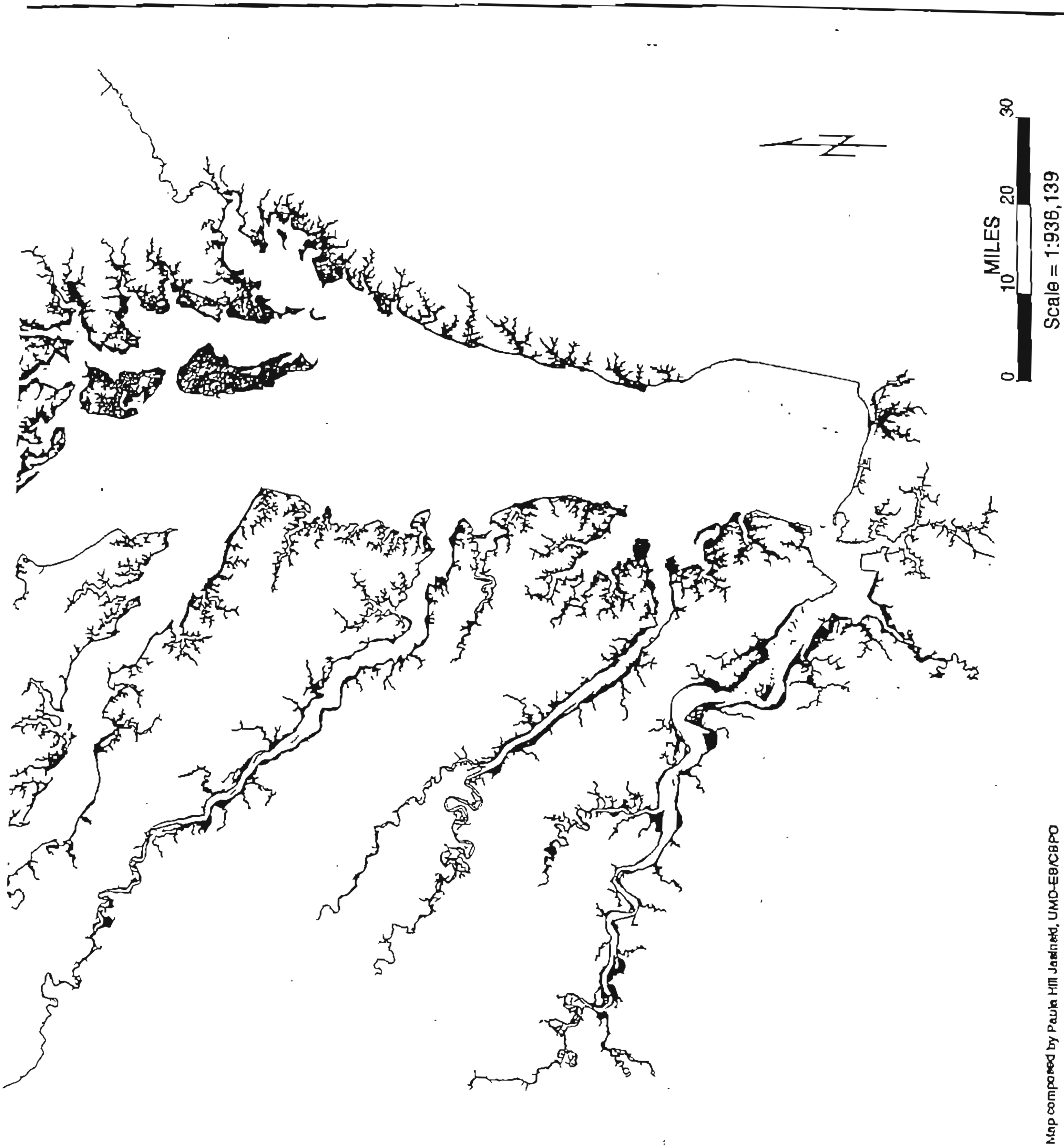
Recommendations based on recent SAV and water quality conditions
Map composed by Paula Hill Jasinski, UMD-EB/CBPO

Figure 15



Potential Submerged Aquatic Vegetation Habitat for Blue Crabs
Tier III SAV restoration goal for Chesapeake Bay (historical beds down to 2 meters in depth)

Figure 15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Map composed by Paula Hill Jasinski, UMD-EB/CBPO

SECTION 2
BLUE CRAB MANAGEMENT IN CHESAPEAKE BAY

Management of the Chesapeake Bay blue crab stock across geographic regions and state boundaries is a dynamic and complicated process. Since the adoption of the *1989 Chesapeake Bay Blue Crab FMP* (CBP, 1989), management measures implemented in Maryland and Virginia limit entry into the fishery and attempt to cap fishing effort. The following sections summarize Baywide management strategies and actions since 1989 and provide a framework for management strategies in the years to come. For a complete list of regulations and legislation pertaining to blue crabs, see Appendix C.

Coordinated Baywide Management Efforts

In January, 1996, the Chesapeake Bay Commission formed the Bi-State Blue Crab Advisory Committee, an ongoing committee of representatives from Maryland and Virginia. The committee will meet at least twice each year to address key elements of the *Blue Crab Fishery Management Plan* and other mutual interests. The Bi-State Blue Crab Advisory Committee offers a discussion and decision forum that supports state efforts to develop consistent and coordinated Baywide crab management policy. The committee consists of eight members each, from the Virginia and Maryland blue crab advisory committees (Maryland's Blue Crab Steering Committee and Virginia's HJR 609 Committee); six additional members from the Maryland and Virginia Delegations to the Chesapeake Bay Commission; the chair of the Bay Program's Living Resources Subcommittee; and a representative from the Potomac River Fisheries Commission (PRFC). The above membership represents the principal appointed officials of marine resources from each state, key legislators, watermen, fisheries managers, recreational crabbers, and individuals from the crab industry. Importantly, this membership approach continues the core representation of each state's crab committees, which have already taken the first steps toward bi-state action through joint meetings and ongoing communication. A select group of scientists and economists will serve as a Technical Workgroup to examine ecological and economic issues, analyze current data, and distill relevant fishery information for the committee's review.

Management Measures Since 1989

Virginia

Authority

The Virginia Marine Resources Commission (VMRC) is the state regulatory agency charged with managing marine resources in tidal waters. Regulations are adopted by a panel of commissioners appointed by the Governor. Virginia's legislative body, the General Assembly, defines the regulatory authority of VMRC and also votes on legislation in addition to regulations passed by VMRC

Regulatory and Legislative Changes Since 1989

In June 1989, VMRC restricted crab dredging from sunrise to sunset through regulation In June 1990, a regulation was promulgated governing the use, placement and maintenance of crab traps/pounds. At the General Assembly level, a bill was passed in 1990 that prohibited the placement of crab, eel or fish pots in a government marked channel. In 1991, House Joint Resolution #384 was passed which directed the Chesapeake Bay Commission to establish a committee to study issues related to the conservation of the living resources of the Chesapeake Bay. Consequently, the Living Resources Roundtable was formed and began meeting in May 1991. The 1992 session of the General Assembly passed a law, as recommended by the Living Resources Roundtable, which required that all commercial fishermen obtain a registration license. A two-year delay process was established for new entrants. The VMRC was given authority to limit or delay the number of participants entering any specific fishery, to require catch reports, and to delay the start of the crab dredge season until after December 1. In addition, the crab pot removal period was shortened by two weeks, to January 1-31.

In August 1992, Virginia adopted a regulation that established the procedures for the registration of commercial fishermen and the manner and form of mandatory harvest reports. This has provided more complete data and information to manage the crab fishery.

In 1993, the Virginia General Assembly enacted a law authorizing VMRC to establish recreational gear licenses. In other action, the commercial license fee structure for crab gear was revamped. New commercial licenses were established, including a peeler pot license and a license for shedding crabs. A regulation was promulgated in May, 1993, by the VMRC which established recreational licenses for up to five crab pots, one crab trap/pound and one crab trotline. In June 1993, the Commission passed a regulation designed to conserve small crabs, which required one unobstructed cull ring (2 5/16 inches diameter) in each hard crab pot, effective January 1, 1994. At their November meeting, the VMRC held public hearings and considered several proposals pertaining to controlling fishing effort and minimizing wasteful harvesting practices. After receiving public comments, the Commission reduced the daily catch limit in the crab dredge fishery from 25 to 20 barrels per vessel and established a limited entry system for the crab dredge fishery. The number of crab dredge licenses issued as of March 31, 1994, would be set as the maximum number for future seasons and the maintenance level was set at 225.

The 1994 session of the General Assembly removed the specifications for crab dredge dimensions in the Code of Virginia and authorized the VMRC to promulgate a regulation limiting the size of crab dredges. For the 1994/95 dredge season, the maximum dredge width of eight feet was reestablished. In October, 1994, Virginia approved a regulatory package of seven conservation measures for the blue crab commercial fishery. A 14,500-acre winter crab sanctuary was established upriver from the Hampton Roads Bridge Tunnel and dredging was prohibited in that area. A second summer spawning sanctuary (48,000 acres) was established Bayside of Kiptopeke on the Eastern Shore and crabbing was prohibited from June through September 15. Language was removed from the regulation allowing obstruction of cull rings during economic hardship. A second, smaller cull ring with an inside diameter of 2 3/16 inches was mandated in all hard crab pots. To address the issue of small mature females escaping through cull rings in certain areas, the larger (2-5/16 inches) cull ring was allowed to be closed within the dredge boundaries, in Pocomoke and Tangier sounds as well as on the seaside of the Eastern Shore. Four cull rings were required (1-1/2 inches inside diameter) in each peeler pound. Gear limits were set on peeler pots with 400 pots per vessel from April through June, and a 400 pot per person limit from July through November with no more than two licensed peeler potters allowed per vessel. A season was also established, whereby peeler and hard crab pots must be removed from the water by December 1 and not set out again until April 1.

In 1995, the General Assembly authorized the City of Norfolk to declare Pretty Lake a crab sanctuary by adoption of an ordinance. In other action, the placement of food in peeler pots was prohibited; previously, it was lawful to place food for jimmy crabs in peeler pots from September 16 through May 14. House Joint Resolution 609 (HJR 609) directed the Virginia delegation to the Chesapeake Bay Commission, VMRC and four industry representatives to study blue crabs. It also recommended a Blue Crab Fishery Management Plan (FMP) be prepared by VMRC, in consultation with research institutions and representatives of industry. The FMP was to be designed to reverse any fishing practices, environmental stress and habitat deterioration negatively impacting the short-term and long-term viability and sustainability of the crab stock in Virginia waters.

The HJR 609 Committee met several times during 1995. Scientists presented technical reports on the status of the crab resource, including spawning stock information, survey results and research needs. Managers reviewed a draft of the *1997 Chesapeake Bay Blue Crab FMP*, and presented current management policies and field research. The Committee voted not to change the current minimum sizes of crabs in 1995, primarily because consistency among Atlantic and Gulf coast states was needed. Members endorsed a proposal to establish a minimum 3½ inches size for soft crabs instead of cull rings in peeler pots. The Committee also voted to recommend legislation which will allow VMRC to define, by regulation, peeler crabs in order to reduce mortality. In addition, the HJR 609 Committee recommended that the *1997 Chesapeake Bay Blue Crab Management Plan* be adopted as Virginia's Plan, with a few revisions including: enhanced provisions regarding SAV; updated regulatory actions by the VMRC; and continued bi-state coordination and cooperation.

The 1996 session of the General Assembly authorized VMRC to modify the statutory definition of peeler crab, by regulation and authorized greater flexibility in setting the crab dredge season, based on conservation factors. Language clarifying the crab cull law was also adopted. In February 1996, Virginia adopted several regulations designed to protect and conserve the blue crab resource. A minimum size limit of 3 ½ inches was established for softshell crabs and a prohibition on the possession of dark sponge crabs was passed. Limits on the sale of commercial hard crab and peeler pot licenses for 1996 were established. Crabbers who held pot licenses in 1995 were allowed to purchase licenses for the same amount of pots in 1996. Crabbers with a history of potting and crew who obtained documentation were granted restricted licenses and hardship exception cases were considered. In addition, maximum daily hard crab pot limits were set. Crabbers were restricted to 300 crab pots in the tributaries or 500 pots in other tidal waters; however, no person could set more than a maximum of 500 pots statewide.

Maryland

Authority

Maryland's Department of Natural Resources (MDNR) is the state regulatory agency charged with managing fisheries in state waters. Authority to regulate is granted to MDNR by the Maryland State Legislature. The Maryland State Legislature must approve any changes to the fishing license structure and votes on legislation in addition to regulations passed by MDNR.

Regulatory and Legislative Changes Since 1989

Prior to 1994, there was no limit on the number of crab pots a commercial fishermen could fish in Maryland. A new license structure, which took effect in 1995, retains the Limited Crab Harvester License (up to 50 pots) and consolidates licenses for more than 50 pots and all other gears into one Crab Harvester License. Crab Harvesters are limited to 300 crab pots per vessel, and licensees may buy single and double allocations for one to two crew members which permits 300 additional pots per allocation, not to exceed 900 pots per boat. The Tidal Fish License, which consolidates finfish, shellfish and crabs in one license, is also limited to 300 pots with allocations up to 900 pots per boat. The deadline for crew authorization application was August 31, 1994.

In 1994, Maryland passed legislation that limits new entries into the commercial fishery. The Limited Entry Bill gives MDNR authority to establish a prescribed number of people to participate in any given fishery. No new licenses have been issued since April 1, 1996. The license moratorium will remain in effect until the number of licenses drops below a prescribed number, which will be determined by 1999. As licenses are lost voluntarily, by revocation, expiration or death, the fishery will be capped at a maximum number of participants, and fishing effort will be limited.

In 1994, times when commercial and recreational crabbers can set and fish their gear in Maryland were defined in regulation (see Appendix C). To limit effort in the number of man-hours spent fishing, start and end times were staggered to minimize conflicts between user groups.

The noncommercial crab license was eliminated through legislation prior to the 1994 harvest season. Maryland currently has no licensing system for recreational crabbers, which includes crabbers who were previously licensed as noncommercial crabbers since 1994. Unlicensed recreational crabbers were limited to five crab traps and/or rings per person; the licensed noncommercial crabber was allowed up to 50 traps and/or rings. All recreational crabbers since 1994 have been limited to 10 traps and/or rings per person, not to exceed 25 traps and/or rings per boat. Trotline, which was limited to 500 feet for recreational crabbers and unlimited for noncommercial crabbers, is now limited for all recreational crabbers to 1000 feet per person, not to exceed 2000 feet per boat. Recreational harvest since 1994 has been limited to no more than one bushel per person and no more than two bushels per boat. A recreational crabbing license was proposed to the Maryland Legislature in 1994, 1995 and 1996, but was not adopted. The Maryland General Assembly is considering a bill during the 1997 Session that would require recreational crabbers to purchase a license, excluding recreational crabbers using handlines or dipnets, and private property owners using crab pots from their property. Revenues would fund an extensive survey of the recreational fishery.

Cull rings enabling undersized crabs to escape have been used on a voluntary basis for several years. Current Maryland regulation requires one cull ring 2 5/16 inches in diameter or one section of 2 inches by 2 inches square mesh with four openings in all crab pots with mesh size greater than 1 ½ inches or less than 2 inches. The cull ring may be obstructed at any time of year for the purpose of catching peelers.

The maximum number of crab pots that can be set from private property in Maryland is two. Prior to 1994, some counties were allowed four. The proposal that pots be set or constructed so trapped air-breathing animals could survive until released was rejected.

In 1996, Maryland passed a regulatory package for blue crabs. All commercial harvest was prohibited one day per week and recreational harvest by trotline, traps, and rings was prohibited one day per week. A second cull ring 2 $^{3}/_{16}$ inches in diameter was required in all crab pots with mesh at least 1 ½ inches and less than 2 inches. Hard crab pots were redefined as pots with mesh 1 ½ inches and greater. Peeler pots must have at least 1 inch mesh.

Potomac River Fisheries Commission

Authority

Blue crab fishery activity on the tidewater portion of the Potomac River is managed by the Potomac River Fisheries Commission (PRFC), an eight-member body empowered under the Maryland-Virginia Compact of 1958. The Commission meets quarterly to establish and maintain a program of conservation and improvement of the fishery resources of the river. The Commission will develop appropriate Actions and Implementation plans, along with Maryland and Virginia, to address the Problems and Strategies identified in this Management Plan.

Regulatory Changes Since 1989

The Potomac River Fisheries Commission (PRFC) implemented limited entry into the commercial crab pot fishery, beginning in 1995. Entrants had until January 31, 1995, to renew existing licenses or to become eligible to receive a commercial license. Issuance of commercial crab pot licenses will be capped at 500.

Improvements in Catch Statistics

Commercial reporting systems in Virginia (VMRC) and Maryland (MDNR) surveyed a portion of harvesters (MD, 1981 to 1994) or dealers (VA, 1973 to 1993) each month. Reporting in Virginia was voluntary and Maryland conducted random samples. Since 1993, both states have converted to mandatory reporting by all commercial harvesters and collect information on amounts of gear and effort, as well as biological characteristics of the catch. Because the various life history stages of blue crab are found in different areas of the Bay and the population is assumed to represent a single stock across state lines, uniform Baywide catch records for both commercial and recreational harvests are necessary to adequately monitor the resource.

Evaluation of Blue Crab Management

Implementing a combination of effort control management strategies, i.e gear, time and license reductions or stabilization, may be effective at containing harvest (National Academy Press, 1994). Although the current regulations on the harvest of blue crabs are significant for both states, it is not yet clear at what level effort may be capped. Maryland's gear limit for crab potters still allows for growth in the fishery. In years prior to gear limits, a large portion of harvesters reported using 200 pots or less. A limit of 300 pots per person may permit effort in the fishery to increase before it stabilizes. In addition, crew allocations allow for up to 900 pots per boat and crew members may be unlicensed License stabilization in the form of the 1994 limited entry law is a giant step towards stabilizing effort in the entire Maryland crab fishery. Maryland has not yet defined what number of licenses the fishery will be capped at. Levels of harvest and harvest rates in following seasons will likely determine whether the fishery should be capped at current license levels or if reduction is necessary.

Virginia recently adopted a regulation which limits the amount of effort in the crab pot fisheries by two methods for the 1996 crab season. This regulation was designed to protect and conserve the blue crab resource by limiting the number of commercial hard crab pot and peeler pot licenses issued and to further control fishing effort by establishing limits on the number of commercial hard crab pots that can be set or fished. Another regulation was already in effect that restricts the number of peeler pots that can be set or fished. This new regulation, in combination with all of the other conservation measures that Virginia has implemented within the last few years, is designed to stabilize fishing effort, increase productivity and conserve the blue crab resource.

Conclusion

Managers from both jurisdictions are careful not to assume recent regulations will be completely effective in limiting effort and harvest in the fishery. These new restrictions and their effectiveness at stabilizing fishing effort must be evaluated. If these actions prove successful in limiting fishing effort on the blue crab stock in Chesapeake Bay, this management plan will have succeeded in the objective of being a "problem preventing" tool rather than solely a "problem solving" plan.

This Plan is designed to be flexible and responsive to new knowledge, changes in stock abundance or fishing mortality rates, and new or revised estimates of stock status. Future management decisions will also depend on the effectiveness of current regulations. Virginia and Maryland still have substantial differences in their management regulations. Although the states are striving for uniformity, differences in regulations are often the result of life history and behavioral characteristics of the blue crab and differences in the fisheries. Therefore, compatibility of regulations may be more appropriate in some instances.

Over the course of the next several years, intensive research and monitoring will be necessary to evaluate whether the Bay states have insured the long-term survival of the blue crab resource or whether new solutions must be sought to preserve the resource. Maryland and

Virginia should continue their cooperative approach in the management and study of this species. Forums such as the Bi-State Blue Crab Advisory Committee will be valuable in assuring open communication and discussions regarding the most up-to-date science, effectiveness of current regulations, and needed changes to management actions.

Blue Crab Management Strategies

1. Stock Status

Problem 1.1: Stock Status

Estimates of stock abundance (Rugolo *et al.*, unpublished) indicate that the blue crab population was high in the late 1980s through 1991 and has returned to average levels of abundance since 1991. Juvenile recruitment indices have been increasing and estimates of fishing mortality have varied without trend between 0.8 and 1.0 (1968-1995). The blue crab fishery is characterized as fully exploited. This description is based on a fishing mortality rate that allows for at least 10% of the spawning stock to escape the fishery to reproduce ($F_{10\%}$; i.e. the estimated weight of the adult female stock if no crabs were removed by the fishery, divided by the estimated total weight of the current adult female stock as influenced by fishing pressure, equals 0.10 or 10%). Results of the Chesapeake Bay blue crab stock assessment indicate that fishing mortality rates have remained at or slightly below estimates of $F_{10\%}$. Although the results of the stock assessment are positive for the blue crab stock, they do indicate that the fishery is overcapitalized (refer to Problem 2.1: Fishing Effort). As long as the fishery does not become more efficient at harvesting blue crabs, the stock should be able to sustain the current level of fishing pressure.

Strategy 1.1

To provide long-term protection for the blue crab stock and maintain a stable stock, quantitative targets (such as abundance, biomass, or other indices) will be developed as references for evaluating stock status and implementing fisheries or habitat management measures. Targets will be the safe management levels. Limits will be the maximum limits for sustainability.

Actions

1.1.1 The Baywide blue crab stock assessment will be updated in 2 years, and every 5 years thereafter, to monitor trends in the blue crab population. New information from other assessments will be evaluated, as well.
Implementation: 1998

1.1.2 The Chesapeake Bay Blue Crab Target Setting Task Force will: 1) examine habitat and environmental variables as they relate to stock size and recruitment; 2) examine blue crab harvest and abundance by life history stage, time, and area; and 3) develop a regional, stage-based model to predict life stages and regions of greatest sensitivity of blue crab to changes in exploitation patterns and rates.
Implementation: 1998

1.1.3 The Chesapeake Bay Commission Bi-State Blue Crab Advisory Committee, a joint panel of legislators, representatives of the industry and commercial and recreational fisheries, and other interests from Maryland and Virginia, will convene twice a year to review the status of the blue crab resource baywide and the effectiveness of current regulations and coordinate efforts. Data and assessments

will be provided to the panel by a technical committee of scientists and resource managers. The panel, based on information provided by the technical committee, will recommend actions as necessary to stabilize harvest and effort at levels that protect the reproductive potential of the blue crab stock.
Implementation: 1996

1.1.4 The Technical Workgroup (TWG) of the Chesapeake Bay Commission's Bi-State Blue Crab Advisory Committee (BBCAC) will assess the economic impacts and benefits of various biologically-determined limits and target levels. In addition, the TWG will assess the economic ramifications of policies designed to stabilize harvest and effort levels which protect the reproductive potential of the blue crab stock.
Implementation: Ongoing

1.1.5 The states will develop estimates of prudent and sustainable spawning stock which gives reasonable promise that the spawning stock will not be so depleted as to reduce future abundance.
Implementation: Ongoing

2. Fishing Effort

Problem 2.1: Fishing Effort

Prior to 1994, Maryland and Virginia fisheries were open access, with no limits the number of participants and few limits on amounts of gear. As a result, baywide fishing effort for blue crab has increased five-fold since 1945. Over this same time period, fishing mortality and total harvest have remained stable. However, high numbers of participants in the fishery, increased competition between participants, and subsequent overcapitalization of the commercial fishery have resulted in a decreased CPUE. Harvesters must deploy greater amounts of gear to harvest equal amounts of crabs. Only limited information regarding fishing effort and harvest in the recreational fishery is available.

Strategy 2.1

Limited entry in the commercial fishery is being implemented in Maryland, Virginia and the Potomac River. In addition, limits on commercial and recreational fishing effort were recently enacted and a design for a baywide survey of recreational catch and effort is being developed. The implementation of these management measures will be monitored and evaluated to determine effectiveness of capping effort, preservation of the social value, and economic sustainability of the fisheries.

Actions

2.1.1 Maryland will determine a maximum number of commercial crabbing licenses and licenses with crew allocations, as required under the state's Limited Entry Law

(Annotated Code of MD, Nat. Res. Article 4-701). Maryland shall consider the number of people historically participating in the fishery, annual harvest, mortality, total biomass, size, number, incidental catch, target species, and any other factors that are necessary and appropriate.
Implementation: 1998

2.1.2 Virginia will continue to evaluate its crab pot and peeler pot limited entry program which was established January 1, 1996. Further adjustments to the program will depend on the future status of the stock and stabilization of the fishery. Minor adjustments to the program will be necessary to insure its long-term application
Implementation: 1997

2.1.3 The Potomac River Fisheries Commission (PRFC) will continue to evaluate its crab pot limited entry program.
Implementation: Ongoing

2.1.4 Maryland, Virginia, and the PRFC will continue to manage blue crab fisheries through the use of time limits, seasons, gear restrictions, catch limits, and size limits, as necessary, to prevent further increases in fishing effort.
Implementation: Ongoing

2.1.5 Maryland will design a survey that estimates catch and effort by the recreational fisheries in Maryland and which could be applied baywide. Virginia will continue to monitor licensed recreational crab harvest data.
Implementation: Maryland, 1999; Virginia, ongoing.

2.1.6 The Technical Workgroup of the Bi-State Blue Crab Advisory Committee will design sample survey procedures that can be used to build a comprehensive effort and economic data base for the fishery. Cost estimates for implementation of the surveys will be provided.
Implementation: 1999

Problem 2.2: Gear Efficiency

With the exception of the scrape fishery and winter dredge fishery, which are both limited in size and area, the blue crab fishery uses passive gears that allow for escapement of a portion of the blue crab population. Changes in the efficiency of the fishery, such as improved gear designs or new gears, have the potential to harvest a greater portion of the blue crab population and overexploit the resource.

Strategy 2.2

The jurisdictions will continue to monitor trends in the commercial and recreational fisheries and manage those fisheries in a manner that allows adequate escapement of blue crabs from harvest and prevents overfishing.

Action

2.2.1 Maryland and Virginia have defined gear for the purpose of catching crabs through regulation and legislation (Appendix C). Any major changes to gear, as currently defined, will be evaluated prior to approval to determine the potential impacts on the efficiency of the blue crab fishery and fishing mortality rates.
Implementation: Ongoing

2.2.2 Maryland, Virginia and the PRFC have modified reporting methods to acquire more accurate and detailed data. The mandatory reporting systems collect data on areas fished, gear types and amounts, hours fished, amounts harvested, and biological data. New reporting methods will continue to be used to monitor effort in the commercial fisheries, including effort by life history stage, sex, and gear type. The jurisdictions will continue to coordinate efforts to develop compatible reporting systems. The effectiveness of current regulations also will be monitored through reporting methods.
Implementation: Ongoing

3. Stock Assessment Needs

Problem 3.1: Commercial Reporting

Virginia and Maryland implemented mandatory reporting by all commercial harvesters in 1993 and 1994, respectively. The states collect data on fishing effort, harvest by area, and harvest by market category (male, female, soft/peeler). The PRFC also requires reporting of similar data by all commercial harvesters on Potomac River. Further refining of data collection and analysis may be necessary to obtain consistent data sets that are comparable across jurisdictions. Prior to 1993, Virginia's reporting system did not collect data on effort or market category and it will take several years before trends and comparisons become apparent.

Strategy 3.1

New reporting methods will be used with continued fishery-independent surveys to monitor blue crab stocks.

Actions

3.1.1 Maryland, Virginia, and PRFC will continue to collect comparable data and refine data collection to achieve greater consistency.
Implementation: Ongoing

3.1.2 Maryland and Virginia will monitor commercial landings to evaluate the relationship between fishery-dependent and fishery-independent estimates of abundance and coordinate management efforts.
Implementation: Ongoing

3.1.3 Maryland and Virginia will explore methods to collect more accurate data on soft and peeler crab harvest.
Implementation: 1998

Problem 3.2: Recreational Harvest

Little is known about the blue crab recreational catch, fishing effort, and the economic impact of recreational crabbing in Chesapeake Bay. Virginia instituted mandatory reporting for all licensed recreational crabbers, including the amount harvested per day, amount and types of gear used, and area. A license is required in Virginia for recreational use of up to 5 crab pots, 300 feet of trotline and/or one crab pound/trap. Maryland has been unsuccessful in attempts to require recreational licenses since 1994 and recreational harvest is unreported. The Potomac River Fisheries Commission has twice considered a recreational crab pot license as a tool to collect recreational data, but no license has yet been enacted for the Potomac.

Strategy 3.2

There will be a baywide effort to collect recreational catch and effort data. The economic, social, and biological impact of the recreational harvest will be evaluated.

Action

3.2.1 Maryland will consider a recreational crabbing license to complement efforts outlined in Action 2.1.4 to obtain recreational catch and effort data.
Implementation: 1997

Problem 3.3: Research Needs

The population dynamics of the blue crab stock is not fully understood. Additional information is needed concerning natural and fishing mortality rates, as well as the stock-recruitment relationship. The effects of environmental variables and fishing mortality on year-class strength and availability, female spawning potential, age, and growth are also areas that require improved understanding.

Strategy 3.3

The baywide effort to collect population data on blue crabs will continue and current methods will be improved.

Actions

3.3.1 Maryland and Virginia will continue cooperation with the Baywide Winter Dredge Survey. Data analysis will be refined.
Implementation: Ongoing

3.3.2 Maryland and Virginia will continue to encourage research that examines the relationships between spawning stock and recruitment and the effects of environmental parameters on fluctuations in crab abundance.
Implementation: Ongoing

3.3.3 Signals of year class abundance early in the life history will be sought and evaluated as guides or triggers for management actions.
Implementation: Ongoing

3.3.4 Studies of the stock of blue crabs on the ocean side of the Eastern Shore, its abundance and economic value, and its potential contribution to the larval and megalopal stock on the continental shelf that may eventually become part of the Bay stock are encouraged.
Implementation: Ongoing

3.3.5 Age and growth studies will be emphasized.
Implementation: Ongoing

4. Wasteful Harvesting Practices

Problem 4.1: Economic Yield

Harvesting small crabs or buckrams does not maximize economic value of the resource. For example, the economic yield of crabs is not always optimum if buckrams (recently shed crabs whose shell is in the process of hardening), which yield small amounts of meat, are marketed.

Strategy 4.1

Optimum use of the blue crab resource will be promoted by eliminating and/or minimizing wasteful harvest practices. Harvesters and consumers should be educated concerning poor-quality or poor-value crabs.

Actions

4.1.1 Size limits which achieve the greatest economic yield for the fishery will be evaluated.
Implementation: 1997

4.1.2 Maryland and Virginia will continue to promote the release of buckrams through brochures and/or newsletters that identify buckrams and demonstrate the potential weight gain through time.
Implementation: Ongoing

4.1.3 Maryland and Virginia will educate the consumer about wasteful harvesting practices and the effects of waste on the resource, so consumers may be better informed when purchasing crabs.
Implementation: 1997

Problem 4.2: Cull Apparatus

Small crabs retained in hard crab pots suffer high mortality rates due to predation by larger crabs. Cull rings may also allow the escape of small, legal-size peelers and mature females during certain seasons. Cull rings that allow sublegal crabs to escape are required in all jurisdictions; however, legislation in Maryland allows cull rings in hard crab pots to be obstructed when fishing for peelers through 1999.

Strategy 4.2

The biological benefits and economic impact of cull rings in crab pots will be investigated. Maryland will define specific seasons when cull rings may be obstructed for harvesting peelers, considering both impact on the resource and economic benefit.

Actions

4.2.1 Maryland will define seasons for peeler fishing with hard crab pots (pots with mesh size 1.5 inches or greater) for which cull rings may be obstructed to minimize the impact on the resource and maximize economic benefits. Outside of the defined season, unobstructed cull rings will be enforced.
Implementation: 1997

4.2.2 Legislation in Maryland allowing cull rings in hard crab pots to be obstructed when fishing for peelers is effective through 1999. Maryland will evaluate the effects of requiring unobstructed cull rings and identify management options with minimum economic impact and maximum benefit to the resource. Seasonal obstructions and cull ring placement and size should be considered.
Implementation: 1997

4.2.3 The Potomac River Fisheries Commission will require two cull rings (one 2 $^{5}/_{16}$ inches minimum and one 2 $^{3}/_{16}$ inches minimum) in hard crab pots and two cull rings 1 ½ inches minimum in peeler pots.
Implementation: 1997

Problem 4.3: Female Harvest Rates

The harvesting of sponge crabs and females at other life history stages may result in a loss of reproductive capability.

Strategy 4.3

Landings and fishery-independent data will be reviewed to determine if low reproductive potential and poor spawning success are resulting from female harvest.

Actions

4.3.1 Virginia and Maryland will continue to collect data on female size at maturity, migration, distribution, and harvest by sex. This data will be used to examine the effects of female harvest on crab population dynamics. Result will be used to guide management measures that protect the reproductive potential of blue crabs.
Implementation: Ongoing

4.3.2 Maryland will investigate the interstate trade of blue crabs to quantify the number of sponge crabs entering the Maryland market. Sponge crabs may not be legally harvested in Maryland. The state will investigate the economic impact of prohibiting possession or sale within the state.
Implementation: 1997

4.3.3 Maryland and Virginia will evaluate studies that examine the effectiveness of sanctuaries as a conservation tool. Sanctuaries include areas where harvest is prohibited seasonally and year-round, and protected nursery habitats. States will consider establishing sanctuaries in areas identified as optimum sites in Chesapeake Bay.
Implementation: 1997

Problem 4.4: Abandoned Pots

Lost and abandoned crab pots are attractive refuge sites that trap and, eventually, kill significant numbers of crabs and finfish. Pots are lost when boat propellers cut buoy lines, during storms, and by sabotage. Pots also may be crushed by clam dredging. Abandoned pots are self-baiting. Weak and dead crabs attract other crabs into abandoned pots. Abandoned pots trap and drown air breathing animals, such as terrapins, that inhabit tributaries. Biodegradable materials and escape panels have been the subject of preliminary investigation in Maryland. In addition to being a hazard to aquatic life, abandoned pots can be navigational hazards for boats. Enforcement of regulations that prohibit pot abandonment is difficult and fines are not significant enough to discourage the practice.

Strategy 4.4

The deliberate abandonment of crab pots will be discouraged and escape mechanisms on pots will continue to be researched.

Actions

4.4.1 Virginia and Maryland will continue to address regulation of abandoned crab pots, including significant fines that may discourage deliberate abandonment.
Implementation: 1996

4.4.2 Virginia and Maryland will continue to investigate materials for biodegradable escape panels and latches in crab pots. Escape mechanisms for air breathing animals and devices to prevent them from entering crab gear will also be investigated.
Implementation: Ongoing

4.4.3 Maryland and Virginia will educate commercial crabbers about the problems of abandoned crab pots and Maryland will educate property owners about the effects of pots left unfished.
Implementation: 1996

4.4.4 The Potomac River Fisheries Commission will provide a mechanism to identify and remove abandoned crab pots.
Implementation: 1996

Problem 4.5: Shedding Mortality

The mortality rate of green crabs (a peeler crab without red or pink coloration in the swim fin) held in shedding floats is high compared with peelers that are close to molting. Mortality rates in shedding floats and poorly operated shedding systems also may be high.

Strategy 4.5

Information will be provided to shedders to minimize mortality in shedding operations.

Actions

4.5.1 Maryland and Virginia will continue to provide technical information to shedding operations that promote reduction of peeler mortalities associated with holding practices and problems related to green crab mortality.
Implementation: Ongoing

4.5.2 Virginia established a commercial shedding license, effective January 1, 1994, and will monitor data reports.
Implementation: Ongoing

4.5.3 Maryland will investigate a joint venture with commercial watermen's associations to establish a shedding facility for the purpose of research and education.
Implementation: To be determined.

5. Regulatory Issues

Problem 5.1: Commercial/Recreational Conflict

The blue crab fishery provides economic, social, and recreational benefits to the community. Conflict between commercial crabbers and recreational boaters has become a serious problem in some of the more densely populated areas of Virginia and Maryland. From the recreational boater's point of view, crab pot floats are interfering with recreational boating. From the commercial waterman's perspective, recreational boaters are interfering with crab potting, because they inadvertently run over and cut off crab pot floats. There is competition for trotline space in Maryland tributaries.

Strategy 5.1

Conflicts among user groups and the general boating public can be minimized by time limits, daily harvest restrictions and gear restrictions to allocate use of the resource.

Action

5.1.1 Maryland and Virginia will continue to monitor conflicts between crabbers and recreational boaters, enforce existing regulations on open and closed crabbing areas and buoy-free channels, and consider additional buoy-free channels.
Implementation: Ongoing

5.1.2 The Potomac River Fisheries Commission will continue to prohibit placement of crab pots in federally marked navigation channels.
Implementation: Ongoing

Problem 5.2: Enforcement

The interstate shipment of crabs between states with inconsistent size limits and other restrictions may circumvent efforts to protect the Chesapeake Bay stock from illegal fishing activities. Enforcement of regulations is necessary to deter illegal fishing activities; however, regulations such as gear limits are often difficult to enforce.

Strategy 5.2

Maryland and Virginia will continue to work towards complimentary management of the baywide blue crab resource and improve enforceability of current regulations.

Actions

5.2.1 Maryland and Virginia will work to achieve consistent minimum sizes and comparable conservation measures, where possible, for all crabs harvested in Chesapeake Bay.
Implementation: Ongoing

5.2.2 Virginia will investigate the feasibility of a crab pot tagging system to improve the enforceability of gear limits.
Implementation: 1997

5.2.3 The Potomac River Fisheries Commission will impose a 3 ½ inches minimum size limit on soft crabs.
Implementation: 1996

6. Habitat Issues

Problem 6.1: Anoxia

Excess nutrients enter the Bay from agricultural and urban runoff, sewage treatment plants, and atmospheric deposition. High nutrient loads support algal blooms, which produce anoxic conditions in the Bay. The anoxic portion of the Bay has steadily increased in size and duration and is reducing the amount of suitable habitat for crabs. Declining habitat area increases intraspecies competition. The area available for blue crab fishing compresses and commercial fishing suffers due to the high mortality of crabs retained in pots in anoxic and hypoxic areas.

Strategy 6.1

The *1987 Chesapeake Bay Agreement* (Chesapeake Executive Council, 1987) committed the signatories of Maryland, Virginia, Pennsylvania, and the District of Columbia, to "achieve by the year 2000 at least a 40 percent reduction of nitrogen and phosphorous entering the mainstem Chesapeake Bay." Oxygen content goals for the Bay are also recommended.

Actions

6.1.1 The jurisdictions will implement tributary strategies to achieve the goal of 40% nutrient reduction to the Chesapeake Bay mainstem by the year 2000. Major goals outlined by the tributary strategies include:

Maryland:
* Upgrade 50 wastewater treatment plants to control nitrogen and phosphorus discharges.
* Encourage farmers to implement nutrient management plans and plant cover crops.

Pennsylvania:
* Implement nutrient control efforts on the state's farm lands.
* Fence hundreds of miles of streams to keep livestock out.

District of Columbia:
* Upgrade Blue Plains wastewater treatment plant, the greatest source of nutrients from the District.

* Control combined sewer overflow to reduce the frequency of overloads.
* Control additional runoff at construction sites, new development, public education, and habitat restoration.

Virginia:

* Present a nutrient reduction strategy for Virginia's portion of the Potomac River to the General Assembly by January 1, 1997.
* Present nutrient reduction strategies for the Rappahannock, York, and James Rivers to the General Assembly by January 1, 1998.
Implementation: 2000

6.1.2 Baywide dissolved oxygen goals for selected Chesapeake Bay species, including blue crab, are recommended as follows[1]:

a. All waters of Chesapeake Bay and its tidal tributaries should contain a minimum of 1.0 mg/L dissolved oxygen at all times;
b. all waters above pycnocline of Chesapeake Bay and its tidal tributaries should contain a monthly average of 5.0 mg/L dissolved oxygen; and
c. dissolved oxygen concentrations between 1.0 and 3.0 mg/L should not occur for longer than 12 hours and the interval between excursions of dissolved oxygen between 1.0 and 3.0 mg/L should be at least 48 hours throughout Chesapeake Bay and its tidal tributaries.

The jurisdictions will consider the above recommendations when reviewing their state standards. Juvenile blue crabs may be less tolerant of hypoxic conditions and the above recommendations should be evaluated specifically for juvenile blue crabs.
Implementation: Recommendations in effect upon adoption of this plan.

Problem 6.2: Submerged Aquatic Vegetation and Intertidal Wetlands

Shoreline development that reduces shallow water habitat, heavy boat traffic, crab scraping, and clam dredging all contribute to local destruction of submerged aquatic vegetation (SAV). Crab scraping in Virginia is restricted to hauling by hand and hard crab bycatch is illegal. In Maryland heavy scrapes with power winders are used during the early season to catch hard crabs. Nutrient influx, as discussed in problem 6.1, and sediment runoff are responsible for widespread declines in SAV throughout the Bay. The loss of SAV and intertidal wetlands has resulted in the loss of blue crab habitat, particularly for crabs in juvenile and molting stages.

[1] Adopted from Chesapeake Bay Dissolved Oxygen Goal for Restoration of Living Resources Habitats (Jordan et al., 1992).

Strategy 6.2

The SAV Workgroup of the Chesapeake Bay Program's Living Resources Subcommittee recommended strategies for SAV protection and restoration to benefit blue crab postlarval settlement. The recommendations apply to the segments of Chesapeake Bay which are shaded and stippled in Figure 3 and only in shallow water (2 meters deep or less), which is considered potential SAV habitat (Batiuk *et al.* 1992). The Bay mouth (segment CB8) was not identified as an SAV restoration area because there is very little potential SAV habitat there (Category D).

Table 4 in Action 6.2.2 includes information on recent SAV trends in each segment and categorizes segments by condition. In general, areas where SAV area is currently increasing are preferred as restoration sites over areas with recent declines. Causes for SAV declines in 1994 and 1995 are not well known. It remains unknown whether or not SAV should be planted in areas with declining SAV populations. If recent SAV declines continue in segments from Category A, they may have to be reclassified as Category B.

SAV restoration efforts focused in segments of Category B would provide the most benefit to blue crab postlarval settlement habitat. Category B includes the lower reaches of four major rivers on the Bay's western shore (Patuxent, Potomac, Rappahannock, and York rivers), and two small tributaries on Maryland's lower eastern shore (Manokin and Big Annemessex rivers). Nutrient and/or suspended sediment reduction efforts are needed in segments in Category C before restoration efforts can be considered and include the lower James River and three other small tributaries on Maryland's lower Eastern shore (Nanticoke, Wicomico, and Pocomoke rivers). However, water quality in these segments can also be influenced by activities in segments up-river and up-Bay.

The Chesapeake Bay Program is committed to, "achieve a net gain in SAV distribution, abundance, and species diversity in the Bay and tidal tributaries over present populations" (Chesapeake Executive Council, 1990). The Bay jurisdictions will maintain a priority status on protection of SAV and intertidal wetlands.

Actions

6.2.1 The Chesapeake Bay jurisdictions will work to restore SAV to their historic levels. Chesapeake Bay Program restoration goals and targets for SAV (CBP, 1993) are as follows:

Tier I Goal	Restore SAV Baywide to 114,000 total acres in areas known to have been inhabited by SAV from 1971 to 1990. The goal is to achieve this recovery by 2005.
Tier II Target	Restore SAV to all shallow water areas delineated as existing or potential SAV habitat down to the 1 meter depth contour. Total restoration area: to be determined.
Tier III Target	Restore SAV to all shallow water areas delineated as existing or potential SAV habitat down to the 2 meter depth contour. Potential restoration area: 611,000 acres.

Implementation:

Tier I: Ongoing

Tier II: 2005 or following full implementation of Tier I

Tier III: Following full implementation of Tier II

6.2.2. Segments of Chesapeake Bay for SAV protection and restoration which would benefit blue crab postlarval settlement in areas 2 meters deep or less are identified. Segments and recommended actions are provided as protection and restoration goals and should also be reviewed when evaluating proposed activities which would cause physical disruption or degradation of water quality in areas 2 meters deep or less. Recommended actions are based on a decision matrix provided in Appendix B. Segments and recommendations are as follows:

Table 4. Strategies for SAV Restoration and Protection for Postlarval Blue Crab Settlement

CBP Segment[1]	Segment Name (see Figure 3 for map of segments)	1994 SAV acres (% of Tier I goal)[2]	1994 % WQ Goals Met[3]	Trends in SAV area
Recommended Action: Protect existing SAV and maintain water quality (Category A)				
CB5	Lower Central Chesapeake Bay	8,727 (56%)	80%	SAV area up 1978-1992, declined 1993-1995
EE3	Tangier Sound	11,301 (72%)	100%	SAV area up 1978-1993, declined in 1994 and 1995
CB6	Western Lower Chesapeake Bay	1,463 (76%)	80%	SAV area up 1978-1993, declined in 1994 and 1995
WE4	Mobjack Bay	11,343 (78%)	100%	SAV area stable since 1991
CB7	Eastern Lower Chesapeake Bay	9,259 (81%)	100%	SAV area up 1978-1993, declined in 1994 and 1995
Recommended Action: Protect existing SAV, maintain water quality, and restore SAV where feasible (Category B)				
LE1	Lower Patuxent River	0 (0%)	100%	Few propagules present?
LE2	Lower Potomac River	345 (49%)	100%	SAV increased 1992-95
ET8	Manokin River	165 (25%)	80%	SAV up & down since 1985
ET9	Big Annemessex R.	400 (45%)	100%	SAV area stable since 1991
LE3	Lower Rappahannock	485 (11%)	100%	SAV area up 1984-1993, declined in 1994 and 1995
LE4	Lower York River	193 (25%)	100%	SAV increased 1991-95
Recommended Action: Improve water quality, then restore SAV where feasible (Category C)[4]				
LE5	Lower James River	15 (38%)	40%	SAV increased 1993-95
ET6	Nanticoke River	0 (0%)	40%	No SAV mapped, 1978-95
ET7	Wicomico River	0 (0%)	60%	No SAV mapped, 1978-95
ET10	Pocomoke River	0 (0%)	40%	No SAV mapped, 1978-95

1 SAV in other areas of Chesapeake Bay are also valuable as habitat for juvenile and adult crabs.
2 Number of acres of SAV mapped in 1994 (1994 acres as a % of the Tier I goal, Orth *et al.* 1995).
3 % of 4 or 5 water quality goals for SAV that were met or borderline in 1994.
4 One segment in Category D not listed because it is not suitable for SAV restoration (see text).

Implementation: Recommendations for restoration must be balanced with other restoration priorities and is contingent upon funding. Recommendations for protection of existing SAV are in effect upon adoption of this plan.

6.2.3 The Bay jurisdictions will cooperatively prepare a report that links land use activities in the Chesapeake Bay watershed and human activities within Chesapeake Bay to negative impacts on fish and shellfish habitat. The document may be used by permitting agencies, local governments, citizens, and commercial and recreational harvesters and will be accompanied by an extensive literature review section and compendium of laws and regulation pertaining to fish and shellfish habitat.
Implementation: 1997

6.2.4 Maryland will consider limits on scraping for hard crabs in the early crabbing season and maximum weight limits for crab scrapes.
Implementation: 1997

Problem 6.3: Toxics

The blue crab appears to be a resilient species. Its migratory nature and short life span make it less susceptible to bioaccumulation of contaminants. Toxicology studies in Baltimore Harbor and the Elizabeth River, the two most heavily polluted areas of the Bay, found minimal accumulation of toxins in tissues of blue crabs. Once toxins are allowed to accumulate, their effects are difficult or impossible to reverse. Blue crabs could be affected by the loss of benthic foods and/or toxins may accumulate beyond some threshold that exceeds the crab's level of tolerance. Blue crabs are most sensitive to toxics during their larval stages.

Strategy 6.3

The Chesapeake Bay Program will continue its commitment to the goal of, "a Chesapeake Bay free of toxics by reducing or eliminating the input of chemical contaminants from all controllable sources to levels that result in no toxic or bioaccumulative impact on the living resources that inhabit the Bay or on human health" (CBP, 1994b).

Actions

6.3.1 Regions of concern will be identified with criteria set by the *Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy* (CBP, 1994b). Within regions of concern the sources and amounts of pollution will be determined, control methods will be explored and implemented, and important habitats within the area and land uses with negative effects will be identified.
Implementation: Ongoing

REFERENCES

Alexander, S. 1986. Diet of the blue crab, *Callinectes sapidus* Rathbun, from near shore habitats of Galveston Island, Texas. Texas J. Sci. 38:85-89.

Abbe, G. 1974. Second terminal molt in an adult female blue crab, *Callinectes sapidus* Rathbun. Trans. of the Amer. Fish. Soc. 103(3):643-644.

Abbe, G., and C. Stagg. 1996. Trends in blue crab (*Callinectes sapidus* Rathbun) catches near Calvert Cliffs, Maryland, from 1968 to 1995 and their relationship to the Maryland commercial fishery. J. Shellfish Research 15(3):751-758.

Batiuk, R., R. Orth, K. Moore, W. Dennison, C. Stevenson, L. Staver, V. Carter, N. Rybicki, R. Hickman, S. Kollar, S. Bieber, and P. Heasly. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis. Chesapeake Bay Program, CBP/TRS 52/92, Annapolis, MD.

Booth, K. and M. Gary. 1993. Striped bass feeding behavior and the potential effect on the blue crab population in the Chesapeake Bay. MD DNR. Fish. Tech. Memo. Ser. No. 2. Jan., 1993.

Brumbaugh, R.D. 1996. Recruitment of blue crab Callinectes sapidus postlarvae to the back-barrier lagoons of Virginia's Eastern Shore. Ph.D. Dissertation. Old Dominion University. Norfolk, Virginia. 174 p.

CBP (Chesapeake Bay Program). 1984-present. Unpublished data. Water Quality Monitoring Program. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1988. Chesapeake Bay Wetlands Policy. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1989. Chesapeake Bay Blue Crab Fishery Management Plan. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1993. Chesapeake Bay Submerged Aquatic Vegetation Restoration Goals. Chesapeake Executive Council Directive No. 93-3. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1994a. Chesapeake Bay Oyster Fishery Management Plan. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1994b. Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1994c. Riparian Forest Buffers. Chesapeake Executive Council Directive No. 94-1. Chesapeake Bay Program Office. Annapolis, MD.

CBP (Chesapeake Bay Program). 1995a. Guidance for protecting Submerged Aquatic Vegetation in Chesapeake Bay from physical disruption. SAV Workgroup, Living Resources Subcommittee. EPA 903-R-95-013, CBP/TRS 139/95. 15 pp. + Appendices.

CBP (Chesapeake Bay Program). 1995b. The State of the Chesapeake Bay--1995. Chesapeake Bay Program, Annapolis, MD. ISBN 0-16-042627-8.

Casey, J. Unpublished. Preserved specimen of mature female blue crab in molt from the wild; personal collection. Maryland Department of Natural Resources. Annapolis, MD.

Casey, J. 1992. A continuation of the study of biodegradable escape panels in crab pots. Maryland DNR Tidal Fisheries Division.

Casey, J. 1990. A study of biodegradable escape panels in crab pots. Maryland DNR Tidal Fisheries Division.

Casey, J. and B. Daugherty. 1989. Evaluation of information on ghost (lost/abandoned) crab pots and methods of mitigating their effects on the resource. MD Dept. Nat. Res., Tidewater Admin., Annapolis, MD.

Casey, J., B. Daugherty, G. Davis and J. Uphoff. 1991. Blue Crab Management Project: Stock Assessment of the Blue Crab in Chesapeake Bay. In house report, Maryland Department of Natural Resources.

Casey, J. and A. Wesche. 1981. A study of derelict crab pots in Maryland's coastal bays. Maryland DNR Marine Fisheries Unit.

Chesapeake Executive Council. 1987. Chesapeake Bay Agreement. Chesapeake Bay Program Office. Annapolis, MD.

Chesapeake Executive Council. 1990. Chesapeake Bay Submerged Aquatic Vegetation Policy. Chesapeake Bay Program Office. Annapolis, MD.

Chesapeake Executive Council. 1992. Amendments to the Chesapeake Bay Agreement. Chesapeake Bay Program Office. Annapolis, MD.

Chesapeake Executive Council. 1996. Adoption Statement of Riparian Forest Buffers. Chesapeake Bay Program Office. Annapolis, MD.

Costlow, J. 1967. The effect of salinity and temperature on survival and metamorphosis of megalops of the blue crab *Callinectes sapidus*. Helgolander wiss. Meeresunhters 15:84-97. Cited in Van Heukelem, 1991

Darnell, R. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Texas University Inst. of Mar. Sci. Publ. 5:353-416.

deFur, P., C. Mangum and J. Reese. 1990. Respiratory responses of the blue Crab *Callinectes sapidus* to long-term hypoxia. Biol. Bull. 178:46-54.

Dennison, W. C., R. J. Orth, K. A. Moore, J. C. Stevenson, V. Carter, S. Kollar, P. W. Bergstrom, and R. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation: Habitat requirements as barometers of Chesapeake Bay health. BioScience 43: 86-94.

Dittell, A., A. Hines, G. Ruiz, and K. Ruffin. 1995. Effects of shallow water refuge on behavior and density-dependent mortality of juvenile blue crabs in Chesapeake Bay. Bull. Mar. Sci. 57(3):902-916.

Eggleston, D. 1990. Foraging behavior of the blue crab, *Callinectes sapidus*, on juvenile oysters, *Crassostrea virginica*: effects of prey density and size. Bull. Mar. Sci. 46:62-82.

Eggleston, D., R. Lipcius and A. Hines. 1992. Density-dependent predation by blue crabs upon infaunal clam species with contrasting distribution and abundance patterns. Mar. Ecol. Prog. Ser. 85:55-68.

Eldridge, P., V. Burrell, Jr., and G. Steele. 1979. Development of a self-culling blue crab pot. Mar. Fish. Rev. Dec. 1979:21-27.

Engel, D. And E. Noga. 1989. Shell disease in the blue crabs of the Pamlico River. Environs, February, 1989:3-5.

Epifanio, C. 1984. Effects of toxic substances on decapod larvae. In: H.H. White (ed.), Concepts in Marine Pollution Measurements. Maryland Sea Grant, College Park, p. 449-509.

Epifanio, C., C. Valenti, and A. Pembroke. 1984. Dispersal and recruitment of blue crab larvae in Delaware Bay, U.S.A. Estuarine, Coastal, and Shelf Sci. 18:1-12.

Everett, R. A., and G. M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities: An experimental test. Oceologica 93:475-486.

FAO (Food and Agriculture Organization of the United Nations). 1990. FAO Yearbook of fishery statistics-catches and landings (Vol. 66, through 1988). FAO Fisheries Series No. 34, FAO Statistics Series No. 92.

Fischler, K. 1965. The use of catch-effort, catch-sampling, and tagging data to estimate populations of blue crabs. Trans. Am. Fish. Soc. 94:287-310.

Fischler, K. And C. Walburg. 1962. Blue crab movement in coastal South Carolina, 1958-59. Trans. Am. Fish. Soc. 91(3):275-278.

Fonseca, M. 1992. Restoring seagrass systems in the United States, pp. 79-110. In Thayer, G, (ed.), Restoring the nations's marine environment. Maryland Sea Grant College Pub. UM-SG-TS-92-06. 716 pp.

Fonseca, M. 1993. A guide to planting seagrasses in the Gulf of Mexico. Texas A&M University Sea Grant College Program, TAMU-SG-94-601.

Fonesca, M., J. Kenworthy and G. Thayer. 1992. Seagrass beds: nursery for coastal species. In: R. Stroud, editor. Stemming the Tide of Coastal Fish Habitat Loss. Mar. Rec. Fish. 14. Ntl. Coalition for Marine Conservation, Inc. Savannah, Georgia.

Funderburk, S., J. Mihursky, S. Jordan, D. Riley (editors). 1991. Habitat Requirements for Chesapeake Bay Living Resources. Prepared for the Living Resources Subcommittee, Chesapeake Bay Program, Annapolis, MD.

Garreis, M. and D. Murphy. 1986. Inner harbor crab survey: Heavy metal and chlorinated hydrocarbon levels in *Callinectes sapidus* in the Chesapeake Bay. Baltimore: MD Dept. of Env., Div. of Standards and Certification, Water Management Admin.

Goodrich, D, J. van Montfrans and R. Orth. 1989. Blue crab megalopae influx to Chesapeake Bay: evidence for a wind-driven mechanism. Estuarine; Coastal and Shelf Science. 29:247-260.

Goshorn, D., J. Casey. 1993. An examination of the relationship between striped bass and blue crabs. Maryland Department of Natural Resources. Fish. Tech. Mem. Ser. 3, Jan. 1993.

Guillory, V. 1993. Ghost fishing by blue crab traps. N. Amer. J. Fish. Mgt. 13:459-466.

Havens, K. And J. McConaugha. 1990. Molting in the mature female blue crab, *Callinectes sapidus* Rathbun. Bull. Mar. Sci. 46:37-47.

Heck, K. and T Thoman. 1981. Experiments on predator-prey interactions in vegetated aquatic habitats. J. Exp. Mar. Biol. Ecol. 53:125-134.

Heck, K. and K. Wilson. 1987. Predation rates on decapod crustaceans in latitudinally separated seagrass communities a study of spatial and temporal variation using tethering techniques J. Exp. Mar. Biol. Ecol. 107:87-100.

Hines, A., R. Lipcius and A. Haddon. 1987. Population dynamics and habitat partitioning by size, sex, and molt stage of blue crabs *Callinectes sapidus* in a subestuary of central Chesapeake Bay. Mar. Ecol. Prog. Ser. 36:55-64.

Holmes, B. 1994. Biologists sort the lessons of fisheries collapse. Science 264:1252-1253.

Horton, T. and W. Eichbaum. 1991. *Turning the Tide: Saving the Chesapeake Bay.* Island Press, Washington, D.C.

Hurley, L. 1991. Submerged aquatic vegetation. In: Funderburk, S., J. Mihursky, S. Jordan and D. Riley (eds.). Habitat Requirements for Chesapeake Bay Living Resources. Ches. Res. Consor., Inc. Solomons, MD. pp. 2.1-2.19.

Jivoff, P. 1995. The role of mate guarding, male size and male investment on individual reproductive success in the blue crab, *Callinectes sapidus*. Ph.D. Dissertation. University of Maryland, College Park. 150 pp.

Jivoff, P. In press. The advantages of large body size in sexual competition among males in the blue crab, *Callinectes sapidus*. Biological Bulletin.

Jones, C., J. McConaugha, P. Geer and M. Prager. 1990. Estimates of spawning stock size of blue crab, *Callinectes sapidus*, in Chesapeake Bay, 1986-1987. Bull. Mar. Sci. 46:159-169.

Jordan, S., C. Stenger, M. Olson, R. Batiuk and K. Mountford. 1992. Chesapeake Bay Dissolved Oxygen Goal for Restoration of Living Resources Habitats. Report to Chesapeake Bay Program's Living Resources Subcommittee and Implementation Committee Nutrient Reduction Strategy Reevaluation Workgroup. CBP/TRS 88/93. 81 pp.

Kemp, W., W. Boynton, R. Twilley, J. Stevenson and J. Means. 1983. The decline of submerged vascular plants in upper Chesapeake Bay: Summary of results concerning possible causes. Mar. Tech. Soc. J. 17:78-89.

Knotts, K. 1989. Preliminary Stock Assessment of the Chesapeake Bay Blue Crab Population. Thesis submitted to University of Maryland. 206 pp.

Kunishi, H. 1988. Sources of nitrogen and phosphorous in an estuary of the Chesapeake Bay. J. Envir. Qual. 17:185-188.

Larkin, P. 1977. An epitaph for the concept of maximum sustained yield. Trans. Amer. Fish. Soc. 106(1):1-11.

Laughlin, R. 1982. Feeding habits of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicoa Estuary, Florida. Bull. Mar. Sci. 32:807-822.

Lipcius, R. Unpublished. Virginia Institute of Marine Science, Gloucester Pt., VA.

Lipcius, R. and A. Hines. 1986. Variable functional responses of a marine predator in dissimilar homogenous microhabitats. Ecology 67:1361-1371.

Lipcius, R., J. van Montfrans, R. Orth, K. Metcalf, M. Montane, and R. Seitz. 1995. Status of the Blue Crab Stock. Virginia Institute of Marine Science, College of William and Mary. Crustacean Ecology Program Technical Report No. 1995(8).

Lipcius, R., E. Olmi, J. Van Montfrans. 1990. Planktonic availability, molt stage and settlement of blue crab postlarvae. Marine Ecol. Prog. Ser. 58:235-242.

Lowery, T. and G. Tate. 1986. Effect of hypoxia on hemolymph lactate and behavior of the blue crab *Callinectes sapidus* Rathbun in the laboratory and field. Comp. Biochem. Physiol. 85A:689-692.

Ludwig, D., R. Hilborn and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Science. 260:17 and 36.

MDNR. 1977-1996. unpublished data. Maryland Department of Natural Resources, Fisheries Service. Annapolis, MD.

Mansour, R. 1992. Foraging ecology of the blue crab, *Callinectes sapidus* Rathbun, in Lower Chesapeake Bay. Dissertation for Ph. D., Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt., VA.

Mansour, R. and R. Lipcius. 1993. The feeding ecology of blue crabs in the lower Chesapeake Bay. Virginia Sea Grant Program, Virginia Mar. Res. Bull. 25(1-2):8-9.

McConaugha, J. 1988. Export and reinvasion of larvae as regulators of estuarine decapod populations. Amer. Fish. Soc. Sympos. 3:90-103.

McConaugha, J.R., 1991. Tag-recapture study of the spawning stock of Chesapeake Bay blue crabs. Old Dominion University Research Foundation Tech Report 91-1, 30pp.

McConaugha, J.R. 1993. Tag recapture study of the spawning stock of Chesapeake Bay blue crabs. Final Rpt. NOAA project NA89EA-H-00060.

McConaugha, J.R. Unpublished. Old Dominion University. Norfolk, VA.

McConaugha, J., D. Johnson, A. Provenzano and R. Maris. 1983. Seasonal distribution of larvae of *Callinectes sapidus* (Crustacea:Decapoda) in the waters adjacent to Chesapeake Bay. J. Crust. Biol. 3(4):582-591.

McKenna, S., M. Jansen and M. Pulley. 1990. Shell disease of blue crabs, *Callinectes sapidus*, in the Pamlico River, North Carolina. N.C. Div. Mar. Fish. Special Scientific Report No. 51. 30 pp.

Messick, G. A. 1994. *Hematodinium perezi* infections in adult and juvenile blue crabs, *Callinectes sapidus* from coastal bays of Maryland and Virginia, USA. Diseases of Aquatic Organisms 19:77-82.

Metcalf, K. and R. Lipcius. 1992. Relationship of Habitat and Spatial Scale with Physiological State and Settlement of Blue Crab Postlarvae in Virginia. Masters Thesis. Virginia Institute of Marine Science. Gloucester Pt., VA.

Millikin, M. and A. Williams. 1984. Synopsis of biological data on the blue crab, *Callinectes sapidus* Rathbun. FAO Fisheries Synopsis No. 138. NOAA Technical Report NMFS 1. pp 1-39.

Montane, M., R. Lipcius, J. Haner and M. Seebo. 1994. A field study of the population dynamics of the blue crab, *Callinectes sapidus* Rathbun, in Chesapeake Bay. Report submitted to CBSAC, NOAA and VA Mar. Res. Comm. Contract No. NA16FU0389-01.

Mosca, T., P. Ruderhausen and R. Lipcius. 1995. Do striped bass and blue crab abundance correlate in Chesapeake Bay? Va. J. of Sci. 46(4):249-258.

National Academy Press. 1994. Improving the Management of U.S. Marine Fisheries. National Academy Press. Washington, DC. 61 pp.

NMFS (National Marine Fisheries Service). 1993. Our Living Oceans. NOAA, US Dept. of Comm. 148 pp.

NMFS (National Marine Fisheries Service). 1995. Fisheries of the United States, 1994. Current Fishery Statistics No. 9400. Silver Spring, MD.

New England Fishery Management Council. 1983. American Lobster Fishery Management Plan and amendments 1-5.

Newell, R. 1988. Ecological changes in Chesapeake Bay: Are they the result of overharvesting the American oyster, *Crassostrea virginica*? In: Lynch, M. and E. Krome, eds. Understanding the Estuary: Advances in Chesapeake Bay Research. Proceedings of a Conference. Baltimore, MD. Ches. Res. Consort. Pub. 129.

Newman, M.W., and C.A. Johnson. 1975. A disease of blue crabs (*Callinectes sapidus*) caused by a parasitic dinoflagellate, *Hematodinium* sp. J. Parasitol. 61:554-557.

Officer, C., R. Biggs, J. Taft, L. Cronin, M. Tyler and W. Boynton. 1984. Chesapeake Bay anoxia: origin, development, and significance. Science 223:22-27.

Olmi, E. 1993. Immigration of Blue Crab (*Callinectes sapidus*) Megalopae in the York River, Virginia: Patterns and Processes. Dissertation presented to the College of William and Mary, Virginia Institute of Marine Science.

Orth, R. and K. Moore. 1983. Chesapeake Bay: An unprecedented decline in submerged aquatic vegetation. Science. 222:51-53.

Orth, R. and K. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in Chesapeake Bay: an historical perspective. Est. 7:531-540.

Orth, R. and J. van Montfrans. 1987. Utilization of a seagrass meadow and tidal marsh creek by blue crabs *Callinectes sapidus*. I. Seasonal and annual variations in abundance with emphasis on post-settlement juveniles. Mar. Ecol. Prog. Ser. 41:283-294.

Orth, R. and J. van Montfrans. 1990. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*. II. Spatial and temporal patterns of molting. Bull. Mar. Sci. 46:95-104.

Orth, R., K. Heck, and J. van Montfrans. 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships. Estuaries 7:339-350.

Orth, R. J., J. F. Nowak, G. F. Anderson, D. J. Wilcox, J. R. Whiting, and L. S. Nagey. 1995. Distribution of Submerged Aquatic Vegetation in the Chesapeake Bay and Tributaries and Chincoteague Bay – 1994. Virginia Institute of Marine Science, Gloucester Point, VA. (Latest survey results available at: http://www.vims.edu/bio/sav)

Orth, R. J., J. van Montfrans, R. N. Lipcius, and K. S. Metcalf. 1996. Utilization of seagrass habitat by the blue crab, *Callinectes sapidus* Rathburn, in Chesapeake Bay: A review, pp 213-224. *In* Kuo, J., R. Phillips, D. Walker, and H. Kirkman (eds.), Seagrass Biology: Proceedings of and International Workshop. University of Western Australia.

Paul, A. and J. Paul. 1992. Second clutch viability of *Chionoecetes bairdi* Rathbun (Decapoda, Majidae) inseminated only at the maturity molt. J. Crustacean Biology. 12:438-441.

Penry, D. 1982. Utilization of *Zostera marina* and *Rupia maritima* habitat by four decapods with emphasis on *Callinectes sapidus*. M.A. Thesis, College of William and Mary, Williamsburg, VA. 101 pp.

Petrocci, C. and D. Lipton. 1994. The Warmwater Crab Fishery in Asia: Implications for the Chesapeake Bay Blue Crab Industry. MD Sea Grant Extension Program, VA Sea Grant Marine Advisory Program. 45 pp.

Pile, A. 1993. Effects of habitat and size-specific predation on the ontogenetic shift in habitat use by newly settled blue crabs, *Callinectes sapidus*. Master's thesis, Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt., VA.

Pile, A., R. Lipcius, J. van Montfrans and R. Orth. 1996. Density-dependent settler-recruit-juvenile relationships in blue crabs. Ecological Monographs. 66(3):277-300.

Prager, M., J. McConaugha, C. Jones, P. Geer. 1990. Fecundity of blue crab, *Callinectes sapidus*, in Chesapeake Bay: biological, statistical, and management considerations. Bull. Mar. Sci. 46(1):170-179.

Raynie, R. and J. Casey. 1992. Results of the 1991 Cull Ring Study. Maryland Department of Natural Resources. 15pp.

Rhodes, A. and L. Shabman. 1994. Virginia's Blue Crab Pot Fishery: The Issues and Concerns. Virginia Sea Grant. VSG-94-09. Charlottesville, VA.

Ricker, W. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of Fish. Res. Board of Can. 191. 382 pp.

Rothschild, B. and A. Sharov. 1996. Abundance Estimation and Population Dynamics of the Blue Crab in the Chesapeake Bay. University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. Submitted to Maryland Dept. of Natural Resources, Chesapeake Bay Stock Assessment Committee, and National Oceanic and Atmospheric Administration. January, 1996.

Rothschild, B., J. Ault, E. Patrick, S. Smith, H. Li, T. Maurer, B. Daugherty, G. Davis, C. Zhang, and R. McGarvey. 1992. Assessment of the Chesapeake Bay Blue Crab Stock. Univ. of Maryland, Chesapeake Bay Biological Lab. CB92-003-036, CEES 07-4-30307, Solomons, Maryland.

Rugolo, L., A. Lange, K. Knotts, V. Crecco, M. Terceiro, C. Bonzek, C. Stagg, R. O'Reilly, and D. Vaughan. 1997. Unpublished. Chesapeake Bay Blue Crab Stock Assessment. Chesapeake Bay Stock Assessment Committee, Technical Subcommittee. Chesapeake Bay Program, Annapolis, MD.

Ruiz, G. M., A. H. Hines, and M. H. Posey. 1993. Shallow water as a refuge habitat for fish and crustaceans in non-vegetated estuaries: an example from Chesapeake Bay. Marine Ecology Progress Series 99: 1-16.

Ryer, C., J. van Montfrans and R. Orth. 1990. Utilization of a seagrass meadow and tidal marsh creek by blue crabs *Callinectes sapidus*. II. Spatial and temporal patterns of molting. Bull. Mar. Sci. 46:95-104.

Sainte-Marie, B. and G. Lovrich. 1994. Delivery and storage of sperm at first mating of female *Chionoecetes opilio* (Brachyura: Majidae) in relation to size and morphometric maturity of male parent. J. Crustacean Bio. 14:508-521.

Sainte-Marie, B., R. Raymond, and J. Brethes. 1995. Growth and maturation of the benthic stages of male snow crab, *Chionoecetes opilio* (Brachyura: Majidae). Can. J. Fish. and Aquat. Sci. 52:903-924.

Schaffner, L. and R. Diaz. 1988. Distribution and Abundance of overwintering blue crabs, *Callinectes sapidus*, in the lower Chesapeake Bay. Estuaries. 11(1):68-72.

Schlesinger, W. 1991. Biogeochemistry, An Analysis of Global Change. Academic Press. 443p.

Sindermann, C. 1989. Shell disease syndrome in marine crustaceans. NOAA Tech. Memo NMFS-F/NEC-64.

Stagg, C., M. Holloway, L. Rugolo, K. Knotts, L. Kline and D. Logan. 1992. Evaluation of the 1990 recreational, charter boat, and commercial striped bass fishing surveys, and design of a recreational blue crab survey. Chesapeake Bay Res. and Monitoring Div. CBRM-FR-94-1.

Stickle, W., M. Kapper, L. Liu, E. Gnaiger and S. Wang. 1989. Metabolic adaptations of several species of crustaceans and molluscs to hypoxia: tolerance and microcalorimetric studies. Biol. Bull. 177:303-312.

Taft, J., E. Hartwig and R. Loftus. 1980. Seasonal oxygen depletion in Chesapeake Bay. Estuaries. 3(4):242-247.

Tagatz, M. 1968. Biology of the blue crab, *Callinectes sapidus* Rathbun, in the St. Johns River, Florida. Fish. Bull. 67:17-33.

Thomas, J., R. Zimmerman and T. Minello. 1990. Abundance patterns of juvenile blue crabs *Callinectes sapidus* in nursery habitats of two Texas bays. Bull. Mar. Sci. 46:115-125.

Truitt, R. 1939. Our water resources and their conservation. Ches. Biol. Lab Contribution 27:1-103.

Twilley, R., W. Kemp, K. Staver, J. Stevenson and W. Boynton. 1985. Nutrient enrichment of estuarine submersed vascular plant communities. I. Algal growth and associated effects on production of plants and associated communities. Mar. Ecol. Prog. Ser. 23:179-191.

Uphoff, J., J. Casey, B. Daugherty and G. Davis. 1993. Maryland's blue crab peeler and soft crab fishery; problems, concerns, and solutions. Maryland Dept. Nat. Res. Tidal Fisheries Tech. Report Ser. 9.

VMRC (Virginia Marine Resources Commission). 1981-1995. Unpublished data. Virginia Marine Resources Commission, Fisheries Plans and Statistics Division. Newport News, Virginia.

Vance, T. 1982. Returns to Effort Management in the Virginia Blue Crab Pot Fishery. Thesis presented to Dept. Of Agricultural Economics, Virginia Polytechnic Institute. Richmond, VA.

Van Engel, W. 1958. The blue crab and its fishery in the Chesapeake Bay. Part I. Reproduction, early development, growth and migration. Comm. Fish. Rev. 20(6):6-17.

Van Engel, W. 1962. The blue crab and its fishery in Chesapeake Bay. Part 2. Types of gear for hard crab fishing. Comm. Fish. Rev. 24(9):1-10.

Van Heukelem, W. 1991. Blue Crab, *Callinectes sapidus*. In: Funderbunk, S., J. Mihursky, S. Jordan and D. Riley (eds.). Habitat Requirements for Chesapeake Bay Living Resources. Chesapeake Res. Consortium, Inc. Solomons, MD.

van Montfrans, J., C. Epifanio, D. Knott, R. Lipcius, D. Mense, K. Metcalf, E. Olmi, III, R. Orth, M. Posey, E. Wenner and T. West. 1995. Settlement of blue crab postlarvae in Western North Atlantic estuaries. Bull. Mar. Sci. 57(3):834-854.

van Montfrans, J., C. Peery and R. Orth. 1990. Daily, monthly and annual settlement patterns by *Callinectes sapidus* and *Neopanopeus sayi* megalopae on artificial collectors deployed in the York River, Virginia: 1985-1988. Bull. Mar. Sci. 46:214-229.

Volstad, J., B. Rothschild and T. Maurer. 1994. Abundance estimation and population dynamics of the blue crab in the Chesapeake Bay. Report submitted to Maryland Department of Natural Resources, Fisheries Department. Annapolis, MD. 53pp.

Wahle, R. and R. Steneck. 1991. Recruitment habitats and nursery grounds of the American lobster *Homarus americanus*: a demographic bottleneck? Mar. Ecol. Prog. Ser. 69:231-243.

Wahle, R. and R. Steneck. 1992. Habitat restrictions in early benthic life: experiments on habitat selection and in situ predation with the American lobster. J. Exp. Mar. Biol. Ecol. 157:91-114.

Wallace, R., W. Hosking, and S. Szedlmayer. 1994. Fisheries Management for Fishermen: A manual for helping fishermen understand the federal management process. Auburn University Marine Extension & Research Center. Sea Grant Extension. Mobile, AL. 56 pp.

Wenner, E. 1989. Incidence of insemination in female blue crabs, *Callinectes sapidus*. J. Crustacean Bio. 9:587-594.

Wilson, K., K. Heck and K. Able. 1987. Juvenile blue crab, *Callinectes sapidus*, survival: an evaluation of eelgrass, *Zostera marina*, as refuge. Fish. Bull. 85:53-58.

Williams, A. 1984. Shrimps, Lobsters and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Inst. Press, Washington, D.C. 550 pp.

Wolcott, T. and A. Hines. 1989. Ultrasonic biotelemetry of small-scale movements and micro-habitat selection by molting blue crabs. Bull. Mar. Sci. 46:83-94.

Appendix A. Schedule for Reviewing and Updating Chesapeake Bay Fishery Management Plans*

SPECIES	REVIEW SCHEDULE	UPDATE SCHEDULE
Blue Crab	1989-adopted 1997- revised	Annually
Striped Bass	1989- adopted 10/95 - reviewed 10/97- Amend. #1	Annually
Summer Flounder	1991- adopted 4/96 - reviewed 6/97 - Amend. #1	Annually
Weakfish/Spotted Seatrout	1990- adopted 4/96 - reviewed	Annually
Shad & Herring	1989 - adopted 7/95 - reviewed 12/97 - Amend. #1	1999 2001
Oysters	1989 - adopted 1993 - reviewed 1994 - revised	1996 1998
Bluefish	1990 - adopted 7/95 - reviewed 1997 - amend	1998 2000
American Eel	1991 - adopted 10/96 - reviewed	1999 2002
Horseshoe Crabs	1994 - adopted	1999 2002
Atlantic Croaker/Spot	1991 - adopted 10/96 - reviewed	1998 2001
Black Drum	1993 - adopted 1997 - review	2000 2003
Black Sea Bass	1996 - adopted	1998 2001
Red Drum	1993 - adopted 1997 - review	2000 2003
Spanish/King mackerel	1994 - adopted 1998 - review	2001 2004

* The review and update schedule will be adjusted as necessary depending on the species-specific needs and/or issues.

Appendix B. Decision Matrix Used to Make Recommendations in Action 6.2.2

Decision matrix used to make recommendations in Action 6.2.2 to maintain and increase the amount of SAV in each area of high postlarval blue crab settlement.

Category	Recent SAV area	Potential SAV area	Recent water quality for SAV growth	Recommended action
A	Moderate to high	Moderate to High	Adequate (80% or more of goals met or borderline)	Protect SAV and maintain water quality
B	Low (50% or less of Tier I[a] goal met)	Moderate to High	Adequate	Protect SAV, maintain water quality, restore SAV where feasible
C	Low	Moderate to High	Inadequate (less than 80% of goals met or borderline)	Improve water quality, then restore SAV where feasible
D	Low	Low	Adequate or inadequate	No action (Not listed in Table 4, Action 6.2.2, for this reason)

[a]See Action 6.2.1 for Tier I goal.

Recommended actions in the above matrix are defined as follows:

- **Protect SAV**: Prevent physical disruption of SAV and potential SAV habitat, mainly by avoiding disruptive activities or limiting them to areas outside SAV habitat or outside the SAV growing season (CBP, 1995a).

- **Maintain or improve water quality**: All signatories of the *1987 Chesapeake Bay Agreement* (Chesapeake Executive Council, 1987) should implement the "tributary strategies for nutrient reduction" called for in the 1992 Amendments to the Chesapeake Bay Agreement (Chesapeake Executive Council, 1992), to reduce nutrient and sediment runoff. More actions to reduce runoff are needed in areas that do not currently meet the SAV habitat requirements than in areas that currently meet them.

- **Restore SAV where feasible**: This involves a series of linked actions, currently being defined by the SAV Workgroup. They are based on successful restoration efforts in Chesapeake Bay and elsewhere in the U.S. (Fonesca 1992; 1993). The first steps involve assembling existing SAV and water quality monitoring data and collecting any additional data needed, including sediment characteristics and potential for disturbance. Potential areas for SAV planting should have historically supported SAV, but currently have little;

have water quality and sediment characteristics adequate to support SAV; and have low potential for disturbance. Results from pilot SAV planting projects are being reviewed to refine these guidelines and add planting technique.

APPENDIX C. LAWS AND REGULATIONS

Limited Entry:

Maryland	Limited entry for all commercial crabbing licenses. No new tidal fish licenses will be issued after April 1, 1996, after which, the state will evaluate the current license structure and determine the number at which commercial licenses will be capped.
Virginia	No crab dredge licenses will be issued to any new applicant after March 31, 1994, until the number of licenses drops to 220 or below, as of December 10 of any year. Crabbers who held crab pot licenses in 1995 were allowed to purchase licenses for the same amount of pots in 1996. Applicants who did not hold a valid crab pot license in 1995 must meet the following criteria to receive a license after 1995: **... List criteria here ...**
Potomac	Only Maryland and Virginia residents may commercially crab. Maximum of 593 commercial crab pot licenses; number of pots selected for on license cannot be changed later. Only one license per boat.

Non-Commercial License

Virginia	-none required for up to 2 crab pots -license required for up to 5 crab pots
Maryland	-none required
Potomac River	-none required

Minimum Size Limit:

	Virginia	Maryland	Potomac	Tolerance
Peelers	No minimum size	3 inches	3 inches	
Soft Crabs	3.5 inches	3.5 inches	3.5 inches	
Male, Hard Crabs	5 inches	5 inches	5 inches	MD & VA - 10/bushel VA - 35/barrel Potomac - 4/bushel and 10/barrel
Females, Mature Hard Crabs	No minimum size	No minimum size	No minimum size	MD and Potomac - Sponge crabs prohibited VA - Minimum tolerance for brown and black sponge crabs
Female, Immature Hard Crabs	5 inches	5 inches	5 inches	VA - 10/bushel and 35/barrel

Creel Limit:

Maryland	All recreational crabbers -	1 bushel/person/day 2 bushels/boat/day
Virginia	Unlicensed sport crabbers -	1 bushel/person/day 2 dozen peelers/person/day
	Licensed sport crabbers -	No limit
Potomac	Unlicensed sport crabbers -	1 bushel/person/day 3 dozen soft or peelers/person/day
	Licensed sport crabbers -	No limit

Harvest Quotas:

Maryland	None in effect	
Virginia	Winter dredge fishery (Dec. 1 - March 1)	20 barrels/boat/day
	Spring crab pot fishery (April 1 - May 31)	51 bushels/boat/day 17 barrels/boat/day
Potomac	None in effect	

By-catch Restrictions:

Maryland — Sponge crabs prohibited; imported sponge crabs must be legally harvested from the state of harvest and accompanied with a bill of landing.

Virginia — Possession of hard crabs prohibited while scraping. Minimum tolerance for harvest of brown and black sponge crabs.

Potomac — Possession of sponge crabs, spawn crabs, blooming females, mother crabs, or females from which the egg pouch or bunion has been removed is prohibited.

Gear Restrictions:

Maryland

<u>Crab Pots</u>

-Cubic and rectangular pots permitted
-Cubic pots cannot exceed 24 inches on any side
-Rectangular pot size limit 12 inches x 24 inches x 48 inches
-All hard crab pots must be wire mesh 1.5 inches by 1.5 inches or greater
-All peeler pots must be wire mesh at least 1.0 inches by 1.0 inches; pots with mesh 1.5 inches by 1.5 inches or greater are not defined as peeler pots
-One 2 5/16 inches and one 2 3/16 inches cull ring in the top or side panels of all hard crab pots, with mesh between 1.5 inches by 1.5 inches and 2.0 inches by 2.0 inches; may be closed when fishing for peelers
-Must be marked with a buoy attached to the pot and clearly visible on the surface and marked with ID number with 2 inches letters
-Commercial limit 300 pots per licensee, additional allocations for up to two crew members, up to 900 pots per boat
-Shoreline property owners limit 2 pots per property from piers or poles within 100 yds. of shore for personal consumption only and must be marked with name and address

-Peeler pots may only be baited with one male hard crab and enough food for the male crab

Trotlines

-Unlicensed sport crabber limit 1000 feet; not to exceed 2000 feet per vessel

Maryland

-Length measured along the baitline

-May not be set within 100 feet of another trotline

Scrapes or Dredges

-Total width may not exceed 60 inches

-Teeth prohibited

-Diver, chain or other device to hold it to the bottom prohibited

-Flat plate on scraping bar prohibited

-Limit 2 scrapes or dredges per engine-powered boat, only one overboard

-Scrapes may not be affixed to each other

Bank Traps

-Enclosure no more than 4 feet long and 4 feet wide

-Limit 1 row of hedging no more than 75 feet long

-Hedging may not exceed 1/3 the distance across the body of water in which its placed

Channel Pounds

-Enclosure no more than 8 feet long and 4 feet wide

-Limit 2 rows of hedging no more than 100 feet long

-Hedging may not exceed 1/3 the distance across the body of water in which its placed

Bank Traps and Channel Pounds

-Must be spaced 100 yards apart

-A 12 inches air space from surface of water at mean high tide required

-Must be marked with name and license number with 2 inches letters

Seines

-Maximum length 50 feet

-Must be hauled up in water

Collapsible Traps

-Limit 10 traps or rings for noncommercial crabbers from shore, bridge or pier

-Limit 25 per vessel for noncommercial crabbers

-Flat bottom and not more than 4 sides, each $\leq 1\ ft^2$

-Must have manual tension on the closing mechanism

-Those not attached to structures must be marked with a buoy and owner ID

-Cannot be set within 100 feet of trotline

SCUBA Diving

-Capture of crabs using diving apparatus prohibited

Virginia

Crab pots

-Wire or thread mesh 1.5 inches or greater

-Crab pot buoys must display assigned number

-One 2 5/16 inches and one 2 3/16 inches cull ring in upper parlor on opposite sides; the 2 5/16 inches cull ring may be obstructed within commercial dredge boundaries in the Bay, and in Pocomoke and Tangier Sounds
- Limit 300 pots/person in tributaries; limit 500 pots/person in Bay mainstem; limit 500 pots total per person in all tidal waters.
-Unlicensed sport crabber limit 2 pots
-Licensed sport crabber limit 5 pots
-Recreational pots must display "R" on buoys
<u>Peeler Pots</u>
-Wire mesh, no minimum mesh size
-Bait only with live adult male hard crabs; food for male crabs in peeler pots prohibited
-Baiting prohibited Sep. 16 to May 14
-No cull ring required
-Limit 400 pots/vessel April-June
-Limit 400 pots/person July-Nov.
-Limit 2 licensees per boat
<u>Trot Line</u>
-Sport crabber limit 300 feet
<u>Scrapes</u>
-Mouth not to exceed 4 feet overall
-No teeth on bar
-Haul by hand only
-Limit 2 scrapes/boat overboard at one time
-No tolerance for hard crabs
<u>Dredges</u>
-Inside mouth not to exceed 8 feet
-Teeth permitted
-When 2 or more dredges are fixed together, total width may not exceed 16 feet
-Use of more than 2 dredges at one time prohibited
-One dredge on each side of boat or two dredges joined over stern
-Hydraulic methods to dislodge crabs prohibited
<u>Rakes, Dredges, and Scrapes</u> (except hand rakes)
-May not be used on seaside of Eastern Shore in water less than 4 feet at mean low tide
<u>Traps/Pounds</u>
-Four 1.5 inches cull rings in retention box

Potomac
-Crab pots, trotlines, dip nets, patent trotlines, and peeler traps permitted
-Minimum mesh size for hard crab pots, 1 ½"
-One 2 5/16 inches cull ring required in exterior panel of upper chamber of all crab pots, may be closed May and June
-Second cull ring, 2 3/16", required in all pots

-Two 1 ½" cull rings required in peeler pots
-Four 1 ½" cull rings required in peeler traps (pounds)
-Dredges prohibited scrapes
-Culling container required on all vessels, must be cleared before leaving area of crabbing
-Noncommercial limits: 1 pot/person/day; 1000' trotline/person; unlimited collapsible traps; dip nets allowed

Area Restrictions:

Maryland

-Crab pots permitted in waters of Chesapeake Bay proper, Pocomoke Sound and waters of Somerset County in Tangier Sound
-Crab pots prohibited in all other bays, sounds, and tributaries; in less than 4 feet of water except in designated areas; and within 200 yards of a public beach May 1-Sept. 30
-Crab scrapes prohibited in portions of Choptank River, Little Choptank River, St. Mary's River, Calvert Bay, Smith Creek, and all submerged lands leased for oyster cultivation.
-Minimum distance of 100 feet between trot lines
-Bank traps/crab pounds only permitted in Somerset and St. Mary's Co. and waters surrounding Eastern Neck Island
-One stake may be set in riparian waters by the respective landowner or leasee marking site for bank traps or channel pounds between March 1 and March 14.
-After March 15, 8 a.m., any licensee may stake sites for bank traps and pounds.
-Bank traps and hedging must be in place by May 1 to maintain stake, and bank traps and pounds must be removed by Dec. 1.
-Hand-drawn net scrapes only permitted in waters of Queen Anne's Co. and Kent Co.

Virginia

-Minimum distance of 100 yards between crab traps or crab pounds
-Crab pots prohibited in marked navigational channels
-Dredges prohibited in rivers, estuaries, inlets, or creeks except seaside of Accomack and Northampton counties
-Unlawful to take crabs for resale from lower Bay crab sanctuaries and Pretty Lake sanctuary June 1 to Sept. 15, inclusive
-Fixed fishing devices prohibited within 300 yards of Chesapeake Bay Bridge Tunnel
-Crab scraping permitted in Tangier Island crab scrape sanctuary, unlawful to set crab pots or take hard crabs by any gear
-Dredges prohibited upriver of Hampton Roads Bridge Tunnel

Potomac -Crab pots prohibited within 200 yards of any public beach May through September
-No pots or floats in federally marked navigation channels

Season/Time Restrictions:

Maryland -Closed season for commercial and recreational crabbing December 1 to March 31
-Closed season for crab scrapes Oct. 31 to April 14
-Scraping from April 15 to Oct. 30 one hour before sunrise to sunset
-Commercial crabbing with crab pots, bank traps, channel pounds, collapsible traps, net rings, handlines, or dipnets prohibited 5 p.m. to 4:30 a.m. and trotlines between 5 p.m. and 3 a.m.
- Commercial crabbing prohibited on either Sunday or Monday except holidays; harvester must display the letters SUN or MON on port side of vessel near stern to identify the chosen day off.
-Recreational crabbing prohibited between 5 p.m. and 5:30 a.m. in Chesapeake Bay or sunset to 5:30 a.m. in tidal Bay tributaries. No limits from shore, bridges, or piers.
-Recreational crabbing with collapsible traps, net rings, and trotlines is prohibited on Wednesdays.

Virginia -Crab dredging prohibited April 1 to November 30
-Crab dredging prohibited on Saturday
-Commercial crabbing prohibited on Sunday (except peeler traps or floats, pens or onshore facilities for soft crab shedding)
-Commercial crabbing prohibited between sunset and 3 hours before sunrise
-Crab dredging prohibited sunset to sunrise
-Crab pots (hard and peeler) prohibited Dec.1 - March 31
-Crab traps/pounds must be removed by December 31
-Crabbing prohibited June 1 to Sep. 15 in lower Bay crab sanctuaries

Potomac -Commercial crabbing prohibited between sunset and one hour before sunrise
-No closed season
-Noncommercial, same as commercial

Appendix D. Glossary of Terms and Acronyms

Anoxia: No oxygen.

Apron: Hard flap underneath a crab that protects the abdomen.

Benthos: Community of organisms associated with the bottom, such as clams that live in the sediments.

Bivalve: Mollusk with two shells connected by a hinge (ex: clams, oysters).

Buckrams: Crabs that have recently shed, but have not grown into their new shell. Buckrams are light weight and yield less meat than fully developed hard crabs.

Catchability (q): The average *portion* of a fish stock that a unit of gear (i.e. one crab pot) is capable of catching. Catchability is a measure of the catch efficiency of the gear.

Catch Per Unit Effort (CPUE): The *number or weight* (biomass) of crabs caught per unit of gear. CPUE may be influenced by changes in crab abundance. For example, higher abundance means more crabs are available to be caught.

CBP: Chesapeake Bay Program

CBSAC: Chesapeake Bay Stock Assessment Committee

Cradle: When a male crab carries a female peeler crab just prior to maturity so that mating can occur immediately after the hard shell is molted.

Cull rings: Plastic rings worked into the mesh of a crab pot and large enough in diameter to allow small, sublegal crabs to escape.

Exploitation (u): The fraction of a population that is removed by fishing over the course of a year (also accounts for any concurrent natural mortality). Exploitation may also be expressed as a percentage of the population.

F_{max}: The level of fishing mortality (F) at which the greatest poundage (yield) is seen from the fishery. F_{max} is the biological reference point used to define overfishing.

$F_{10\%}$: Fishing mortality rate that allows for at least 10% of the spawning stock to escape the fishery to reproduce. $F_{10\%}$ is measured as 10% of the estimated spawning stock under unfished conditions.

Fishery dependent: Data obtained from commercial or recreational harvest.

Fishery Independent: Data collected from an independent survey rather than from commercial or recreational harvest.

Fishing mortality (F): a measure of the *rate* at which blue crabs are removed from the population by the fishing activities of man. If F is constant over time, harvest will be greater during times of high abundance and less during times of low abundance. F= Z-M.

FMP: Fishery Management Plan

Fully exploited: When a fishery is fully utilized and additional harvest is discouraged to avoid overfishing. In an underutilized fishery, additional harvest does not threaten the population.

Ghost pots: Crab pots lost to storms or left abandoned at the end of the fishing season.

Growth overfishing: The losses in weight (biomass) from harvest and natural mortality exceed the gain in weight due to reproduction and growth. Growth overfishing results in a net loss of crab poundage from one year to the next, which is characterized by a decreasing proportion of older and larger crabs in the catch.

Hypoxia: Low oxygen.

Insemination rate: The proportion of females in the population that successfully mated during their terminal molt.

Instar: Crabs increase shell size when old shells are molted (shed) and new shells are soft and expandable. Instar is the hard shell stage between molts when a crab is not increasing in size.

Maximum Sustainable Yield (MSY): The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. The MSY for Chesapeake Bay blue crabs is the greatest poundage of crabs that can be removed from the Bay without reducing the capacity for the crabs to replenish the population to the same level for harvest in future years.

MDNR: Maryland Department of Natural Resources

Megalopae: Blue crab postlarvae.

Natural mortality (M): The rate of removal of crabs from a population due to natural death (disease, predation, old age).

Nominal fishing effort (f): Fishing effort measured in time (days fished) and number of gear units (ie. number of pots).

Optimum yield (OY): A modified MSY that considers economic, social or ecological issues. OY is frequently used as justification for harvest exceeding MSY.

Overcapitalization: When harvesters invest in and deploy amounts of fishing gear greater than what is necessary to harvest a given amount of crabs. For example, when a harvester enters the fishery using 100 pots to catch 20 bushels of crabs, and later increases his investment to 200 pots but still catches only 20 bushels of crabs.

Passive gear: Gear that requires the animal to enter voluntarily (as opposed to active gears such as trawls and dredges which must move to trap animals and prevent them from escaping.

Plankton: Small or microscopic algae and organisms associated with surface water and the water column.

ppt: Parts per thousand.

Recruitment: Entry of crabs from one size class to the next class higher. May also refer to entry of crabs into the population as they are spawned and develop into juvenile crabs, or entry of juvenile crabs into the mature population as they grow.

Recruitment overfishing: The rate of fishing above which recruitment to the fishable stock is reduced. Recruitment overfishing is characterized by a reduced spawning stock and generally very low production of young year after year.

SAV: Submerged Aquatic Vegetation. Also called grass beds.

Size class: Crabs within close size range of each other, and presumably close in age.

Soft shell phase: Immediately after a crab molts when the new shell is soft and expandable.

Spawning stock: All females that survive natural and fishing mortality to reproduce.

Spermatheca: A receptacle on the underside of female crabs for receiving and holding sperm for use later to fertilize eggs.

Terminal molt: Last molt in female blue crabs that precedes maturity.

Total mortality (Z): Natural mortality plus fishing mortality.

Year class: see size class.

Zoeae: Blue crab larvae

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Chesapeake Bay Program

The Chesapeake Bay Program is a unique regional partnership leading and directing restoration of Chesapeake Bay since 1983. The Chesapeake Bay Program partners include the states of Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission, a tri-state legislative body; the U.S. Environmental Protection Agency (EPA), which represents the federal government; and participating citizen advisory groups.

In the *1987 Chesapeake Bay Agreement*, Chesapeake Bay Program partners set a goal to reduce the nutrients nitrogen and phosphorus entering the Bay by 40% by the year 2000. In the *1992 Amendments* to the *Chesapeake Bay Agreement*, partners agreed to maintain the 40% goal beyond the year 2000 and to attack nutrients at their source--upstream in the tributaries. The Chesapeake Executive Council, made up of the governors of Maryland, Pennsylvania, and Virginia; the mayor of Washington, D.C.; the EPA administrator; and the chair of the Chesapeake Bay Commission, guided the restoration effort in 1993 with five directives addressing key areas of the restoration, including the tributaries, toxics, underwater bay grasses, fish passages, and agricultural nonpoint source pollution. In 1994, partners outlined initiatives for habitat restoration of aquatic, riparian, and upland environments; nutrient reduction in the Bay's tributaries; and toxics reductions, with an emphasis on pollution prevention.

The 1995 *Local Government Partnership Initiative* engages the watershed's 1,650 local governments in the Bay restoration effort. The Chesapeake Executive Council followed this in 1996 by adopting the *Local Government Participation Action Plan* and the *Priorities for Action for Land, Growth and Stewardship in the Chesapeake Bay Region*, which address land use management, growth and development, stream corridor protection, and infrastructure improvements. A 1996 riparian forest buffers initiative furthers the Bay Program's commitment to improving water quality and enhancing habitat with the goal of increasing riparian buffers on 2,010 miles of stream and shoreline in the watershed by the year 2010.

Since its inception, the Chesapeake Bay Program's highest priority has been the restoration of the Bay's living resources--its finfish, shellfish, bay grasses, and other aquatic life and wildlife. Improvements include fisheries and habitat restoration, recovery of bay grasses, nutrient reductions, and significant advances in estuarine science.

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