MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Adoption Statement

Fishery Management Plan for Largemouth Bass (*Micropterus salmoides*) in Maryland Tidewater 2015

We, the undersigned, adopt the Fishery Management Plan for largemouth bass (*Micropterus salmoides*) as a guide for managing largemouth bass fisheries in Maryland Tidewater. The plan provides a management framework for the protection, maintenance and improvement of largemouth bass fisheries and supports the development of policy decisions. The purpose of the plan is to ensure the population integrity and sustainability of largemouth bass in Maryland tidewater, to promote and protect angling opportunities for a wide diversity of constituents, and to respond to public concerns about the fishery with the best scientific information available.

The plan adopts management strategies and actions to assess the current status of largemouth bass populations; to develop biological reference points; to identify, protect, promote, and improve quality habitats; to improve the quality of the fishery; and to incorporate ecosystem considerations in all aspects of management. We recognize this is a multi-year commitment and that it will take a coordinated effort within the Department of Natural Resources to implement the plan.

The Maryland Department of Natural Resources Fisheries Service will periodically review and update the plan with stakeholders, and report on progress made in achieving the management plan's goal and objectives.

[signature]	10/22/15
Secretary	Date
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Assistant Secretary, Aquatic Resources	Date
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Director, Fisheries Service	Date

FISHERY MANAGEMENT PLAN

FOR

LARGEMOUTH BASS (*Micropterus salmoides*)

In MARYLAND TIDEWATER

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1.0 DESCRIPTION OF MANAGEMENT PLAN

1.1 *Executive Summary*

Largemouth bass populations are arguably one of the most important resources for sport fish anglers in Maryland tidewater. The species is also a keystone predator that affects many species within aquatic food webs. The sustainability of largemouth bass populations in tidewater of Maryland is affected by impervious surface development, climate change, invasive species, and fishing mortality. These threats have prompted anglers to request management of tidewater largemouth bass fisheries.

The goal of this fishery management plan is to develop a management framework that guides the maintenance and improvement of largemouth bass fisheries of various populations or stocks in Maryland tidewater. The objectives of the management plan are: 1) Assess current status of largemouth bass populations by using long-term population assessments in tidewater; 2) Develop biological reference points for assessing largemouth bass populations; 3) Identify, protect, promote, and improve quality habitats for largemouth bass; 4) Achieve stakeholder expectations that are within bounds of our management principles; and, 5) Incorporate ecosystem considerations in all aspects of largemouth bass management.

This fishery management plan outlines how staff will assess population status and impose management actions, when necessary. Assessment includes long-term, fishery independent and dependent surveys used to develop biological indices. The indices were developed to evaluate the status of populations within river systems. The indices were assigned reference points identified from the literature and/or 25th and 75th percentiles of the current dataset. Both indices and reference points will be re-evaluated periodically and when other factors, such as habitat loss or spread of invasive species, demand it. Thus, this fishery management plan will be updated and reviewed on a regular basis. Reference points can be used to set restoration goals or indicate the need for management actions. Management actions may include: protect habitat conditions; stocking; change and enforce creel limits and size limits; closing the fishery; adoption of catch-and-return seasons or areas; and angler awareness strategies.

Several major knowledge gaps in largemouth bass fisheries of Maryland's tidewater have been noted: 1) Lack of 10-year baseline data for determining biological reference points for some tidewater areas; 2) Need better estimators of annual indices from survey work; 3) Lack of knowledge of discrete populations for appropriate management units; 4) Poor information on the economic impact of the fishery; 5) Lack of information on angler satisfaction; and 6) Lack a refined habitat index that addresses habitat quality for spawning habitat, submerged structure, and future impacts by climate change and land use development.

1.2 *Guidance on Reviewing Management Plan*

This Fishery Management Plan describes biological characteristics of largemouth bass (Sections 3.0 and 4.0), the history and current status of the fisheries of largemouth bass in Maryland (Sections 5.0 and 6.0), and the proposed management strategy for tidewater populations of largemouth bass in Maryland (Sections 7.0 and 8.0).

1.3 *Terms and Definitions*

Cohort – a subset of organisms within a population having the same age

e.g. – *exempli graitia*; for example

Fishery – a population of one or more species that is burdened by targeted fishing mortality

i.e. – *id est*; that is, or in other words

Impervious – not allowing fluid, such as rain, to pass through

Morphological - describes shape characteristics

NTU – Nephelometric Turbidity Unit; a measure of water clarity

Oligohaline – water with a salinity of 0.5 – 5.0 ppt

Piscivory – the property of consuming fishes

Population –an ecological term designating a discrete group of individuals that share a gene pool, is self-perpetuating, and is geographically or otherwise isolated from other similar groups; see Stock

ppt – parts per thousand; a measure of salinity

Recruitment – a population process describing the growth of an individual (or recruit) into sexual maturation to become a member of the spawning stock

Riverine – of or pertaining to rivers

Sensu – in the sense of

Spawning Stock – a fraction of the population that is sexually mature

Stock – a management term designating a discrete group of individuals that share a gene pool, is self-perpetuating, and is geographically or otherwise isolated from other similar groups

Stock Size – the minimum size of an individual that enters into a fishery

Stocking – the human release of an animal that was not naturally propagated in the environment into which it is released

Taxonomy – process of classification of organisms into species and higher order groups

Tidewater – an estuary affected by rising and falling tides; tidal freshwater is a special case of tidewater and is defined as freshwater (< 0.5 psu) that is influenced by tides.

Trophic – nourishment; describing how the organism obtains energy

Zooplanktivorous – the property of consuming zooplankton

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3.0 SPECIES DESCRIPTION

3.1 *Species Taxonomy*

Largemouth bass belongs to the genus *Micropterus* within the family of sunfishes, Centrarchidae (Fig. 3.1.1). Largemouth bass (*M. salmoides* Lacépède) was originally described from South Carolina in 1802 and placed within a different genus, *Huro*, because of its deeply emarginated dorsal fin, large mouth, and other morphological aspects (Jenkins and Burkhead 1993). It was later reclassified as *Micropterus* (Bailey and Hubbs 1949).

Two sub-species of largemouth bass were originally recognized: the northern largemouth bass (*M. s. salmoides*) and the Florida largemouth bass (*M. s. floridanus*)(Jenkins and Burkhead 1993). Current molecular and morphological data indicate that *M. s. floridanus* be elevated to a species, *M. floridanus* (Kassler et al. 2002). The Florida species can be identified by smaller and more numerous scales (69 – 73) in the lateral line series than *M. salmoides*, (59 – 65) (Bailey and Hubbs 1949). The two species also differ in patterns of growth, with *M. floridanus* growing faster and reaching maturity earlier in warm water of southern states (Clugston 1964). Hybrids (*M. salmoides* x *floridanus*) were twice as common within Choptank River as other surveyed areas of the Chesapeake Bay watershed in the late 1990's (MD DNR 1999). However, such hybrids may be genetically inferior to either species and backcrosses may be detrimental to populations of *M. salmoides* (Philipp et al. 1981, Philipp 1991). Backcrosses suffer from poorer growth and higher overwinter mortality than *M. salmoides*. In Virginia, the stocking hybrids has not led to poorer growth or mortality; instead, those hybrids recruit to the spawning stock and exhibit similar patterns of growth as wild stock (unpubl. data, Bob Greenlee, Virginia Department of Game and Inland Fisheries). While stocking of *M. floridanus* or *M. salmoides* x *floridanus* beyond the native range of Florida is not currently encouraged (Kassler et al. 2002), in southern states such stocking may be effective. The value or survivorship of such hybrids in Maryland waters has never been assessed.

The classification of largemouth bass is currently described by:

Superorder:	Acanthoptyergii
Order:	Perciformes
Suborder:	Percoidei
Family:	Centrarchidae
Genus:	*Micropterus*
Species:	*Micropterus salmoides*

Smallmouth Bass (*M. dolomieu* Lacépède) is less common in Maryland tidewater and therefore, not included in this management plan. The Smallmouth Bass is distinguished from largemouth bass by their relatively small mouth and coloration. The maxillary bone (mouth) of Smallmouth Bass does not extend beyond the rear margin of the eye when the mouth is closed. Smallmouth Bass have vertical, dark bands on the lateral side of their body and are slightly brownish. In contrast, largemouth bass has a horizontal stripe along its lateral line and a slightly greenish color. Also, the maxillary bone extends beyond the rear margin of the eye when the mouth is closed, which distinguishes it from other species of *Micropterus*.

Four other species of *Micropterus* are described in the literature and are not found in Maryland's tidewater or reservoirs. Of these, spotted bass (*M. punctulatus* (Rafinesque)) has the largest native range. This species is found throughout the southeastern United States and can be distinguished from other similar species by heavy spotting on the ventral body surface. The redeye bass (*M. coosae* Lacépède) is native to streams of Alabama, Georgia, South Carolina, and Tennessee. While it has been introduced to other areas of the United States, this bass is not reportedly found in Maryland. It can be distinguished from other members of *Micropterus* by white outer margins of the caudal, soft dorsal and anal fins. The Suwannee bass (*M. notius* Bailey and Hubbs) is restricted to Florida and Georgia in the Suwannee and Ochlockonee rivers. The Guadalupe bass (*M. treculi* (Vaillant and Bocourt)) is restricted to streams in Texas.

3.2 *Species Distribution*

The distribution of largemouth bass has greatly expanded from the southeastern United States over the past 2 centuries (Fig. 3.2.1). Historically, largemouth bass was distributed throughout the Mississippi and Great Lakes' basins and into Florida and Mexico. Because of introductions and stocking efforts, largemouth bass is now distributed throughout the United States, including ecosystems of the northeast and Atlantic coastal states. Largemouth bass has also been introduced worldwide, most notably in Japan where a tying world-record was caught in 2009 (22 lbs, 4.97 ounces). Smallmouth Bass historically had a smaller distribution, largely restricted to the northern parts of the Mississippi and Laurentian basins (Fig. 3.2.1). While slightly larger today, the distribution of Smallmouth Bass is currently not as widespread as that for largemouth bass (Lee et al. 1980).

Largemouth bass is non-native to Maryland streams. Largemouth bass was introduced from the Ohio River basin sometime near or around 1874 to tidal rivers of southern Maryland and the eastern shore. In 1896, 250 largemouth bass were stocked in the Potomac River from the Ohio River basin. In 1899 and 1900, 3000 adults were introduced to tidal rivers of the eastern shore. It was generally thought that eastern shore tidal rivers would be more suitable for largemouth bass. Smallmouth Bass adults from Virginia were introduced into the Chesapeake Bay watershed in 1854. The species rapidly spread throughout the Potomac River. Smallmouth Bass was expected to do well in the upper Potomac River. Once introduced both Largemouth and Smallmouth Bass populations grew fast, rapidly expanding their distributions.

Propagation efforts for largemouth bass and Smallmouth Bass in State hatcheries began after 1917. Successfully raised bass and those collected during a brief commercial fishery of the mid-20th Century led to established populations in impoundments across the state. Today, largemouth bass is found in all major rivers of the Chesapeake Bay watershed (Fig. 3.2.2), and many impoundments, storm water ponds, and farm ponds.

3.3 *Consequences of Introduction*

The introduction of largemouth bass into Maryland's rivers as a source of food for people, likely impacted the food web. In many cases, largemouth bass can become invasive (Jackson 2002). It is an omnivore, consuming prey from many trophic levels. When introduced to Maryland, both largemouth bass and smallmouth bass "destroyed all other fish and were, themselves, diminishing" (Powell 1967). Because largemouth bass has existed in Maryland's tidewater for at least 140 years, it has become a well-integrated member of the fish community. Indeed, in some habitats it may now be a keystone species (Mittelbach et al. 1995), which is a species that has a low biomass in the community and has a disproportionately large impact on other species. In tidal rivers of Maryland, it is no longer considered invasive, but an important year-round top predator in fish communities.

In new habitats, largemouth bass quickly adapts to different prey resources and can cause harm to ecosystems (Almeida et al. 2012). When introducing largemouth bass to new habitats, it is prudent to consider the indigenous fauna, particularly rare species that may become quickly extirpated because of depredation. The introduction and subsequent establishment of invasive species in new habitats is a leading cause of fish extinctions in the world (Clavero and García-Berthou 2005).

3.4 *Species Movement and Home Range*

Generally, largemouth bass does not move great distances. Distance traveled is generally less than 0.10 km in both rivers and lakes (Lewis and Flickinger 1967; Winter 1977; Pribyl et al. 2005). The home range of an adult largemouth bass is likewise small, but can range up to 17 hectares (Ridgway 2002) and is usually defined by distinct landmarks, such as bank shape or shoreline topography (Hubert and Lackey 1980). Shoreline topography and underwater contours are important for largemouth bass when navigating home after displacement. An individual may move long distances because of storm events, water temperature, spring spawning events, and displacement (Todd and Rahen 1989; Richardson-Heft et al. 2000; Ridgway 2002). The home range may temporarily increase if there are declines in the forage base (Savitz et al. 1983). In the Potomac River, home ranges can be as large as 2 km^2 (Siebold 1991), but are generally smaller. Movement rates measured from tagged and recaptured largemouth bass in tidewater of the Chesapeake Bay averaged 0.18 km/day ± 1.31 SD (Tables 3.4.1-3.4.5). Only one individual in the Chesapeake Bay was recorded with a maximum rate of 14.8 km/day and may have been moved by anglers. When the data for that individual was removed from the analysis, the movement rate of individuals averaged 0.09 km/day ± 0.56 SD and ranged from 0 – 6.3 km/day. The tendency to move small distances is apparent for juveniles as well (1 km, on average), unless they are of hatchery-origin and have the tendency to move greater distances (Jackson et al. 2002). Some adults will travel long distances naturally (Funk 1957; Siebold 1991; Stang et al. 1996; Ridgeway 2002).

A largemouth bass may remain in a new area if it is displaced from its home (Lewis and Flickinger 1967; Pribyl et al. 2005). If the new area is not suitable, then the fish typically leave the area. The absence of submerged cover or presence of high salinities (>5 ppt) elicit movement away from the release site (Hubert and Lackey 1980; Meador and Kelso 1989). Largemouth bass adults that spend their life in freshwater apparently differ in tolerance to salinity levels, in growth patterns, and in body condition when compared to largemouth bass raised in brackish (3 – 8 ppt) water (Meador and Kelso 1989, 1990). Largemouth bass from brackish areas of Mobile Basin do not live as long or achieve large sizes as freshwater counterparts (Norris et al. 2010). Individuals may be locally (and possibly genetically; Borden 2008) adapted to the salinity profile of their home stream. Adults reared in freshwater may be more likely to leave a brackish area than adults reared in brackish water. Local adaptation of populations may be reinforced by relatively small home ranges and limited movement (Meador and Kelso 1990; Borden 2008). If adults do not return to their stream of capture, then populations may become locally depleted after fishing events.

The probability of returning to a "home stream" following displacement has been intensively studied in both lakes and rivers, including the Chesapeake Bay watershed (Siebold 1991; Richardson-Heft 2000). In the Northeast and Susquehanna Rivers of the Chesapeake Bay, Richardson-Heft et al. (2000) reported that displaced largemouth bass adults generally remained at the site of their release for at least 1 week. After one week, most adults stayed in the area they were transported to, with a little less than half returning to their area of capture. Siebold (1991) also noted that only slightly more than half of the adults returned to their stream of capture in the Potomac River. In the Hudson River, Stang et al. (1996) reported very little evidence that adults returned to a home stream (or philopatry); only 8 of 42 tagged fish returned to their original stream of capture following displacement. It took from 2 to 22 weeks for fish to return to their original stream of capture. Similarly, in the Grand River (Ontario, Canada), only 5 of 14 displaced largemouth bass adults returned to their stream of capture, which took approximately 1 month (Ridgway 2002). Such patterns are also evident in lakes and reservoirs. In Rideau Lake (Ontario), of 19 largemouth bass adults that were displaced up to 16.5 km, only 4 returned to streams of capture, which took approximately 1 – 4 weeks (summer). In summary, displaced adults remained within 0 – 1 km of their release site for approximately 1 – 4 weeks (Richardson-Heft et al. 2000; Ricks 2006); most may remain within 3 km of their release site for longer periods of time (Ricks 2006), depending on conditions at the release site. It is recommended that largemouth bass be returned to an uninterrupted area within at least 30 km of their capture and within the river of capture.

3.5 *Species Life History*

There are three, general stages of development for largemouth bass: larval, subadult (or juvenile), and adult (Fig. 3.5.1). Largemouth bass larvae hatch approximately 3 – 4 days after fertilization, depending on water temperature. As temperatures warm to 17° C (or 60 - 65° F), largemouth bass larvae emerge from their eggs (Kramer and Smith 1960). In Maryland, hatching occurs in the spring (April – mid May). Cold temperature snaps (>10° C variation) or cooler temperatures (below 15.5° C) lower the survivorship of hatching fish (Kramer and Smith 1962). While 5,000 – 80,000 ova may be deposited per female (Kelley 1962), only 1/3 of them may survive to become larvae (Kramer and Smith 1962). Largemouth bass larvae are 3.0 – 5.5 mm total length (TL) at hatching. Following their hatch, larvae swim near the substrate where they exhaust their yolk supply. As water temperature increases, growth for this larval stage likewise increases (Kramer and Smith 1960). After 5 – 8 days and at 5.9 – 6.3 mm (or 0.2 in) TL, the yolk is depleted and larvae enter the water column to feed. The principal prey items are rotifers and other zooplankton. Water temperature plays a less important role for this larval stage and larger prey items tend to increase growth rates (Kramer and Smith 1960). Larvae school over the nest for several weeks. While on the nest, a male largemouth bass vigorously defends the larvae from potential predators, such as bluegill (*Lepomis macrochirus*)(Colgan and Brown 1988). During this time, the male does not eat. The level of defense does not differ as larvae hatch and school (Cooke et al. 2002). If the male is removed from the nest, then offspring may be quickly preyed upon by surrounding predators (Carr 1942). As larvae reach sizes near 32.5 mm or 1 in (within 26 – 31 days in Minnesota; Kramer and Smith 1962), the male departs and older larvae or juveniles disperse completely.

During their first summer, largemouth bass juveniles grow between 0.18 to 0.30 mm/day in reservoirs of North Carolina (Jackson et al. 2002). In Maryland's tidewater, largemouth bass juveniles have an estimated growth rate of 0.4 mm/day (45 – 60 mm size group), or 22 mm (0.9 in, 4.7 SD) to 32.5 mm (1.3 in, 7.9 SD) per month during summer and fall. Prey consumption and growth rates can be highly variable day-to-day (Smagula and Adelman 1982). Largemouth bass juveniles that are smaller than 48 mm TL consume crustaceans. As they grow larger, juveniles also prey upon decapods (e.g. grass shrimp) and fishes. Largemouth bass juveniles that consume fish grow about twice as fast as those consuming primarily aquatic invertebrates (Applegate and Mullan 1967). Both the type and level of prey consumption decline with decreasing water clarity (Crowl 1989; Huenemann et al. 2012) and decreasing density of submerged structure (Hoyer and Canfield 1996). At 50 NTU (water clarity measurement), foraging by age 1 largemouth bass is reduced by at least 33% (Huenemann et al. 2012). In 2012, monthly estimates of water clarity varied between 0.7 NTU and 127 NTU, averaging 16.7 NTU for the Potomac River.

Age 1 cohort survival after the first winter depends on individual growth during the first summer, and the initial cohort strength (Fuhr et al. 2002). Insufficient energy reserves during winter can result in starvation for smaller juveniles (Ludsin and Devries 1997; Post et al. 1998; Garvey et al. 2002) except at southern latitudes where growth occurs throughout the year (Peer et al. 2006). Motility and presumably foraging rate slows as water temperatures decline below 7° C (Lemons and Crawsha 1985). Because overwinter mortality is the major factor limiting recruitment and population sustainability of largemouth bass (Fullerton et al. 2000), monitoring trends in winter water temperature may help predict strong or weak age classes and partially explain patterns of recruitment. Because largemouth bass is cannibalistic, density dependent regulation can occur (Post et al. 1998). In addition to predator density, low pH (4.9-7.0) may increase risk of starvation during winter (Shuter et al. 2006).

As noted above, survivorship of juvenile largemouth bass to later age classes is largely dependent upon environmental conditions. Recruitment for largemouth bass is therefore more limited by environmental conditions rather than the number of adults with successful nests (Allen et al. 2011). While removal of adults from nests can lead to nest failure, the overall influence of angling during the spawning season is less that of environmental factors. Ensuring quality habitats during the first year of growth for juvenile largemouth bass is likely a more effective management strategy than restricting angling, unless catch rates are exceptionally high and productivity is low (Gwinn and Allen 2010).

After the first year of life, individual growth among the first age cohort is highly variable and individuals may grow to 200 mm (8 in) TL in tidewater areas of the Chesapeake Bay. Estimated growth rate slows after age 1, with individuals growing approximately 50 mm/yr (2 in/yr) through age 4. After age 4 growth rate estimates plateau. Ages 5 - 13 are not easily discernable by size of the fish (Table 3.5.1). These estimates of growth generally correspond with those measured from tagged individuals. Using tag-recapture information from largemouth bass in Chesapeake Bay, tagged fish that were 254 - 300 mm (10 – 12 in) TL grew 60–80 mm/yr (2 – 3 in/yr). Larger and older fish (>300 mm or 12 in TL) grew from 20–40 mm/yr (1 – 2 in/yr).

Largemouth bass reaches maturity within 2 or 3 years and males mature faster than females. Size at maturity for males and females in Mississippi is 220 mm (9 in) TL and 250 mm (10 in) TL, respectively (Ross 2001). However, size at maturity can vary with latitude and fish from southern latitudes may mature at smaller sizes relative to their northern counterparts. The size at maturity for males and females in Maryland is not known, but growth rates slow after about 300 mm (12 in) TL when energy may be invested into gonad production. Because growth rates of individuals do not differ among tidewater areas, sexual maturation may be reached at similar sizes for different populations. Largemouth bass continues to grow throughout its lifespan which may be up to 15 years.

During the spring spawning season, males construct a nest by fanning a depression in the substrate using their caudal fin. Nests are built early in the year by adults larger than 400 mm, which allows for a longer growing season for their offspring (Goodgame and Miranda 1993). Nests in sloughs and lakes of Minnesota were constructed within a month of increasing water temperatures that climbed from 4.4° C (40° F) to 15.5° C (60° F)(Kramer and Smith 1962). The depth at which nests are built in impoundments range from 0.1 – 2.8 m, but the average depth can vary among years (Hunt et al. 2002). Nests constructed in deeper water are less prone to destruction by wind and waves and are more thermally buffered (Kramer and Smith 1962). In tidal rivers, males build nests preferentially in coves or embayments and stable water bodies (Nack et al. 1993). Nests are usually built near some type of physical structure and over firm substrate (Carr 1942; Hunt et al. 2002). Coarse woody structure (e.g., downed trees) appears to be preferred over dock structures (Lawson et al. 2011). The space between nests is approximately 2 m, depending on the availability of underwater objects that block vision among nests (Clugston 1966; Heidinger 1976).

As structural complexity within a nesting habitat increases, the defensive behavior of the male also increases (Hunt et al. 2002). Males may defend nests from many types of aquatic predators, such as sunfish (*Lepomis* spp.), yellow perch (*Perca flavescens*), birds and humans.

4.0 ESSENTIAL FISH HABITAT

4.1 *Established and Enhancing Habitat*

Largemouth bass prefers oligohaline or freshwater, but growth can be high in brackish water (3 – 8 ppt) depending on prey availability (Meador and Kelso 1990). In tidal rivers, coves and embayments are preferred during the spawning season (Nack et al. 1993) because of their stability and lake-like characteristics. In general, channelized sections of rivers (e.g., the Chesapeake-Delaware Canal) are likely poor habitats and do not support fishable populations (Marler and Jackson 1992).

Largemouth bass is commonly found near submerged aquatic vegetation (SAV; Durocher et al. 1984) or other submerged structure (Slipke and Maceina 2007). When *Hydrilla verticillata* colonized and rapidly spread in the Potomac River (early 1980's), Killgore et al. (1989) reported intensive use of vegetated areas by largemouth bass, particularly in intermediately dense (~500 g/m^2) and highly dense (~1000 g/m^2) habitats. Submerged structure enhances foraging and growth (Hoyer and Canfield 1996). Water clarity enhances the growth of SAV and possibly the visual acuity of piscivorous fish such as largemouth bass. In the absence of submerged vegetation as refugia, prey fishes may be more susceptible to predation by juvenile largemouth bass, which can also result in a high growth rate of juvenile largemouth bass (Bettolli et al. 1992). Hence, growth rates may be higher in habitats with low to intermediate levels of submerged vegetation, depending on the availability of prey. While there are consistently low levels of submerged vegetation in some areas of Chesapeake Bay, there is artificial structure that is not measured during Tidal Bass Surveys. Artificial structure in areas without grasses is an important habitat feature for largemouth bass because it is preferentially selected in the absence of submerged vegetation (Colle et al. 1989).

Habitat suitability across the many tidewater areas for the Chesapeake Bay populations of largemouth bass was moderately high. Using a habitat suitability index (HSI; Stuber et al. 1982), Love (2011) found that water quality and submerged grasses was suitable for largemouth bass in the majority of Chesapeake Bay tidewater. Abundance was highest in tidewater with high HSI, with some exceptions. High abundance of some streams was associated with low HSI because the index failed to account for submerged structure that was not vegetation. This submerged structure can include sunken barges, piers, and woody snag habitat. Annual variation in HSI was minimal, but monthly increases from March – September due to increases in water temperature and growth of SAV are concurrent with the spawning and growing season of largemouth bass.

In the event that there are widespread SAV die-offs (Orth and Moore 1983) or if fishery managers seek to enhance habitat for largemouth bass, two considerations are necessary. Habitats may be enhanced for reproduction or catch rates, which may be, but not always, mutually exclusive. Enhancing habitat for improving reproduction generally includes improving habitat for nesting males. This consideration may also include enhancing the forage fish availability for age-0 largemouth bass, which improves growth, presumably lowers overwinter mortality, and facilitates recruitment. Submerged aquatic vegetation appears to be an important element for nest building (Weis and Sass 2011). However, coarse woody habitat is a suitable alternative to grasses for nest building. Weis and Sass (2011) found that while 68% of 1703 nests were constructed on beds of macrophytes, 38% were built near structure and 41% of those were near coarse woody habitat. Fewer nests were constructed near large rocks or boulders. As *Hydrilla* beds disappeared in a reservoir in Georgia, largemouth bass began to associate with submerged logs with greater frequency (Sammons et al. 2003). They did not leave the area or die, but maintained their home ranges and exhibited greater movement. The addition of structures that are similar to natural logs or coarse woody habitat may stimulate nest building (Hunt and Annett 2002) and improve piscivory and foraging (Sass et al. 2011). Logs may be spaced apart by 1 m to maximize nest building. The addition of such structure to waterways should mimic that of existing structure, be placed near such existing structure and with an intermediate level of complexity that provides limited refuge for ambush, nest predators (Hunt et al. 2002). Docks, which are also submerged structure, are not good alternatives for improving reproduction and the availability of nesting habitat (Lawson et al. 2011). Unfortunately, the influence of tide on nesting habits is not well-known for largemouth bass. It is important to consider tide, however, and ensure the enhancement of habitat that is at least 0.5 - 1 m deep throughout the tide cycle.

Recruitment may be improved by enhancing forage fish availability. Typically, age-0 largemouth bass forage on plankton, small insects, and fishes (Sule 1981). Protecting species within these lower trophic levels will promote growth of young largemouth bass. Either competition with other species or unsuitable habitats can limit resource availability, hence limiting recruitment naturally. Unsuitable habitats may be improved by mitigation and protecting valued habitats. Competition with other species, particularly invasive species, can be minimized by harvesting the life stage of invasive species that compete with young largemouth bass. Better practices of ecosystem-based management should inform fishery managers of the probability of success when managing the biomass of competitors, predators, and prey.

Habitat enhancement to improve angler catch rates has inspired numerous submerged inventions, including reefs and other forms of structure. Because largemouth bass tend to associate with submerged structure, increasing the abundance of structure should likewise promote catch rates. Historically, tire reefs were thought to improve habitat for fishes. Hartwell et al. (1994) found that leachate from tires was especially toxic in freshwater to fish, plankton, and crustaceans. Other alternatives include discarded Christmas trees, concrete structures, reef balls (i.e., a specially shaped concrete structure), porcupine fish attractors, discarded ships or barges, cinder block – brush piles, and PVC pipe structures. Research addressing the effectiveness of catching largemouth bass near one or all of these types of structures is sparse, at best. They all may work because largemouth bass arguably associates with submerged structure and tends to avoid open water, though exceptions have certainly been noted. It would be preferable to utilize a structure that does not interfere with other water usage, and is natural or biodegradable because tidewaters stage during floods and structures may dislodge to move many kilometers downstream.

4.2 *Possible Impacts of Climate Change, Land Use Development, and Invasive Species*

World-wide changes in climate patterns influence an ever-changing landscape of watershed development in ways that could adversely impact largemouth bass fisheries. Climate change consequences for the Chesapeake Bay include increased frequency of storm events and greater precipitation (Najjar et al. 2010). As years with extremely high precipitation levels increase in frequency and impervious surface levels increase in density, the amount of run-off or discharge to a waterway is also expected to increase. Impervious surfaces can prohibit precipitation from entering into groundwater. Loss of freshwater habitat excludes habitat use by freshwater-dependent species such as largemouth bass (Love et al. 2008), likely leading to long-term negative consequences on largemouth bass fisheries. Impervious surface development also causes frequent flashing of streams. During spring, this flashing can destroy bass nests, lower juvenile production, and limit the floodplain area available for foraging opportunities for juveniles (reviewed in DeVries et al. 2009).

As the Chesapeake Bay water temperatures increase because of climate change (Najjar et al. 2010), the consequences to SAV in tidewater may be dramatic (Short and Neckles 1999). A change in distribution of SAV is likely to occur and could be associated with a decline in SAV biomass because of saltwater intrusion and spread of disease. In addition, some species of SAV (e.g., *Valliscenaria*) may be outcompeted by nuisance species (e.g., *Hydrilla*), which may become highly dense, restrict circulation of water, and locally reduce the availability of dissolved oxygen to fishes during photosynthesis. As discussed in section 4.1, a change in grass distribution or biomass could threaten recruitment of juvenile largemouth bass. For offspring that survive into summer, though, annually increasing summer water temperatures may promote growth and survivorship. Thus, populations may ultimately decline in size as the Chesapeake Bay warms in the future, largely because of lower levels of recruitment. In addition to a decline, recruitment may become more variable among years because frequent extreme climatic conditions are expected (Jentsch et al. 2007). For late born bass or emaciated bass, extremely cold winters may lead to starvation and death (Suski and Ridgway 2009).

Land development leading to increased impervious surface cover and progressive loss of riparian corridors may result in greater sedimentation and increased stream water temperature. Higher water temperatures can threaten growth of SAV. Coupled with potentially higher non-point source pollution of nitrogenous wastes, higher water temperatures could also foster changes in other types of primary production. Shading effects from suspended sediments that kill submerged grasses may indirectly promote the bloom of phytoplankton, including cyanobacteria. These effects would inevitably change the structure of phytoplankton communities (Buchanan et al. 2005), but could lead to larger populations of zooplankton via bottom-up effects. Because largemouth bass larvae are zooplanktivorous, early juvenile growth may benefit from such increases in primary and secondary production. Survival of juveniles during summer, however, may be reduced by the loss of submerged vegetation and increased risk of predation. Loss of submerged vegetation in Chesapeake Bay is expected because of climate change (Najjar et al. 2010).

Invasive species occur throughout the Chesapeake Bay watershed. Two recent examples of invasive species are northern snakehead (*Channa argus*) and blue catfish (*Ictalurus furcatus*). Invasive species may alter their environments in unpredictable ways over time, especially as they become abundant. Northern snakehead has greatly expanded its range and biomass in less than a decade. It also consumes a diverse prey assortment (Odenkirk and Owens 2007) and shares a prey base with largemouth bass (Saylor et al. 2012). Its widespread establishment could negatively affect the fishery for largemouth bass if left uncontrolled (Love and Newhard 2012). Current gut analyses indicate that Northern Snakehead has consumed white perch (*Morone americana*), yellow perch (*Perca flavescens*), crayfish, and rarely, juvenile largemouth bass (pers. obs., JWL; pers. comm., J. Newhard, US Fish and Wildlife Service, Maryland Fishery Resources Office). In addition to Northern Snakehead, Blue Catfish is now considered invasive in Potomac River because of its increase in biomass in the past 2 decades (unpubl. data, E. Durrell, MD DNR Striped Bass Seine Survey), rapid growth rates, and opportunistic foraging. Its impact on largemouth bass may be minimal because co-occurrence is low, though larger blue catfish (> 500 mm or 20 in) is locally abundant during late spring and summer in a small number of areas that may also be occupied by largemouth bass (unpubl. data, M. Groves, MD DNR Southern Regional Office).

5.0 THE FISHERY

5.1 *Stocking History in Maryland*

Introduction of largemouth bass across the United States in the 1800's led to a rapid expansion of the fish and the fishery. Largemouth bass is a year-round resident and top predator, which was considered as missing from the food web of the tidal fresh stretches of the Chesapeake Bay watershed (Powell 1967). The watershed had putatively supported residents of only catfish, suckers, Fall Fish (*Semotilus corporalis*), and a few minnows (Powell 1967). Native predators such as Striped Bass, White Perch, American Eel, and Yellow Perch were seasonally abundant during their migration, which occurred primarily during spring. Once introduced, largemouth bass was considered an important, year-round supply of food for the people inhabiting the Potomac River watershed. In an effort to protect the new and popular fishery, the first legislation addressing largemouth bass in Maryland was introduced in 1885 and supported by Rod and Gun clubs of Maryland, Virginia, and West Virginia. It established a season for harvesting bass (1 April – 1 June) and required a hook and line to be used while fishing (Powell 1967). Widespread declines of the fish due to overfishing and ineffective management by state agencies also led to the Black Bass Act, a federal law created in 1926 (16 U.S.C.A. §§ 851–856). The law effectively prevented interstate transport of illegally caught largemouth bass. While it has been refined to include international transport and was later incorporated into the Lacey Act, it remains the first federal law that regulated the largemouth bass fishery. Three years later, growing sentiment to protect largemouth bass spawning populations led to a law that established a no-take season from April to July. However, in 1959, the no-take season in tidewater was repealed following an intensive survey that demonstrated bass were no longer being depleted (Powell 1967).

The recreational fishery for largemouth bass was evidently popular since at least the mid-20th century in Maryland. Anglers in the mid-20th century reported catching bass ranging from 0.9 – 2.5 kg (or 2 – 5.5 lbs) using plugs, live bait, and stonecats. Largemouth bass was generally larger from eastern shore tidal rivers (Powell 1967; reported in 1876). In 1950, largemouth bass ranked high among the "gameiest fish in tidewater Maryland" (MBNR 1950). It was later ranked as the most popular target for Maryland anglers in the upper Chesapeake Bay and throughout the eastern shore of Maryland (MBNR 1952). Later in the decade, it was found that White Perch (*Morone americana*) and Yellow Perch (*Perca flavescens*) were more frequently caught and harvested by recreational anglers than largemouth bass (Elser 1960). In southern Maryland, largemouth bass ranked third after perch and catfish, and represented about 19% of the creel (Elser 1960). This is a much larger percentage than observed today because catch-and-release dominates the fishery for bass anglers (MD DNR 1995).

Commercial harvest for largemouth bass is reported from as early as the 1900's when largemouth bass was netted in the upper Chesapeake Bay and sold in the open market (Powell 1967). Largemouth bass constituted a small, but lucrative commercial fishery for Maryland. The commercial value of largemouth bass at the time was approximately $0.10/pound, which was similar to the commercial value of Striped Bass (*Morone saxatilis*). Other commercially harvested species such as herring (Clupeidae) and Atlantic Croaker (*Micropogonias undulatus*) were valued at $0.01/pound. In 1935, the large number of bass taken and commercially sold for their meat from the upper Chesapeake Bay was not overlooked. In 1945, it became unlawful to sell harvested bass within Maryland. In 1946, the Board of Natural Resources presented three new recommendations to the Governor: 1) to shorten the no-take season of tidal bass from April – July to April – June, based on new evidence that bass do not spawn in July; 2) to set a creel limit of 10 fish per day, per angler, which was similar to that for non-tidal waters; and 3) to prohibit the capture of largemouth bass (or Smallmouth Bass) by seines or nets, and effectively eliminate the commercial harvest (COMAR 08.02.05.19). While the season and the creel limits were embraced by the General Assembly, the third recommendation was not. Commercial harvesters for largemouth bass demanded continued access to the resource and denounced relegating the species to solely "game fish" status. However, in 1959, Maryland declared it unlawful to sell live or dead largemouth bass, except for stocking purposes (COMAR 08.02.14).

Commercial anglers sold live bass to the Board of Natural Resources, Department of Game and Inland Fish (a precursor to Maryland Department of Natural Resources, MD DNR) for stocking to ponds and lakes throughout Maryland (MBNR 1951). From 1936-1964, over 300,000 largemouth bass were caught by commercial harvesters and the fish were stocked to public waters, including Deep Creek Lake and Conowingo Lake (Powell 1967). The level of removal was considered sustainable while supporting robust tidewater populations (Elser 1961). Presumably, commercial interests for selling largemouth bass ended when the Department ended their program to buy live fish and stock them in waterways.

With the demise of the commercial fishery and the production of monofilament lines and trolling motors in the 1950's and 1960's, a new type of fishing pressure on bass emerged in the 1970's: competitive angling. The so-called "gameiest" fish in Maryland took center stage as a sport fish in competitive angling. In 1969, Ray Scott organized the Bass Anglers Sportsman Society (B.A.S.S.) and its first competitive bass tournament. Organized tournaments redefined the way anglers viewed the largemouth bass fishery. The focus quickly shifted from the harvest fishery of the early and mid-20th century to catch-and-release in the 1960's and 1970's. Unfortunately, increased fishing pressure during the 1970's and 1980's led to improper handling practices and high levels of mortality resulting from bass tournaments. Recognizing the importance of a productive bass population for future tournaments, directors began re-evaluating their handling practices and tournament organization. Several research studies were published to assist tournament directors and catch-and-release anglers in their efforts. The current model of bass fishing is heavily dominated by an approach to keep bass alive (Gilliland and Schramm 2009).

5.2 *Angler Strategies and Regulations*

Angling activities are regulated by restricting minimum size and creel limits for tidewater populations of largemouth bass. Regulations are found in Code Of Maryland Regulations (COMAR) 08.02.05.19. The creel or catch limit is currently 5 largemouth bass (or smallmouth bass) per day, per angler. A bass that is either harvested or transported anglers must be 12 inches TL (305 mm) from 16 June through the last day of February; and, 15 inches TL (381 mm) from 1 March through 15 June. Historically, the minimum size of 12 inches protected early age classes from commercial and recreational harvest. Current catch-and-release behavior of anglers, however, has changed the justification of the size and creel limits. The size limits generally protect younger age classes from mortality or transplant due to sport fishing tournaments. The higher minimum size during the spawning season protects about 66% of the spawning population from fishing mortality or transplant due to sport fishing tournaments (unpubl. data, JWL).

Fishing has been permitted year-round for tidewater bass in Maryland since the 1950's following an intensive survey that demonstrated largemouth bass was not being heavily harvested (Powell 1967). In 2000, 35 states allowed year-round fishing for largemouth bass (Quinn 2002).

Some northern states such as Michigan and Pennsylvania have closed or restricted fisheries during the spawning season. Removing male largemouth bass from their nests during the spawning season leaves their offspring defenseless against potential predators and can lead to nest abandonment (Siepker et al. 2009). Habitat sanctuaries or areas that are completely closed to all fishing during the spawning season have been used to help protect spawning adults (Suski et al. 2002). Either closed seasons or areas may benefit populations with low productivity and high fishing capture rates (Gwinn and Allen 2010), which do not currently characterize tidewater populations within the Chesapeake Bay watershed (*sensu* Beamesderfer and North 1995). In non-tidal waters of Maryland, there is a catch-and-release spring season that was instituted because of relatively high harvest of older adults and insufficient reproduction to support recruitment (pers. comm. C. Gougeon and D. Cosden, MD DNR). Maryland's spring restrictions were followed by improvements in bass populations in a number of important fisheries; however, the regulations may not have been 100% responsible. During this same period bass anglers were developing a strong catch-and-release ethic which was promoted by well-known outdoor writers, large tournament organizations like B.A.S.S. This change in attitude nearly eliminated harvest among the best and most avid bass anglers. It is often cited by managers and researchers as the largest factor in sustaining quality bass populations across the country.

Largemouth bass populations are currently impacted in different ways by three types of angling strategies: 1) recreational harvest; 2) immediate release; and 3) delayed release. Recreational harvest directly and permanently removes fish from the population. Based on numerous creel census surveys conducted by MD DNR (1995), less than 10% of bass anglers harvest their fish. Many anglers practice immediate release of all size classes of largemouth bass. This type of angling activity does not permanently remove the fish from the population or locally deplete populations. During the spawning season, however, immediate release angling temporarily removes males from their nests and leaves their offspring vulnerable to predators (Siepker et al. 2009). This could affect the sustainability of some populations, but not likely for low-latitude populations that exhibit fast early growth rates and early maturation (Gwinn and Allen 2010). Sub-lethal effects of catch-and-release angling could affect fitness (Cooke and Schramm 2007), but not long-term changes in growth, at least for lake populations (Pope and Wilde 2004; Cline et al. 2012). Sub-lethal effects of catch-and-release angling have not been well-studied for populations in more dynamic, riverine systems. During the catching process, hooking injuries can wound or kill a fish, even 48 hours after release (Muoneke and Childress 1994; Cooke et al. 2003; Wilde and Pope 2008). Slightly more than 50% of the fish that are hooked in the esophagus or gut survive catch-and-release (Wilde and Pope 2008 and references therein). The proportion of esophagus or gut hooked fish could change seasonally and may be greater when water temperatures are warmer (Wilde and Pope 2008).

Delayed release angling of older size fish (≥ 12 or 15 inches, depending on season) has become increasingly common as bass tournaments have become popular. Organized groups of catch-and-delayed release anglers who compete for a prize may constitute a tournament. Public opinion regarding the impacts of sportfishing for largemouth bass continues to be as divisive as it was in the 1990's (Wilde 1998). Catch-and-delayed release angling temporarily removes adults from a local population. In many cases, largemouth bass may not return to its home territory in tidewater systems (Siebold 1991; Richardson-Heft et al. 2000; Ridgway 2002). Therefore, local populations may become depleted by catch-and-delayed release activities. Anglers are not encouraged by MD

DNR to move bass among populations because of the potential to deplete populations, spread viruses (e.g., largemouth bass virus), or spread invasive species that "hitch hike" on boats (e.g., zebra mussel).

5.3 *Population Structure*

A population (or stock; King 1995) was defined as a discrete and semi-isolated group of individuals that has the same gene pool and is self-perpetuating. The extent to which populations constitute management units has not been determined using genetic data; instead, the scale of management has been largely inferred as a gene pool of potentially mixed individuals. Because largemouth bass is non-migratory and generally maintains small home ranges (Pribyl et al. 2005), its populations are disjunct, confined to major rivers, and are not expected to be commonly mix throughout the Chesapeake Bay. The one exception of this may be in the upper Chesapeake Bay where individuals may disperse between Susquehanna River and Northeast River across habitats of relatively shallow, vegetated freshwater (Richardson-Heft 2000).

5.4 *Fishing Mortality*

Total annual mortality is estimated from an instantaneous mortality rate (Z). High levels of Z can lead to genetic bottlenecks, marked declines in population size, and changes in size structure of a population. Mortality may vary seasonally and may be higher during the spawning season for adults (Waters et al. 2005). In their review of Florida water bodies, Allen et al. (2002) reported Z ranged from 0.37 (31% annual mortality) to 1.88 (85% annual mortality). For systems throughout North America, estimates range from 0.27 (24% annual mortality) to 2.41 (91% annual mortality)(Allen et al. 2008). The Z includes the additive effects of natural mortality (M) and fishing mortality (F). Natural mortality can approach 0.33 (28% annual mortality)(Allen et al. 2002). Natural mortality is influenced by juvenile survivorship, longevity, and carrying capacities (Post et al. 1998).

Fishing mortality can be directly estimated or indirectly estimated from models when M is known or assumed. For largemouth bass, F can be further divided into harvest, catch-and-release mortality, and tournament mortality. Few bass anglers harvest their fish (MD DNR 1995), though harvest is not well-known for many smaller fisheries in Maryland. In some cases, harvest rates or exploitation rates can be quite high ($\mu = 0.73$), depending on the fishery (Allen et al. 2008). The probability of mortality following immediate release of a caught fish depends on handling stress and hooking injury (Muoneke and Childress 1994; Pope and Wilde 2004). For example, fish that are hooked in the esophagus or gut have been observed as having a 50-50 chance of survival, with a much greater percentage of survivorship (98.3%) for fish hooked in the mouth (Wilde and Pope 2008). In a study conducted with the Youth Chapter of the Maryland Bass Nation (MBN; June – July 2011), MD DNR found that 14% of fish caught from hatchery ponds were gut-hooked when using primarily soft plastic worms. Assuming this level of gut-hooking, and using parameters of Wilde and Pope (2008), then the probability of survival following normal catch-and-release angling was calculated to be 90% (JWL, unpubl. data).

Tournament mortality can be described as mortality of bass that are contained in live wells, displaced, weighed on land and then released at a single site. For three tournaments in Texas, Wilde et al. (2002) found that mortality following live well containment and displacement ranged from 0.3 – 5.8%. Once fish were weighed and released, the percentage of bass that then died ranged between 0 and 61.6%. This type of delayed mortality may also be influenced by the handling of fish during a tournament's weigh-in. Some conditions, such as poor live-well maintenance, exceptionally warm temperatures, or parking-lot weigh-ins may impose additional stress and exacerbate delayed mortality. In a study conducted in partnership among MD DNR, the Paralyzed Veterans of America, and MBN (July 2011), total tournament mortality was estimated at 22% (assuming a 40% loss to emigration; Siebold 1991).

5.5 *Population Rebuilding*

To offset losses due to fishing or natural mortality or to augment ecosystems with low recruitment due to lack of spawning habitat, MD DNR hatcheries have stocked more than 4 million largemouth bass to tidewater areas of the Chesapeake Bay from 1980 to 2010 (Table 5.5.1). The upper Chesapeake Bay and the Patuxent River have received the most fish, each receiving over 1 million fish. An estimate provided by B. Richardson (Hatchery Manager), and later adjusted for potential number of fingerlings produced, indicated that the 2012 cost per fingerling (~50 mm TL) is $0.87. The cost per *advanced* fingerling (or 102 mm – 152 mm TL) is $1.14. The private hatchery cost per fish of an advanced fingerling ranged from $1.00 - $3.50.

The production of largemouth bass in hatcheries is not consistent and can depend on weather or other conditions. For example, in 2010 five hatchery ponds at the Cedarville Hatchery were stocked with adult largemouth bass, but no offspring were collected. The abundance of clams and filamentous algae (waternet) in these ponds prevented adequate survival of offspring. Of four hatchery ponds that did produce offspring, two suffered from an estimated loss of 91% larvae because of the abundance of clams. Based on estimated fecundities of females and egg survivorship levels (*see* Species Life History), approximately 132,319 fingerlings were not produced because of the abundance of clams and waternet. The other two ponds produced 70,000 fingerlings (i.e., 2 inches or 55 mm) and had much lower larval mortality (30% and 73%). This level of variability among ponds is not uncommon (pers. comm., MD DNR D. Pritchett, Production Manager). Once fingerlings are removed from the ponds, they are placed in in-house tanks to train them to feed on pellets. Because of stress and crowding, the fish may then suffer from disease, particularly a bacterial infection caused by *Flexibacter columnaris*. In 2010, approximately 50% of the fingerlings died because of this bacterial infection.

In a preliminary effort to characterize habitat contribution to the population, fingerlings were tagged with a coded wire tag (CWT) and released in reservoirs and rivers. Recaptured fish were measured to assess growth rates. Survivorship models were also constructed using recapture information. Recapture rates differ across rivers. There was a greater difficulty in recapturing tagged juveniles in the Choptank River and Chester River than in the Patuxent River. While a modest number of stocked bass (87) was needed to get 1 CWT recapture in the Patuxent River, greater numbers (2,483 and 24,434, respectively) were needed to obtain 1 tagged fish from the Chester River and Choptank River, respectively.

Growth and survivorship rates of hatchery-released fish are similar to those observed for wild caught fish, as reported by Jackson et al. (2002). Hatchery-reared fish grew at a rate of ~0.18

mm/day in a reservoir in North Carolina (Jackson et al. 2002). That estimate of growth rate is lower than that measured in the Patuxent River, where hatchery fish grew approximately 0.85 mm/day. Hatchery fish also did not have higher levels of mortality than wild populations. Mortality levels were 0.47 (37% annual mortality) for Patuxent River and 0.29 (25% annual mortality) for Chester River.

Hatchery-released fish recruit to older age classes. Of 256 CWT recaptures in tidewater areas of the Bay, 31.6% were fish age 2+ or older, which demonstrates recruitment to the adult spawning stock. Continued stocking of fingerlings greater than 55 mm TL (or 2 inches) appears equally successful among young-of-year size classes (Diana and Wahl 2009), but the success of stocking fish less than 55 mm is not well-known. Buckmeier and Betsill (2002) and Buckmeier et al. (2005) stocked young fish (< 54 mm TL) and found poor contribution to the natural populations; they concluded that determining the best time (low predator to prey ratios) to stock is incredibly important for using stocking as a management tool. Similarly, Powell (1967) chronicled the stocking success of Smallmouth Bass fry in tidewater:

> "We began the season (in 1928) with 120 smallmouth brood that produced 70,000 advanced fry...Our observations over the period of years in the stocking of largemouth bass advanced fry had convinced us that the stocking of this size fish was nearly useless. On many occasions we had observed minnows and sunfish, in particular, devouring the stocked fish and in one instance the entire lot was consumed in the matter of an hour."

Despite the similarities in growth and survivorship of hatchery-reared and wild-caught juveniles, the success of rebuilding largemouth bass populations from hatcheries in Maryland has not been unequivocally demonstrated for tidewater areas. Stocking of over 200,000 fingerlings to the upper Chesapeake Bay may have helped to rebuild the fishery in the 1980's, but it is not possible to distinguish the effects of stocking from the effects of synchronous resurging grasses (MD DNR 1990). Poor environmental conditions of some tidewater areas have contributed to poor success in rebuilding populations using hatchery fish. A single sampling event conducted in May 2011 indicated that the density of food for young largemouth bass, zooplankton (e.g., *Daphnia*) differed greatly among Watts Creek (Choptank River; 6.74/sample), the upper Wicomico River (1602/sample), and Chicamuxen Creek (Potomac River; 321/sample). When habitat conditions are not suitable, then stocking young juveniles may do little to rebuild a fishery. Multiple, but simultaneous, approaches that include improving habitat conditions, releasing older, advanced fingerling (100 – 200 mm) hatchery-reared fish, and limiting harvest or transplant during sportfishing tournaments may be necessary for successfully mitigating significant declines of largemouth bass populations in some tidewater areas.

6.0 ECONOMIC CHARACTERISTICS OF THE FISHERY

6.1 *Commercial Harvesting*

There is no commercial harvest of largemouth bass in Maryland. Furthermore, largemouth bass meat cannot be sold, offered to be sold or purchased, exposed for sale, or purchased within

Maryland (COMAR 08.02.05.19). Additionally, live specimens cannot be sold for pond aquaculture within Maryland unless approved by Maryland DNR.

6.2 *Recreational Fishing*

Maryland ranks 46th among 48 states in the number of participants who take part in recreational angling (freshwater and saltwater)(unpubl. analysis, JWL; ASA 2011). This ranking is independent of population size in the State, as reported in 2010:

http://www.census.gov/2010census/data/apportionment-dens-text.php.

The census records of 2010 indicate Maryland (2633 mi^2 of all water) had 5.8 million people, similar to the population of Wisconsin (11,188 mi^2 of water) and Missouri (818 mi^2 of water)(Water area data from Population, Housing Units, Area, and Density: 2010 - United States -- States; and Puerto Rico at:

http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml.

However, Wisconsin and Missouri had 1.2 million and 1.1 million anglers, respectively (ASA 2011). Maryland, in contrast, had slightly less than 0.5 million anglers. Much of the Chesapeake Bay watershed is only accessible by boat, which may limit angling activity. While not as popular in Maryland as elsewhere, recreational fishing remains important activity for many of its citizens and visitors. The popularity is likely owed to the diversity of angling opportunities of the State.

In 2006, there were 645,000 anglers (age 16 or older) who fished a total of 8.2 million days in Maryland (USFWS 2008). Of these, 242,000 were non-residents. These statistics were much different than those reported in 2011 when only 426,065 anglers fished a total of 4.7 million days (ASA 2013). Beginning near 2008, a great recession led to economic uncertainty in the United States, possibly contributing to the marked decline in angling activity in Maryland. Interestingly, the number of days spent on the water by freshwater anglers was similar (approximately 3.0 million days) for both years.

Among freshwater fishes in non-tidal habitats, bass constitutes the most important fishery in Maryland. Approximately half (44% in 2008 and 53% in 2011) of Maryland, freshwater anglers fished for bass. Non-tidal, freshwater anglers (residents and non-residents) fished at least 2-times as many days for bass than for trout or other species (USFWS 2008, 2013). Because of more days fished on the water and the popularity of the bass fishery among resident and non-resident anglers, expenditures are expected to be a significant contribution to county and statewide revenue.

6.3 *Competitive Sports Tournaments*

Direct and indirect economic revenue can be generated from competitive sports tournaments. The number of recorded tournaments has varied from 110 – 161 on Potomac River and in the upper Chesapeake Bay (2002 – 2012; MD DNR 2012). Thousands of anglers participate in tournaments each year and many are Maryland residents. Residents purchase fishing licenses that directly support management of the fishery. Non-residents, particularly those who do not live in bordering states, spend additional money on lodging, meals, and transportation and increase state tax revenue when bass fishing (Chen et al. 2003).

6.4 *Economic Revenue*

Anglers spent $600 million and $550 million in Maryland on fishing in 2006 (USFWS 2008) and 2011, respectively (USFWS 2013). In 2011, freshwater anglers spent $407 million, which was 74% of all retail money spent on angling in Maryland (ASA 2013). Because bass is by far the top targeted species in non-tidal, freshwater habitats, a large proportion of total expenditures by anglers is expected to be spent on bass fishing. Chen et al. (2003) determined that for Lake Fork (Texas), the total spent by bass anglers in a single year (1994-1995) was $27.5 million (or $38.9 million in 2010), with most of that entering into the revenue for the county or city rather than the state. The fishery for bass in Lake Meade (Texas) reportedly contributed $69 million (Martin et al. 1982), increasing to $154 million after adjusting for inflation to 2010. Thus, a popular bass fishery on a single water body may contribute hundreds of millions of dollars to the local economy each year. Unfortunately, the number of anglers who target largemouth bass in tidewater habitats is not known. In Maryland, the Potomac River and the upper Chesapeake Bay are considered to have national popularity with bass anglers.

In 2010, the Forrest L. Woods American Fishing Series estimated that a single, 4-day tournament of approximately 350 anglers provided over $700,000 directly into the local economy of Charles County (pers. comm., D. Simmons, FLW Outdoors). During 1999, it was estimated that tournament fishing for largemouth bass generated $7.0 million in Charles County (unpubl. data, J. Roland, Charles County Office of Tourism). While the level of economic input from competitive angling tournaments is not annually assessed for Maryland, revenue generated from the tournaments appears to be significant. Club tournaments in Texas contributed 1/6th of the annual revenue of the largemouth bass fishery at Lake Meade (Martin et al. 1982).

Non-resident anglers typically spend more than resident anglers (Hunt and Ditton 1996; Chen et al. 2003). In 2006, the number of non-resident anglers fishing in Maryland for bass was higher than that for other fisheries. Non-resident anglers spent more time fishing for bass than any other species – 1,350,000 days. In contrast, only 88,000 days were spent by non-resident freshwater anglers, and 756,000 days were spent by non-resident saltwater anglers in targeting other species. Thus, non-residents constituted a significant portion of the bass fishery, relative to other fisheries. Chen et al. (2003) found that non-residents spent ten-times more than locals on fishing. In Maryland, the average spent by non-resident anglers ($1,329/yr) was only slightly higher than the average spent by in-state anglers ($1,062/yr) in 2006. With more non-resident anglers dedicated to fishing bass than any other species, it is expected that significant economic revenue is generated from non-resident anglers who participate in the bass fishery.

Economic input-output models utilizing creel survey information are required to provide better economic revenue estimates that are specific for bass. The information required for these surveys usually include zip code, money spent for various commodities, and time spent fishing. There are three types of economic input that describe spending in a local economy: direct, indirect, and induced (Bergstrum et al. 1990). Direct support of the economy would result from anglers purchasing supplies and gasoline directly from local vendors. While some anglers have been observed harvesting largemouth bass from docks and piers (pers. obs., JWL), most of the fishery is characterized by boaters. These boaters include recreational anglers, guides, and tournament anglers. These boats may be purchased from Maryland suppliers. When launched, anglers pay launch fees and entrance dues to state parks. Anglers may participate in the fishery once a week or more and pay for travel costs associated with drives and boat rides to fishing locations. Indirect support of the economy is generated by vendors replenishing their supplies with imports from other commercial dealers. For example, a company that sells bass boats would replenish its supplies from the distributors of such boats. As purchases are being made, local vendors and their distributors may need to increase their workforce and possibly pay their employees greater salaries. This type of induced support of the economy can be widespread and contribute nationally to unemployment levels and wage averages.

7.0 INDICES AND REFERENCE POINTS

7.1 *Fishery Independent Data*

Indices describing and reflecting population status will be determined from a tidewater bass survey conducted each year during fall for fisheries targeted by biologists and supported by anglers or angling activities. The Standard Operating Procedure for the Tidal Bass Program describes a sampling methodology for the Tidal Bass Survey. Some methodological information is also described in Markham et al. (2002) and Love (2011). Indices produced from the survey will be compared with reference points (see below) to assess the status of largemouth bass fisheries for each river. Management actions will be taken as needed to address problems when indices differ relative to their reference points. Currently, there are no specified combinations of indices for implementing management actions. Management actions will need to be determined on a system by system basis using the best expert advice to improve a fishery. Because the goal of management includes satisfying angler needs, relationships between the fishery independent data, angler catch, and angler satisfaction should be developed.

Indices and reference points will be developed for selected tidewater populations within the Chesapeake Bay watershed. The criteria for selecting a population include its importance or use as a fishery and the availability of access points (e.g., boat launch areas) to the fishery. Importance as a fishery may be determined by examining Angler's Log reports posted on the MD DNR Fisheries website or through the MD DNR Volunteer Angler Survey. Access points may be determined from maps, such as the MD DNR Fishing Access Map. Currently, the following populations are selected: 1) Potomac River; 2) upper Chesapeake Bay system; 3) Choptank River; 4) Wicomico River; 5) Patuxent River; 7) Marshyhope Creek; 8) Pocomoke River; and 9) Gunpowder River. Rankings will be re-evaluated periodically.

Typically the Tidal Bass Survey samples largemouth bass individuals that range in age from 0 – 13 and lengths from 53 mm TL (2 in) to 559 mm TL (22 in)(Fig. 7.1.1). The majority of fish caught during the survey include juveniles (≤ 200 mm TL or 7.9 in) and adults that are greater than 280 mm (11 in). Fish in the size range from 200 – 280 mm TL are not represented relative to true abundance by sampling.

7.2 Fishery Independent Indices

Fishery independent indices are calculated from data collected during the Tidal Bass Survey. While surveys have been conducted since 1975, these early surveys were not consistent among rivers. Of these earlier surveys, the Potomac River received the greatest level of effort. Between 1975 and 1999, there is size data for 17,489 individuals from the Potomac River. Because of dissimilar sampling methodology prior to 1999, those data are not included in generating the following indices. The indices are related to: 1) catch; 2) body growth; 3) relative weight (Henson 1991) and condition (Cone 1989); 4) size structure in the population (Guy et al. 2006); 5) mortality; 6) reproduction; and 7) habitat suitability (Love 2011).

Catch/effort (arithmetic mean and Delta-mean)

The most common index used in fishery surveys is catch. Two indices of catch will be used. The catch estimates are standardized by effort to yield a catch per unit effort (CPUE).

The most common and effective method of collecting largemouth bass is electrofishing from boats. The number of fish caught is divided by the number of hours spent electrofishing (Bonar et al. 2009). The effort expended to estimate catch differs widely between different fish species, body shapes, and individual fish size.

The arithmetic mean CPUE is generated for the Tidal Bass Survey in Maryland from a stratified, randomized, site selection design (Markham et al. 2002) that is cost-effective and robust. The proposed number of surveyed sites ranges from 25 to 45, depending on the number of potentially surveyed sites and size of the tidewater area selected. Power analyses of data collected from 1999, 2008, and 2009 indicate that the minimum number of sites that should be surveyed in a reasonably powerful design (alpha = 0.05; Power = 0.80) ranges from 3 to 48 for most rivers. For most systems, a minimum number of 25 sites is recommended to provide precise catch estimates and provide enough largemouth bass to yield good information on age structure and size distribution. Since the beginning of the stratified survey, all areas have been surveyed at this level of effort.

A corrected-CPUE (Cor-CPUE) model may also be used to standardize the arithmetic mean CPUE for environmental factors. The Cor-CPUE model is similar to the Delta-Gamma model that produces catch estimates that are corrected for some sampling conditions that covary with catch (Stefánsson 1996; Campana et al. 2006). Environmental factors that affect catchability of largemouth bass include water clarity (measured with a Secchi disk), specific water conductivity or conductivity, and water temperature. These factors may also affect fish distribution. For this index, predicted catch for each site in each river and year is determined after standardizing actual catch for environmental factors and time spent fishing. The predicted catch is then multiplied by the probability of catch (corrected for environmental factors). The index Cor-CPUE is created by averaging these products across sites for a river and year. The index *cannot* be interpreted as number of fish caught per unit time. It is, however, a river-wide index that can be used to monitor mean CPUE trends that are relatively independent of factors that affect catchability and distribution of the species.

The CPUE and Cor-CPUE estimates have been relatively similar since the early 2000's for the Potomac River, upper Chesapeake Bay, and Patuxent River. This is consistent with reports for centrarchids dominated by density-dependent population regulation (Cooke and Phillipp 2009). The largemouth bass populations of some eastern shore tidal rivers have dramatically changed over the past 10 years. The CPUE of largemouth bass is much lower now than ten years ago in the Chester River and Choptank River. In the Choptank River, widespread anecdotal evidence indicates that larger populations existed during the mid-1990's, but not prior to that decade. However, the Cor-CPUE model estimates for the Choptank River indicate little change in relative abundance since 1999 (MD DNR 2011).

Body Growth Rates (GR-EXP and GR-VBGF)

Growth rate (GR) will be computed from the growth constant (k), a common parameter derived from fitting a von Bertalanffy growth function (VBGF) to length-at-age data. Ages are annually determined using a length-at-age key developed from 347 fish aged using otoliths (Buckmeier and Howels 2003; Isermann and Knight 2005). Variation in this parameter can reflect changes in GR of individuals as they age. Because changes in length-at-age diminish after age 3 in the current datasets, GR (i.e., difference in length between ages) will be computed and averaged between successive ages for ages 1 – 3. Growth is seasonal and periodic and the von Bertalanffy model was modified accordingly following Cloern and Nichols (1978). The k is biased by the quality of data used to fit the growth model (Gwinn et al. 2010). This bias depends on the vulnerability of largemouth bass to sampling gear. For largemouth bass, anecdotal evidence indicates that size classes older than 2 are equally vulnerable to the sampling gear used during tidewater bass surveys. These anecdotes are supported by catch data from competitive sportfishing anglers, but should be verified by a tag-recapture study. While sportfishing anglers weigh-in slightly larger fish than those observed during the Tidal Bass Survey, the difference is negligible. Thus, assuming an asymptotic vulnerability curve, the deletion of small fish (< age 2) and fixing $t_0 = 0$ will produce a growth constant that is precise and accurate (Gwinn et al. 2010).

Growth rate will also be computed from an exponential rise (EXP) model fit to length-at-age data. The form of the model is $y = x\text{-intercept} + a*(1-B^x)$, where x = age, y = length, and a and B are fitted parameters. Because changes in length-at-age greatly diminish after age 3, growth rates (i.e., difference in length between ages) will be computed and averaged between successive ages for ages 1 – 3.

Relative weight (W_r), Relative condition (K_n), and L-W slope

Body condition is an important metric that measures the fattiness of a fish. It can be predictive of survivorship, particularly for juveniles entering their first winter. Body condition has been measured using lipid (fat) analysis, which is expensive and time consuming. Alternative methods that calculate the ratio of weight to length for an individual fish are more widely used. During the spawning season, body condition will differ between sexes and age classes due to the production of gonads that constitute a significant portion of weight. Here, the body condition indices are calculated for post-spawn individuals.

Two indices of body condition are traditionally computed from length (L) at weight (W) models: relative weight (W_r) and relative condition (K_n). While debate surrounds which of these is best to use, relative weight is usually the most widely accepted method (Bonar et al. 2009). Relative weight is the weight of a fish (W_i) relative to its expected weight (W) based on a length-weight model ($\log_{10} W = a + b*\log_{10} x$) for the entire distribution of the species (generally, North America for largemouth bass). The parameters used to estimate weight for a known length of fish are: a = -5.316 and b = 3.191 for fish greater than 150 mm (Wege and Anderson 1978). Average relative weight and reference points are only computed for fish greater than 150 mm.

As stressed by Cone (1989), relative weight assumes isometric growth that is not necessarily appropriate for widely distributed species. Therefore, a second index that is directly related to the parameters of the length-weight relationship may be more accurate (Cone 1989). This latter index is the ratio of an individual's ($\geq$ 150 mm) observed weight to an expected weight predicted from the river L-W regression parameters; it is termed relative condition (K_n). As data are acquired each year, the parameters of the length-weight relationship for the river likewise change each year. Relative condition is therefore computed each year for all years of the survey. The K_n is averaged among individuals from the targeted population.

The estimated slope of the L-W relationship will also serve as a third index that directly reflects the relationship between length and weight. It is not computed from the L-W relationship, but is a property of the model depicting the relationship. The L-W slope reflects the gain in weight per unit of length within a population.

Size structure (PSD_{305} and PSD_{381})

Proportional size distribution (PSD) indices reflect the relative proportion of size classes within a sample (Guy et al. 2006; Guy et al. 2007). Hence, it is a convenient measure of size structure, which can change annually due to natural or fishing mortality of older age classes. The PSD values for Chesapeake Bay watershed may be lower than that for southern populations. Relative to southern populations, there may be fewer larger individuals at age in tidewater of the Chesapeake Bay because of a shorter growing season. The longer growing season associated with southern waterways yields larger individuals at age (Beamesderfer and North 1995).

There is high spatiotemporal variation in juvenile production. Thus, the PSD's calculated for the tidewater areas of the Chesapeake Bay do not include individuals less than or equal to 200 mm TL. The indices are traditionally calculated as proportions of the sample that are greater than stock size, which is 200 mm TL for largemouth bass (Bonar et al. 2009). The proportions represented by size classes of PSD_{305} ($\geq$ 305 mm TL or 12 inch) and PSD_{381} ($\geq$ 381 mm or 15 inch) are of interest because of their utility in the fish management objectives and in the fishery. These size classes are well-sampled by current Tidal Bass Survey methods and represent the reproducing and harvestable adults in the population.

Total Mortality (Z)

Mortality is commonly measured as an instantaneous total mortality rate (Z). The proportion of fish that survive annually (S)(a finite rate) can be calculated as $S = e^{-Z}$. Survivorship may be a more intuitive value than instantaneous mortality, but is not usually directly estimated. Total mortality rates are estimated with catch-curve analysis through the decline in relative numbers of individuals across age groups within a simple. The catch-curve analysis is a linear model of counts (transformed by natural log) within each age cohort as abundance changes across ages. Estimates of Z may be biased by size-specific catchability, the robustness of the age-at-length key, and the assumption of constant recruitment. Size-specific bias in catch resulting from sampling gear bias can be standardized using standardized sampling methods. The length-at-age key is developed using a robust dataset, aging methods well-established in the literature (Buckmeier and Howells 2003), and validated statistical methods (Isermann and Knight 2005). It is unlikely that recruitment is stable among years. Thus, for catch-curve analyses, ages 0 and 1 are excluded because those cohorts are expected to the most influenced by reproductive effort. Ages 8 and older were also excluded to improve colinearity. For each catch-curve analysis, a goodness of fit test is used to assess the fit of data to a linear model. When goodness of fit is indicated ($r^2 > 0.5$ and $p < 0.05$), then Z is utilized.

The Z for tidewater populations of largemouth bass in the Chesapeake Bay is generally lower than those reported for other nationwide fisheries (Allen et al. 2002). Instantaneous mortality is comprised of natural mortality (M) and fishing mortality (F) and $Z = F + M$.

Reproduction (JUV_{CPUE}, JUV_{PSD}, $JUV_{\%OCC}$)

For each targeted river, the geometric mean of juvenile (≤ 200 mm TL) CPUE (#/hr) is calculated (JUV_{CPUE}). The geometric mean of abundance for juveniles generally predicts the proportion of age 2 fish, indicating that it is a reasonable index for assessing recruitment (Fig. 7.2.1). To calculate the geometric mean, data were excluded for sites when juveniles were not collected. The standard error of the geometric mean was computed by transforming the data using a $\log_{10}$ transformation, computing the arithmetic standard error, and then applying a power transformation to the standard error (base 10). Variation in this estimate may represent the variation in production of juveniles during the spawning season or juvenile survivorship during summer. Patterns of juvenile CPUE have been variable among years. In a meta-analysis of published and unpublished studies, Allen and Pine (2000) also noted high levels of variability in the number of juvenile largemouth bass, ranging widely from 11 – 189%.

The proportion of the sample represented by juveniles was calculated when survey data were available (JUV_{PSD}). The proportion of the sample represented by juveniles peaked at 40% to 60% for the Potomac River in the late 1980's and around 2000 and 2006. The JUV_{PSD} in the upper Chesapeake Bay has been relatively high (~50%) and stable since 2000, with the exception of a steep decline in 2007. The PSD_{JUV} for largemouth bass populations in rivers of the eastern shore of Maryland has not changed appreciably and is around 20%.

The percent occurrence ($JUV_{\%OCC}$) was calculated as the number of sites where juveniles were collected, divided by the total number of sites surveyed, and multiplied by 100. Variation in this estimate may be due to the variation in distribution of juvenile bass over time. The percentage of high quality sites occupied by juveniles has usually been greater than 50% and has been fairly stable in the Potomac River and upper Chesapeake Bay. In the eastern shore tidal rivers, the percentage of high quality sites occupied by juveniles has varied from 0 – 100%, possibly owed to high inter-annual variation in spawning stock size, the distribution or amount of available spawning habitat, and the amount of hatchery contribution.

Habitat Suitability Index (HSI)

In some cases, the proportion of suitable habitat for largemouth bass may contribute to population declines and hence the quality of a fishery. In an attempt to monitor trends in the quality of habitat, a habitat suitability index (HSI) for largemouth bass has been adapted from Stuber et al. (1982). The HSI is a tool that can be used to identify and protect essential habitat, enhance stocking success, and evaluate species responses to changes in habitat suitability. Habitat suitability index models were originally conceptualized by the U.S. Fish and Wildlife Service (1981) and have been developed for sport fishes (Struber et al. 1982; Raleigh et al. 1986) and wildlife (Allen 1983; Roloff and Kernohan 1999). While considered valuable management tools (Brooks 1997), most HSI models have been considered problematic because of unconvincing empirical evidence and spatial biases associated with model development (Roloff and Kernohan 1999). In addition, they are not well-validated and should be adapted for populations based on local habitat conditions (Wesche et al. 1987).

The data used to create an HSI for tidewater populations of largemouth bass in the Chesapeake Bay included data that were available for several years and locations via the Chesapeake Bay Program, Virginia Institute of Marine Science (VIMS), and U.S. Geological Survey (Love 2011). The variables included: water temperature (°C) during the growing season (V_1 = average from June – September); dissolved oxygen (DO; mg/L) during the growing season (V_2= average from June – September); pH during the growing season (V_3 = average from June – September); maximum, monthly salinity (ppt) for the year (V_4); average percent of all potentially sampled sites located within 25 m of SAV (V_5) determined using data from VIMS (1999 – 2007); water clarity by Secchi depth (m) averaged across months within a year (V_6); and stream discharge (ft/sec^3) during the spawning season (March – June)(V_7).

The HSI usefully describes changes in habitat quality, particularly as it relates to SAV and water clarity that vary greatly among rivers and tributaries within a river. The HSI was positively correlated with CPUE across rivers and within a river (Fig. 7.2.3). Other variables, such as the occurrence of shoreline structure and distance of shoreline to deep water could also explain variation in the suitability of shoreline habitat for largemouth bass. More variables can be included in the HSI. Unfortunately, the HSI is not appropriate for characterizing habitats at smaller scales than tributaries, or for nesting habits.

7.3 Fishery Independent Reference Points

Current status of tidewater largemouth bass populations will be determined by comparing the aforementioned indices to reference points. Reference points will be determined from at least a 10-year reference period, when possible (Table 7.3.1). A 10-year period includes environmental stochastic variation inherent to tidewater of interest. In some tidewater, the Tidal Bass Survey continues to generate baseline information on tidewater largemouth bass populations.

River-specific reference points are the 25th and 75th percentiles of the reference dataset for the riverine population. Periodically, the 25th and 75th percentiles of the reference dataset will be compared with newly generated percentiles for the entire data set. The original percentiles and newly generated percentiles will be compared statistically. When percentiles significantly differ, the reference dataset will be re-computed from all available data. When possible, indices may be compared with general reference point-estimates that are obtained from the literature (see below).

Catch/effort (arithmetic mean and delta-mean)

River-specific reference points will be generated for CPUE and delta-mean models. Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). Values below the 25th percentile reflect catch estimates that are lower than the normal or average values. Anecdotal evidence may be also used as reference information. For example, in 1994 over a hundred fish and high levels of reproduction were recorded in the Choptank River (MD DNR 1995). During this work, six sites (including two from Tuckahoe River) were surveyed intensively to generate a CPUE estimate (9.67 fish/hr) that is similar to current estimates from good quality habitats. No other reference point-estimates are available as references for CPUE.

Body Growth Rates (GR-EXP and GR-VBGF)

River-specific reference points will be generated for computed growth rates from exponential rise (EXP) and von Bertalanffy Growth Function (VBGF) models. Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). Additional reference points of growth rates were provided by Elser (1962). In a 10 year study (1949-1959), largemouth bass was collected from statewide ponds and lakes (mountain, piedmont, and coastal plain); average length at age data yielded a growth curve and a general reference point-estimate of 68.44 mm ± 6.82 SE per year for ages 1 – 6.

Relative weight (W_r), Relative condition (K_n), and L-W slope

River-specific reference points will be generated for W_r, K_n and L-W slope. Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). Estimates below the 25th percentile will reflect years with fish that had below average body condition. A value of 1.0 is often used as a general reference point-estimate for W_r. When $W_r = 1.0$, robustness of the fish is exactly as predicted from national surveys of length-weight relationships (Wege and Anderson 1978; Henson 1991). A general reference point-estimate of 3.0 was used for the L-W slope (Calder 1996).

Mortality (Z)

River-specific reference points will be generated for the instantaneous mortality rate (Z). Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). The 75th percentile is a useful reference point because absolute values of Z that are greater than the percentile reflect above average instantaneous mortality rates. Notably, Z can heavily depend upon the data set and collection method, and can range widely. For example, Z for data collected from various rivers of the southeastern United States (Ridgway 2002; Allen et al. 2002) has 25th and 75th percentiles that are 0.57 (S = 0.56) and 1.05 (S = 0.35), respectively. A Z of 0.57 (or S = 0.56) will be used as a general reference point.

Size structure (PSD_{305} and PSD_{381})

River-specific reference points will be generated for PSD_{305} and PSD_{381}. Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). Bonar et al. (2009) provide general reference point-estimates for populations inhabiting a similar ecoregion; however, they are derived for populations from large, standing bodies of water. Published standards for large, tidewater habitats are not available. The expected PSD_{305} is 0.572. The expected PSD_{381} is 0.245.

Reproduction (JUV_{CPUE}, $JUV_{\%OCC}$, JUV_{PSD})

River-specific reference points will be generated for the juvenile indices. Reference points are the 25th and 75th percentiles of available time series (Table 7.3.1). There are no general reference point-estimates for these indices.

Habitat Suitability Index

Reference points for HSI were established by computing 25th and 75th percentiles of the available series of data across tidewater areas. There is no general reference point-estimate for this index. In order to do so, a suitable reference habitat must be identified.

7.4 Fishery Dependent Data

Beginning in 2005, directors of competitive fishing tournaments for largemouth bass were asked to file a tournament activity report. These activity reports provide data regarding the size (# anglers/boats/duration) of the tournament and the catch. Each year, some largemouth bass that die following tournament activities are retained by MD DNR biologists. These fish are used to generate life history information (age, size, diet, LMBV infection load) for fish within the Potomac River and upper Chesapeake Bay. There are data for 359 tournament-induced mortalities that ranged in size from 213 – 575 mm TL (2006-2010). The sex ratio for sampled fish was 1:1 (n=215, 112 females and 103 males). These data help provide a baseline reference of life history and length-at-age for largemouth bass in tidewater.

Estimates of catch per angler-hour and survivorship are obtained from fishery dependent data (see below). Beginning in 2010, directors have also been asked to register their tournaments with the MD DNR. The data provided via registration forms include contact information, number of participants, and the cost of registration.

7.5 Fishery Dependent Indices

Catch per-angler-hour (CPAH)

The catch per-angler-hour (CPAH) will be computed each year for the spawning and non-spawning seasons (June 16 – March 14). The catch rate will be calculated by dividing total catch during a tournament by the product of angler number and hours fished. The CPAH will be computed for a subset of organizations that have a creel limit of 5 fish/angler. The CPAH will be compared across years for targeted rivers.

Fishing Mortality

The index of initial mortality (IM) will be computed by dividing the number of dead fish reported during the weigh-in and until release by the total number of fish caught on the day of fishing. Other aspects of fishing mortality such as delayed mortality (DM) and harvest (H) are not routinely measured and will not be considered indices. However, directed studies and creel surveys have been performed to measure them.

7.6 *Fishery Dependent Reference Points*

Catch per-angler-hour (CPAH)

Specific references can be generated for the Potomac River and upper Chesapeake Bay. Reference points are the 25th and 75th percentiles of available time series obtained during the spawning, 15 inch season (1 March – 15 June) and the remaining, non-spawning season. Only CPAH generated for tournaments (TX) that have a 5 creel limit are used for this analysis. Because CPAH can be biased by the amount of data, level of experience of participating anglers, and conditions of the fishing day, the CPAH estimates should not solely be used to elicit management actions. Instead, they should be used to determine if there is a positive correlation between CPAH and fishery-independent, CPUE indices.

Fishing Mortality

Reference points for IM are the 25th and 75th percentiles calculated for the dataset for small (SM) and large (LG, ≥ 50 boats) tournaments. A general reference point-estimate for IM can be calculated from: $0.00194 \times T^{2.4569}$ ($r^2 = 0.28$, $p < 0.0001$)(Wilde 1998). As modeled, the IM increases with water temperature, possibly as a response to seasonal differences in hooking injuries (Wilde and Pope 2008). While predicted daily IM reference will differ because of water temperature conditions, the general reference point-estimate for IM will be calculated from the average water temperature of the active tournament season (April – November).

7.7 *Relating Reference Points to the Quantity of Legal Bass*

For some indices and reference points, a population model was developed to examine whether indices would reflect changes in the population of largemouth bass. The indices that were evaluated included instantaneous mortality (Z), growth rates (GR), and juvenile survivorship (reflected by juvenile indices). Instantaneous mortality affects the absolute abundance of the species, which influences CPAH of anglers and availability of older age classes (e.g., PSD_{381}). Growth rates affect the proportion of fish available to the fishery, and therefore to anglers. Finally, juvenile survivorship influences relative abundance, recruitment, and ultimately CPAH. The remaining indices and reference points, such as IM, W_r, and K_n are also important; however, their relationships to the percentage of fishable largemouth bass were not known.

When fishing mortality was fixed at 0, natural mortality yielded an expected 56.1% of 15 inch or larger largemouth bass (PSD_{381}) in the population. As fishing mortality increased to current levels, this percentage declined to 30 – 40%, which are levels currently observed. As fishing mortality (i.e., IM + DM + H) increased above the 75th percentile (i.e., above average mortality), then the PSD_{381} decreased below 20%. Thus, maintaining levels of mortality below the 75th percentile would protect size structure in the population.

Juvenile survivorship can be highly variable and depend on foraging and depredation during summer, as well as winter water temperatures, during the first year of life. The population model indicated that juvenile survivorship directly and positively influenced the percentage of legal, fishable largemouth bass. The level of survivorship from hatching to the first year of life for largemouth bass in Maryland is not definitively known. The relationships among juvenile indices, reference points, and the survivorship of young-of-year warrants further studies.

In all of the above cases, the PSD was considered a surrogate for angler satisfaction whereby it was assumed that angler satisfaction would improve as availability of 12 inch or greater sized fish increased. Because angler satisfaction may depend on other factors, effort should be made to relate the fishery independent indices to a measure of angler satisfaction as well, with such satisfaction measures stemming from creel surveys.

7.8 Cautions when Applying Reference Points

Indices reflect biological components of an ecosystem. The ability to detect real changes in those components using indices will be biased by sampling error and affected by natural variation (i.e., environmentally random effects). For example, sampling error is tied to detection that can be affected by the environment, sampler awareness, fish awareness, or sampler experience. There will be random variation in these indices without respect to actual changes in biological components.

It was found that approximately 22% of the CPUE estimates were expected to occur below the 25th percentile due to systematic error and natural variation. Systematic error is unavoidable as it includes sampling differences among biologists, differences in gear efficiency and catchability of bass. The delta-mean model catch indices varied more and 26.75% of the values in a time series are expected to occur below 25th percentile due to systematic error and natural variation. For a 10 year time series, this indicates that 3 years would typically have values that fall below the 25th percentile because of systematic error and natural variation.

For W_r and K_n, approximately 27.3% and 22.1% of the values, respectively, were expected to be lower than the 25th percentile because of systematic error and natural variation. Similarly, 23.4% of the estimates of Z were expected to be greater than the 75th percentile. For PSD_{381}, 26.2% of the estimates may occur below the 25th percentile due to systematic error and natural variation. Thus, for these indices, it would be expected to have 2 – 3 years with indices that may elicit concern simply because of natural variation or systematic errors. Even the best fisheries management cannot always account for such natural variation or errors. A successive 3 years of low values may indicate a chronic problem worth further investigation.

8.0 PROPOSED MANAGEMENT

8.1 *Management Authority*

The first laws regulating fishing activity in Maryland were passed in 1654, about 20 years after the colony was settled. The law prevented settlers from striking fish as they were congregated over spawning grounds. The creation of laws to help protect fishes led to the creation of a Conservation Commission in 1916. In 1939, the Commission was divided into the Maryland Game and Inland Fish Commission and the Commission of Tidewater Fisheries. These Commissions were later governed as Departments by the Board of Natural Resources, which was developed in 1941 to report to the Governor regarding the status and conservation of natural resources in Maryland. Official annual reports to the Governor began in 1944. At this time, it was widely recognized that aquatic resources of Maryland were the "basis of...wealth and the chief physical attractions of [the] state...".

In the late 19th Century, the Chesapeake Bay was considered far more productive than well-known fishing grounds, such as Georges Bank. The resources were considered inexhaustible. However, as boats and gear improved in efficiency for targeted species, the once inexhaustible resources began to decline. The high efficiency of the gear also led to biased catch estimates and these declines were largely unnoticed until species were practically extirpated. The public outcry regarding depleted resources led to legislative action and the directed conservation efforts of the Board of Natural Resources. The scope of natural resource management began with the Blue Crab (*Callinectes sapidus*) and American Oyster (*Crassostrea virginica*) fisheries, but expanded to wildlife and many of the fisheries currently managed. An official licensing system was developed for commercial fishing in 1918 and recreational anglers in 1927. In 1969, the agencies that had developed within the Board of Natural Resources were organized into the Department of Natural Resources. The purview of the tidewater largemouth bass management program rests currently within the Department of Natural Resources, Fisheries Service Division of Inland Fisheries.

8.2 ***Regulatory Process***

This fishery management plan outlines a framework for conservation, management, and sustainability of largemouth bass and its fishery. Management actions via regulation may be necessary in order to protect the fish and fishery. The complete process from proposing an idea to establishing a regulation takes approximately 1 year, though the time between proposing a regulation and adoption takes only 4 – 6 months or 3 – 4 weeks for an emergency regulation. For more details on the process and pre-process outreach, please refer to the Regulations homepage at:

http://dnr.maryland.gov/fisheries/regulations/regindex.asp.

Inland fisheries regulations are promulgated once each year. To be considered, ideas should be submitted in writing by September 1 by anyone to the Division Manager for Inland Fisheries. Because results of the Tidal Bass Survey are disseminated and discussed with stakeholders by February, the September 1 deadline provides stakeholders the opportunity to request additional work during summer or consult other agencies prior to drafting a letter to the Division Manager for

Inland Fisheries. The decision to initially decline or support the idea is dependent upon recommendations from the Regional Managers and fishery biologists with relevant expertise. The formal, written review by regional managers and fishery biologists is due 15 December. The reviews will be used to construct and send a letter by the Division Manager for Inland Fisheries to the submitter by 30 December. In the letter, the Division Manager will discuss the review of the idea and indicate either the decline or continued consideration of the idea.

Once accepted, the item of consideration undergoes the process of *scoping*. The item is presented and discussed with target groups (or those groups that would be affected), the general public by social media networks, internally with intra-agency groups, and federal and state agency stake holders. The item of consideration may also be presented to other groups (*e.g.*, Natural Resources Police or Sport Fisheries Advisory Commission) using other mechanisms, as appropriate. The purpose of this initial discussion phase is to refine the item of consideration and determine if its implementation is of widespread interest.

In June, the idea will be formally outlined in a written proposal if it is to be continually considered. Proposals are drafted based on public comment and staff discussions. They are then sent to the Administrative, Executive and Legislative Review Committee (AELR) of the General Assembly. The Office of Attorney General reviews all proposed and emergency regulations prior to AELR submission. The proposals are posted on-line once they are submitted to AELR.

Once reviewed by AELR, the amended proposal will be sent to the Maryland Register. A public comment period is legally required and is opened for 30 days after the proposal appears in the Maryland Register. Comments may be sent by e-mail or mail.

If the proposal is widely accepted without correction, then a final notice for the proposal will be posted in the Maryland Register later in the fall. If there are minor changes of the proposal because of comments either by the Attorney General's Office or the public, then these changes will appear with the final notice in the Maryland Register. If there are *significant* changes of the proposal, then the proposal must be withdrawn and re-proposed. The proposal will be edited by the drafters and then reviewed by lawyers of DNR and the Attorney General's Office. If deemed acceptable, then the corrected or improved proposal will be sent to the Maryland Register for enactment.

8.3 *Mission Statements*

1) Ensure population integrity and sustainability of largemouth bass in tidewater of Maryland
2) Promote and protect angling opportunities for a wide diversity of constituents
3) Respond to public concerns of the largemouth bass fishery in tidewater of Maryland with well-researched answers and awareness programs or materials

8.4 *Goal of the Plan*

To develop a management framework that enables the creation of policy decisions for conflicting user groups (i.e., stakeholders) and guides the protection, maintenance and improvement of largemouth bass fisheries in Maryland tidewater.

8.5 *Objectives Addressed by the Plan*

1) Assess current status of largemouth bass populations by using long-term surveys of tidewater areas in Maryland.
2) Develop biological reference points for assessing largemouth bass populations.
3) Identify, protect, promote, and improve quality habitats for largemouth bass.
4) Achieve stakeholder expectations that are within bounds of our management principles.
5) Incorporate ecosystem considerations in all aspects of largemouth bass management.

8.6 *Management Recommendations*

1. Assess current status of largemouth bass populations by using long-term surveys of tidewater areas in Maryland.

In order to develop the indices needed to assess the status of populations, MD DNR biologists must conduct annual surveys of tidewater largemouth bass. Additional data from directors of sportfishing tournaments should also be collected. Targeted tidewater areas will be surveyed as needed. The popularity of a largemouth fishery will determine whether a tidewater area is targeted and how often. Information related to abundance, health, and life history of largemouth bass will be collected. In addition, fishery-dependent data will be collected to assess angler impact on and use of the resource. These data are necessary for comparing catch rates among years and monitoring survivorship or longevity. Both fishery-independent and fishery-dependent data should ultimately be predictive of angler satisfaction with a fishery. Thus, measures of angler satisfaction via creel surveys are encouraged. Estimates of population parameters will be improved in precision through improved data collection techniques. Improved data collection techniques will improve overall population assessments, lead to effective management decisions, and ultimately, quality fishing experiences. Data will be stored within a statewide database (GIFS; Geographic Inland Fisheries Survey) or federal database (MARIS), which will improve data sharing across regions or states, respectively. Data are valuable for other programs within MD DNR, such as the Blue Infrastructure Initiative that targets the protection and restoration of habitats within Maryland.

Strategy 1.1 Annually conduct Tidal Bass Surveys on targeted rivers, critically evaluate indices that are used to describe changes in the abundance, health, and life history of largemouth bass within tidewater areas of the Chesapeake Bay watershed, and develop new indices as necessary.

> **Action 1.1.1** Coordinate with regional managers to survey tidewater areas and collect data needed to develop indices

Action 1.1.2 Share results with anglers, stakeholders, and the general public via a Federal Aid Report, one-page summary sheets, an annual information booklet, and other forms as requested.

Action 1.1.3 Discuss indices with members of partner agencies, organizations, and universities to evaluate causes or consequences of changes in the indices

Action 1.1.4 Develop new indices, such as angler satisfaction indices, or adjust existing indices as needed

Action 1.1.5 Improve sharing of data with other Department biologists and programs, such as the Blue Infrastructure Initiative and GIFS

Strategy 1.2 Annually assess data quality and effective usefulness of data collection.

Action 1.2.1 Conduct general assessments of variance within catch and other indices and ensure variance is considerably lower than the average point estimate.

Action 1.2.2 Discuss the scope of data collection with regional managers and directors within Inland Fisheries so that data collection is determined to be sufficient for meeting the demands of the Department.

Action 1.2.3 Allow internal and external peer-review of data collection and analysis to refine methods based on expert opinions

Action 1.2.4 Deliver technical reports to regional managers, other internal reviewers, and reviewers of refereed journals for review of methods and data analysis

Action 1.2.5 Assess and/or improve sampling equipment for efficiency

2. **Develop biological reference points for population assessments.**

Indices must be calculated using biological data collected during annual surveys of tidewater largemouth bass. The indices can be categorized by: catch, longevity or size structure, robustness or body condition, growth rates, and reproduction. Additional indices will be calculated using data collected from directors of sportfishing tournaments. These indices will be compared to biological reference points and will provide historical significance to current measures (see Table 7.3.1). The reference dataset should be of broad enough span to encapsulate substantial index variation attributed to natural, environmental and sampling variation. The reference dataset should be evaluated periodically and when other factors, such as habitat loss or spread of invasive species, demand it to determine whether it differs significantly from current trends in the indices. Additional reference points may be determined from the literature. Some indices may be derived from fishery-dependent data, such as those taken during creel surveys. One of these indices is fishing mortality, which includes harvested fish and those that die during catch-and-release fishing.

Fishing mortality will be measured in order to maintain levels that are sustainable for continued persistence of the population.

Indices will be compared with biological reference points in order to establish concern for the fishery and evaluate appropriate management actions (Table 8.6.2). If indices fall below average for a given year, then the population may be surveyed for the subsequent year and at the discretion of fishery managers, to determine if the index estimate is anomalous.

Strategy 2.1 Establish biological reference points for populations of tidewater largemouth bass and use them to assess population status

> **Action 2.1.1** Compute 25th and 75th Percentiles for each index from the reference dataset, which will be annual averages computed across a minimum of 10 years of data

> **Action 2.1.2** Obtain additional data for populations surveyed less than 10 years and develop reference points

> **Action 2.1.3** Use reference points from the peer reviewed literature, when possible, as comparisons to reference points, particularly for populations that do not have a reference dataset of at least 10 years

> **Action 2.1.4** Adjust reference points as additional data are acquired regarding their inter-correlations and importance in reflecting the status of populations

Strategy 2.2 Compare current indices to the reference points and assess significant differences between current indices and historical reference points

> **Action 2.2.1** Evaluate indices relative to all available reference points and historical data to determine which reference points informatively describe a problem with the fishery.

> **Action 2.2.2** Develop a management strategy for imperiled populations by constructing a framework of management actions (see Table 8.6.2) for improving indices

> **Action 2.2.3** Conduct population modeling to determine if and how management actions will influence indices and the population

Strategy 2.3 Establish reference points for angler exploitation of largemouth bass populations in tidewater

> **Action 2.3.1** Coordinate with directors of competitive sportfishing events to obtain information on catch and initial mortality of largemouth bass

Action 2.3.2 Promote registration and activity reporting of tournament directors to foster communication between MD DNR and bass tournament directors and compliance of tournament directors

Action 2.3.3 Report results during an annual or semi-annual bass roundtable meeting that includes participants from tournaments and the recreational angling community

Action 2.3.4 Perform angler creel surveys, as necessary, to determine angler satisfaction, catch, and harvest rates by recreational anglers

Action 2.3.5 Produce studies and provide guidance on live well operating procedures to reduce mortality of largemouth bass during tournaments

3. **<u>Identify, protect, promote, and improve quality habitats for tidewater largemouth bass.</u>**

In order to protect valuable habitat for viable largemouth bass populations, the habitat conditions that promote survivorship, longevity, and recruitment for largemouth bass will be identified. Specific negative effects to these habitat conditions should be prioritized according to risk and the sources of those effects, identified. Habitat conditions will be evaluated throughout river drainages and important habitats will be geospatially referenced. These data will be shared with other programs, such as GreenPrint (Office of Sustainability) that identifies and protects important and rare habitats within Maryland. Valuable habitats and habitat conditions will be protected and promoted through MD DNR's Environmental Review process, through watershed development plans, and through awareness campaigns for anglers and stakeholders. Where necessary, habitat conditions may be improved by advocating and enacting land use impervious values, limiting access, adding submerged structure, removing invasive species, or reconstructing habitat features such as wetlands, riparian forests, and other means that soften the impact of storm water in suburban and urban watersheds.

Invasive species occur throughout the Chesapeake Bay watershed. Invasive species may alter their environments in unpredictable ways over time, especially as they become abundant. Additional information is necessary on the interactions of potentially threatening invasive species to the largemouth bass fishery. The occurrence and abundance of invasive species that are potentially threatening to the largemouth bass fishery need to be identified.

Climate is expected to change the composition, distribution and abundance of aquatic species. Projected climate changes include increasing air temperature, increasing sea level, changes in precipitation, changes in the timing/amount of stream flow, and the potential for more extreme weather-related events. Steps should be identified to facilitate the resilience and response of the aquatic ecosystem. Current stressors like nutrient and sediment loads, thermal pollution, and habitat fragmentation need to be addressed as part of determining climate change adaptation strategies.

Strategy 3.1 Identify valuable habitat and habitat conditions for largemouth bass and promote their protection.

Action 3.1.1 Refine the habitat suitability index using important habitat variables (e.g., impervious surfaces, nutrient loading) for identifying and prioritizing suitable habitat for largemouth bass

Action 3.1.2 Ensure that the most informative variables are being measured during the Tidal Bass Survey by conferring with MD DNR Fisheries Habitat and Ecosystem Program regarding adoption of new or alternative variables

Action 3.1.3 Use a habitat suitability index and consult anglers and regional managers to identify habitats important for the spawning success and growth of largemouth bass

Action 3.1.4 Consult published literature and experts to help identify valuable habitat for spawning success and growth of largemouth bass

Action 3.1.5 Generate and submit to GreenPrint the spatial data reflecting valuable habitats for largemouth bass and anglers

Action 3.1.6 Consider the effects of climate change on largemouth bass habitat and develop adaptive management to address possible changes

Action 3.1.7 Utilize the proposed Climate Sensitive Areas for use in land-use planning and increased protection of vulnerable habitats especially in regards to largemouth bass habitat

Action 3.1.8 Provide comments during permit review via MD DNR Environmental Review to help minimize ecological impacts on populations from tidewater of the Chesapeake Bay watershed and largemouth bass habitat

Action 3.1.9 Write letters on official letterhead to stakeholders or on behalf of stakeholders to acknowledge and promote the significance of the largemouth bass fishery

Action 3.1.10 Promote a level of imperviousness that is lower than 10% of the drainage to Counties, through outreach conducted by DNR Office of Sustainable Futures, through GIS tools, and through Environmental Review and MDP (Maryland Department of Planning), as feasible; high densities of impervious surfaces in a watershed can lower the water quality of tidewater and impair the growth or survival of adult largemouth bass

Action 3.1.11 Ensure that natural variability in stream discharge is maintained by encouraging "smart growth" and limiting channelization

Action 3.1.12 Encourage lower levels of nitrogen and phosphorus waste from entering waterways via non-point and point sources

Action 3.1.13 Proactively work through a comprehensive plan renewal process to identify and protect important habitat features

Action 3.1.14 Collect data on invasive species as habitat data is collected in order to better monitor changes in habitat conditions over time and evaluate how those changes would affect the largemouth bass fishery

Strategy 3.2 Improve habitat conditions for largemouth bass and species on which largemouth bass depend

Action 3.2.1 Identify and determine the need for protected areas (e.g., habitat sanctuaries) that are completely or temporarily closed to largemouth bass fishing either year-round or during the spawning season (to specifically improve reproduction) to prevent displacement or high levels of catch-and-release mortality

Action 3.2.2 Use ecosystem-based management to provide management options that protect growth or survival of largemouth bass and accounts for competition or predation by invasive species

Action 3.2.3 Tidal Bass Program staff may work with Artificial Reef Program staff (MARI and the Artificial Reef Committee) as needed to develop reefs and other artificial habitat for largemouth bass, when needed, using a combination of plastic and wood/brush materials (per guidelines within the Maryland Artificial Reef Plan; Lukens and Selberg 2004; Loftus and Stone 2007) and deposited in areas permitted by Army Corps of Engineers, Maryland Department of Environment, and U.S. Coast Guard Aids to Navigation Office.

Action 3.2.4 Develop innovative storm water management techniques, promote storm water management retrofits where applicable, creation of wet marshy conditions throughout watersheds, and reconnect streams to riparian areas

Action 3.2.5 Upgrade and improve semi-natural landscape elements, such as man-made wetlands, ponds, and recreated natural lands

Action 3.2.6 Promote low sedimentation of streams

4. Achieve stakeholder expectations that are within bounds of our management principles.

When appropriate, strategies to improve tidewater largemouth bass fisheries may be adopted. Examples of fishery problems and management strategies, with responsive indices, are given in Table 8.6.2. A Decision-Making Process will be developed to mitigate problems that arise when a combination of indices depart significantly from reference points or targets. Currently, there is not a defined point at which corrective management measures will be taken because of departures of indices from reference points.

Strategy 4.1 Generate a decision making process to resolve identified problems with the population and fishery as they relate to significant departures of indices from reference points

Action 4.1.1 Hold public meetings to determine angler behavior and perceptions on the quality of the fishery

Action 4.1.2 Evaluate the adequacy of current regulations in supporting the sustainability and quality of the fishery

Action 4.1.3 Establish relationships between fishery independent data, angler catch, and angler satisfaction

Strategy 4.2 Enhance fish populations by releasing hatchery raised largemouth bass, when natural reproduction or recruitment is deemed insufficient for sustaining a fishery

Action 4.2.1 Target tidewater areas that require stocking of largemouth bass that are determined to be at risk and would be expected to suffer a decline in the quality of the fishery without stocking efforts.

Action 4.2.2 Generate a stocking strategy with an objective to either support or improve the fishery

Strategy 4.3 Promote the survival and abundance of older, larger fish

Action 4.3.1 Adjust creel limits or size limits for promoting survival of older fish when: a) there are few adults in the population for enabling sufficient recruitment that sustains the population; or b) catch rates for adults are too low to provide a quality fishery

Action 4.3.2 Improve and promote angler awareness that increases survivorship of largemouth bass during catch-and-release fishing, which is the dominate form of fishing for largemouth bass in Maryland: 1) limit the amount of time bass are exposed to air; 2) prevent excessive handling of largemouth bass; 3) if largemouth bass are contained in live wells, make sure live wells are clean and the recirculator is functioning; and 4) use a small amount of salt to reduce bacterial infections if bass are contained in live well.

Action 4.3.3 Engage in meaningful studies that benefit the angling community by informing them on methods to improve survivorship.

Action 4.3.4 Enforce restrictions on holding more than 5 bass/angler/day by specially permitted release boat captains; these restrictions are: 1) keep the density of the fish in holding tanks at most, 1 pound per gallon of water; 2) maintain a water temperature at or slightly below ambient levels (± 5 – 7 °F); and 3) maintain dissolved oxygen at saturated or near saturated conditions (> 6 mg/L or > 100%).

Action 4.3.5 When necessary, discourage the transportation of largemouth bass among river systems or to an uninterrupted area greater than 30 km from its area of capture.

Strategy 4.4 Protect, enhance and improve important angler access points to the tidewater largemouth bass fishery

Action 4.4.1 As part of the Chesapeake Bay Watershed Access Plan (a product of Executive Order 13508), 300 public access sites will be developed in the watershed and important angler access points to the tidewater largemouth bass fishery should be provided.

Action 4.4.2 Determine crowding of angler access points and mitigate, when possible

Action 4.4.3 Encourage public or DNR Fisheries to identify potentially new access areas for motor boats and to pursue Waterway Improvement Grants for consideration by Boating Services

Action 4.4.4 Create and/or advertise new angler access points to the tidewater largemouth bass fishery, when possible

Action 4.4.5 Promote small craft and shore based angler access

5. <u>Incorporate ecosystem considerations in all aspects of largemouth bass management.</u>

An ecosystem's components can function to promote the sustainability of top predators, such as largemouth bass. Some of these components include species composition, nutrient availability, watershed influences, and climatic phenomenon. These components inter-relate to yield a carrying capacity that supports a finite population size for largemouth bass. While many components of an ecosystem are not easily managed (e.g., climate), some components are. Management options include, but are not limited to: habitat enhancement, improvements to water quality, and invasive species control.

Strategy 5.1 Improve habitat for largemouth bass

Action 5.1.1 Control and manage invasive species that threaten the health or sustainability of largemouth bass populations

Action 5.1.2 Monitor, protect or enhance the availability of prey for largemouth bass by partnering with other agencies or other programs within MD DNR

Action 5.1.3 Control or limit pollution sources to impaired waterways in order to improve the sustainability of largemouth bass populations

Strategy 5.2 Maintain important aspects of ecosystem function to maintain habitat for largemouth bass

Action 5.2.1 Identify components of ecosystem function essential for the sustainability of largemouth bass populations

Action 5.2.2 Identify possible threats to the maintenance and functioning of an ecosystem that promotes the sustainability of largemouth bass populations

Action 5.2.3 Preserve ecosystem components that are essential and potentially threatened

8.7 *Plan Revisions*

The Maryland largemouth bass FMP provides a general framework for managing the largemouth bass resource. As strategies and actions are implemented, it may be necessary to change or adjust the actions based on how the resource responds or as new information becomes available. The basic tenet of adaptive management is to "learn from experience." This tenet is applied through a cyclic process that consists of setting goals and objectives that lead to implementing strategies and actions. Through time, the actions are monitored and evaluated for their effectiveness. Periodically, the management program is reviewed and the results of the evaluation are reported. The report may recommend changes to the management strategies and actions to enhance effectiveness. The changes are incorporated into the management framework through amendments and revisions which continues the adaptive management cycle. The review of effectiveness of this FMP may occur once or twice a year, depending on need and input from stakeholders.

9.0 SUMMARY OF MANAGEMENT PLAN

9.1 *Background*

Largemouth bass was first introduced to Maryland's tidewater in the 1800's and has quickly established itself as a dominant predator in many portions of tidewater. As the species increased in number and distribution, commercial and recreational fisheries rapidly developed. Regulations for the species were imposed over a century ago and have undergone an interesting history wrought with political influence and tempered with biological assessments. The regulations have been equally applied to Largemouth and Smallmouth Bass, but the latter species is far less abundant in tidewater. The proposed management plan is a two point approach led off by calculating indices that reflect population surveys and then by comparing indices to biological reference points. These comparisons may lead to management actions specified herein. The management framework may change based on newly acquired information.

9.2 *Management Needs*

To support objectives of this plan, the following research needs have been prioritized:

1) Continue Tidal Bass Survey so that a 10-year baseline of data is established for targeted tidewater areas populations and populations are monitored at least bi-annually.
2) Generate better estimates for annual indices from survey work and develop other important indices, such as fishing mortality, from other studies.
3) Determine the appropriate management units of populations using genetic markers, particularly in the upper Chesapeake Bay.
4) Develop measures to determine angler satisfaction and relate those measures to fishery-independent and fisher-dependent indices.
4) Determine economic impact of the fishery.
5) Refine a habitat index that addresses habitat quality for spawning habitat, submerged structure, and future impacts by climate change and land use development.

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11.0 LITERATURE CITED

Allen, A.W. 1983. Habitat suitability index models: Beaver. U.S. Fish and Wildlife Service. FWS/OBS-82/10.30.

Allen, M.S. and W.E. Pine III. 2000. Detecting fish population responses to a minimum length limit: effects of variable recruitment and duration of evaluation. North American Journal of Fisheries Management 20: 672-682.

Allen, M.S., C.J. Walters, and R. Myers. 2008. Temporal trends in Largemouth Bass mortality, with fishery implications. North American Journal of Fisheries Management 28:418-427.

Allen, M.S., M.W. Rogers, M.J. Catalano, D.G. Gwinn, and S.J. Walsh. 2011. Evaluating the potential for stock size to limit recruitment in Largemouth Bass. Transactions of the American Fisheries Society 140: 1093-1100.

Almeida, D., A. Almodóvar, G.G. Nicola, B. Elvira, and G.D. Grossman. 2012. Trophic plasticity of invasive juvenile Largemouth Bass *Micropterus salmoides* in Iberian streams. Fisheries Research 113:153-158.

Applegate, R.L. and J.W. Mullan. 1967. Food of young Largemouth Bass, *Micropterus salmoides*, in a new and old reservoir. Transactions of the American Fisheries Society 96:74-77.

ASA (American Sportfishing Association). 2013. Sportfishing in America: An economic force for conservation. www.ASAfishing.org.

Bailey, R.M. and C.L. Hubbs. 1949. The black basses (*Micropterus*) of Florida, with description of a new species. Occasional Papers of the Museum of Zoology University of Michigan 516.

Beamesderfer, R.C.P. and J.A. North. 1995. Growth, natural mortality, and predicted response to fishing for Largemouth Bass and Largemouth Bass populations in North America. North American Journal of Fisheries Management 15:688-704.

Bergstrom, J.C., H.K. Cordell, G.A. Ashley, and A.E. Watson. 1990. Economic impacts of recreational spending on rural areas: a case study. Economic Development Quarterly 4:29-39.

Bettoli, P.W., M.J. Maceina, R.L. Noble, and R.K. Betsill. 1992. Piscivory in Largemouth Bass as a function of aquatic vegetation abundance. North American Journal of Fisheries Management. 12:509-516.

Bonar, S.A., W.A. Hubert, and D. W. Willis, editors. 2009. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, MD.

Borden, W.C. 2008. Assessment of genetic divergence between lacustrine and riverine Largemouth Bass in Lake Erie and four tributaries. Northeastern Naturalist 15:335-348.

Brooks, R.P. 1997. Improving habitat suitability index models. Wildlife Society Bulletin 25:163-167.

Buchanan, C., R.V. Lacouture, H.G. Marshall, M. Olson, and J.M. Johnson. 2005. Phytoplankton reference communities for Chesapeake Bay and its tidal tributaries. Estuaries 28:138-159.

Buckmeier, D.L. and R.K. Betsill. 2002. Mortality and dispersal of stocked fingerling Largemouth Bass and effects on cohort abundance. Pages 667-676 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Buckmeier, D.L. and R.G. Howells. 2003. Validation of otoliths for estimating ages of Largemouth Bass to 16 years. North American Journal of Fisheries Management 23: 590-593.

Buckmeier, D.L., R.K. Betsill, and J. W. Schlechte. 2005. Initial predation of stocked fingerling Largemouth Bass in a Texas reservoir and implications for improving stocking efficiency. North American Journal of Fisheries Management 25:652-659.

Calder, W.A. III. 1996. Size, Function, and Life History. Dover Publications, Inc. Mineola, NY.
Campana, S.E., L. Marks, W. Joyce, and N.E. Kohler. 2006. Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. Canadian Journal of Fisheries and Aquatic Sciences 63: 670-682.
Carr, M.H. 1942. The breeding habits, embryology, and larval development of the large-mouth black bass in Florida. Proceedings of the New England Zoology Club 20: 43-77.
Chen, R.J., K.M. Hunt, and R.B. Ditton. 2003. Estimating the economic impacts of a trophy Largemouth Bass fishery: Issues and applications. North American Journal of Fisheries Management 23:835-844.
Clavero, M. and García-Berthou, E. 2005. Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution 20:110.
Cline, T.J., B.C. Weidel, J.F. Kitchell, and J.R. Hodgson. 2012. Growth response of Largemouth Bass (*Micropterus salmoides*) to catch-and-release angling: a 27-year mark-recapture study. Canadian Journal of Fisheries and Aquatic Sciences 69:224-230.
Cloern, J.E. and F.H. Nichols. 1978. A von Bertalanffy growth model with a seasonally varying coefficient. Journal of Fisheries Research Board of Canada 35:1479-1482.
Clugston, J.P. 1964. Growth of the Florida Largemouth Bass, *Micropterus salmoides floridanus* (LeSuer), and the northern Largemouth Bass, *M. s. salmoides* (Lacépède), in subtropical Florida. Transactions of the American Fisheries Society 93: 146-154.
Colle, D.E., R.L. Cailteaux, and J.V. Shireman. 1989. Distribution of Florida Largemouth Bass in a lake after elimination of all submersed aquatic vegetation. North American Journal of Fisheries Management 9:213-218.
Colgan, P.W. and J.A. Brown. 1988. Dynamics of nest defense by male centrarchid fish. Behavioural Processes 17:17-26.
Cone, R.S. 1989. The need to reconsider the use of condition indices in fishery science. Transactions of the American Fisheries Society 118:510-514.
Cooke, S.J., D.P. Philipp, and P.J. Weatherhead. 2002. Parental care patterns and energetics of Smallmouth Bass (*Micropterus dolomieu*) and Largemouth Bass (*Micropterus salmoides*) monitored with activity transmitters. Canadian Journal of Zoology 80:756-770.
Cooke, S.J., C.D. Suski, M.J. Siepker, and K.G. Ostrand. 2003. Injury rates, hooking efficiency and mortality potential of Largemouth Bass (*Micropterus salmoides*) captured on circle hooks and octopus hooks. Fisheries Research 61: 135-144.
Cooke, S.J. and C.D. Suski. 2005. Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? Biodiversity and Conservation 14: 1195-1209.
Cooke, S.J. and H.L. Schramm. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fisheries Management and Ecology 14: 73-79.
Cooke, S.J. and D.P. Philipp, editors. 2009. Centrarchid Fishes, Diversity, Biology, and Conservation. Wiley-Blackwell Publishers, West Sussex, United Kingdom.
Crowl, T.A. 1989. Effects of crayfish size, orientation, and movement on the reactive distance of Largemouth Bass foraging in clear and turbid water. Hydrobiologia 183: 133-140.
DeVries, D.R., J.E. Garvey, and R.A. Wright. 2009. Early life history and recruitment. Pages 105 – 133 in S.J. Cooke and D.P. Philipp, editors. Centrarchid Fishes, Diversity, Biology, and Conservation. Wiley-Blackwell Publishers, West Sussex, United Kingdom.

Diana, M.J. and D.H. Wahl. 2009. Growth and survival of four sizes of stocked Largemouth Bass. North American Journal of Fisheries Management 29:2653-1663.

Durocher, P.P., W.C. Provine, and J.E. Kraai. 1984. Relationship between abundance of Largemouth Bass and submerged vegetation in Texas reservoirs. North American Journal of Fisheries Management 4:84-88.

Elser, H.J. 1960. Creel census results on the Northeast River, Maryland, 1958. Chesapeake Science 1:41-47.

Elser, H.J. 1961. An evaluation of the effect of removing Largemouth Bass from the Northeast River, MD. Maryland Department of Natural Resources, Reference Number 61-6.

Fuhr, M.A., D.H. Wahl, and D.P. Philipp. 2002. Fall abundance of age-0 Largemouth Bass is more important than size in determining age-1 year-class strength in Illinois. Pages 91 – 100 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, MD.

Fullerton, A.H., J.E. Garvey, R.A. Wrigth, and R.A. Stein. 2000. Overwinter growth and survival of Largemouth Bass: interactions among size, food, origin, and winter severity. North American Journal of Fisheries Management 129:1-12.

Funk, J.L. 1957. Movement of fishes in Missouri. Transactions of the American Fisheries Society 85: 39-57.

Garvey, J.E., R.A. Stein, R.A. Wright, and M.T. Bremigan. 2002. Exploring ecological mechanisms underlying Largemouth Bass recruitment along Environmental Gradients. Pages 7-23 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, MD.

Gilliand, G. and H. Schramm. 2009. Keeping Bass Alive: A Guidebook for Tournament Anglers and Organizers, 2nd edition. B.A.S.S.

Goodgame, L.S. and L.E. Miranda. 1993. Early growth and survival of age-0 Largemouth Bass in relation to parental size and swim-up time. Transactions of the American Fisheries Society 122: 131-138.

Gwinn, D.C. and M.S. Allen. 2010. Exploring population-level effects of fishery closures during spawning: an example using Largemouth Bass. Transactions of the American Fisheries Society 139:626-634.

Gwinn, D.C., M.S. Allen, and M.W. Rogers. 2010. Evaluation of procedures to reduce bias in fish growth parameter estimates resulting from size-selective sampling. Fisheries Research 105: 75-79.

Guy, C.S., R.M. Neumann, and D.W. Willis. 2006. New terminology for proportional stock density (PSD) and relative stock density (RSD): proportional size structure (PSS). Fisheries 31:86-87.

Guy, C.S., R. M. Neumann, D.W. Willis, and R.O. Anderson. 2007. Proportional size distribution (PSD): a further refinement of population size structure index terminology. Fisheries 32:348.

Hartwell, S.I., D.M. Jordahl, C.E.O. Dawson, and A.S. Ives. 1994. Toxicity of scrap tire leachates in estuarine salinities. Maryland Department of Natural Resources, Tidewater Administration, Chesapeake Bay Research and Monitoring Division, Annapolis, MD.

Heidinger, R.C. 1976. Synopsis of biological data on the Largemouth Bass. FAO Fisheries Synopsis 115:1-85.

Henson, J.C. 1991. Quantitative description and development of a species-specific standard growth form for Largemouth Bass, with application to the relative weight index. Master's thesis. Texas A&M University, College Station.

Hoyer, M.V. and D.E. Canfield, Jr. 1996. Largemouth Bass abundance and aquatic vegetation in Florida lakes: An empirical analysis. Journal of Aquatic Plant Management 34:23-32.
Hubert, W.A. and R.T. Lackey. 1980. Habitat of adult Largemouth Bass in a Tennessee River reservoir. Transactions of the American Fisheries Society 109: 364-370.
Huenemann, T.W., E.D. Dibble, and J.P. Fleming. 2012. Influence of turbidity on the foraging of Largemouth Bass. 141:107-111.
Hunt, K.M. and R.B. Ditton. 1996. A social and economic study of the Lake Fork Reservoir recreational fishery. Texas A&M University, College Station, Texas.
Hunt J., N. Bacheler, D. Wilson, E. Videan, and C.A. Annett. 2002. Enhancing Largemouth Bass spawning: behavioral and habitat considerations. American Fisheries Society Symposium 31: 277-290.
Hunt, J. and C.A. Annett. 2002. Effects of habitat manipulation on reproductive success of individual Largemouth Bass in an Ozark reservoir. North American Journal of Fisheries Management 22:1201-1208.
Isermann, D.A. and C.T. Knight. 2005. A computer program for age-length keys incorporating age assignment to individual fish. North American Journal of Fisheries Management 25:1153-1160.
Jackson, J.R., R.L. Noble, and J.R. Copeland. 2002. Movements, growth, and survival of individually-marked fingerling Largemouth Bass supplementally stocked into a North Carolina Reservoir. Pages 677 – 689 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, MD.
Jackson, D.A. 2002. Ecological effects of *Micropterus* introductions: The dark side of black bass. Pages 221-234 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, MD.
Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD.
Jentsch, A., J. Kreyling, and C. Beierkuhnlein. 2007. A new generation of climate change experiments: events, not trends. Frontiers in Ecology and Environment 5:315-324.
Kassler, T. W., J. B. Koppelman, T. J. Near, C. B. Dillman, J. M. Levengood, D. L. Swofford, J. L. VanOrman, J. E. Claussen, and D. P. Philipp. 2002. Molecular and morphological analyses of the black basses (*Micropterus*): Implications for taxonomy and conservation. American Fisheries Society Symposium 31:291–322.
Kelley, J.W. 1962. Sexual maturity and fecundity of the Largemouth Bass, *Micropterus salmoides* (Lacépède), in Maine. Transactions of the American Fisheries Society 91:23-28.
Killgore, K.J., R.P. Morgan II, and N.B. Rybick. 1989. Distribution and abundance of fishes associated with submersed aquatic plants in the Potomac River. North American Journal of Fisheries Management 9:101-111.
King, M. 1995. Fisheries biology, Assessment, and Management. Fishing News Books, Blackwell Science, Malden, MA.
Kramer, R.H. and L.L. Smith, Jr. 1960. First-year growth of the Largemouth Bass, *Micropterus salmoides* (Lacépède), and some related ecological factors. Transactions of the American Fisheries Society: 222-233.
Kramer, R.H. and L.L. Smith, Jr. 1962. Formation of year classes in Largemouth Bass. Transactions of the American Fisheries Society 91: 29-41.

Lawson, Z.J., J.W. Gaeta, and S.R. Carpenter. 2011. Coarse woody habitat, lakeshore residential development, and Largemouth Bass nesting behavior. North American Journal of Fisheries Management 31:666-670.

Lee, D.S. and 5 others. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History. Publication# 1980-12 of the North Carolina Biological Survey, Raleigh, N.C.

Lemons, D.E. and L.I. Crawshaw. 1985. Behavioral and metabolic adjustments to low temperatures in the Largemouth Bass (*Micropterus salmoides*). Physiological Zoology 58:175-180.

Lewis, W.M. and S. Flickinger. 1967. Home range tendency of the Largemouth Bass (*Micropterus salmoides*). Ecology 48: 1020-1023.

Love, J.W., J. Gill, and J.J. Newhard. 2008. Saltwater intrusion impacts fish diversity and distribution in the Blackwater River drainage (Chesapeake Bay watershed). Wetlands 28:967-974.

Love, J.W. 2011. Habitat suitability index for Largemouth Bass *Micropterus salmoides* in tidal rivers of Chesapeake Bay watershed. Transactions of the American Fisheries Society 140:1049-1059.

Love, J.W. and J.J. Newhard. 2012. Will the expansion of northern snakehead negatively affect the fishery for largemouth bass in the Potomac River (Chesapeake Bay)? North American Journal of Fisheries Management 32:859-868.

Ludsin, S.A. and D.R. DeVries. 1997. First-year recruitment of Largemouth Bass: The interdependency of early life stages. Ecological Applications 7:1024-1038.

Maryland Board of Natural Resources (MBNR). 1950. Seventh Annual Report, Maryland Department of Natural Resources, Annapolis.

Maryland Board of Natural Resources (MBNR). 1952. Ninth Annual Report, Maryland Department of Natural Resources, Annapolis.

Maryland Department of Natural Resources (MD DNR). 1990. Statewide Fisheries Survey and Management. Final Report for Federal Aid Project F-29-R 1986-1990, Annapolis, MD.

Maryland Department of Natural Resources (MD DNR). 1995. Survey and management of Maryland's fishery resources, annual (1994) performance report. MD DNR, Federal Aid in Sport Fish Restoration, Project F-48-R-19, Annapolis, MD.

Maryland Department of Natural Resources (MD DNR). 1999. Survey and management of Maryland's fishery resources, annual (1998) performance report. MD DNR, Federal Aid in Sport Fish Restoration, Project F-48-R-19, Annapolis, MD.

Maryland Department of Natural Resources (MD DNR). 2011. Survey and management of Maryland's fishery resources, annual (2010) performance report. MD DNR, Federal Aid in Sport Fish Restoration, Project F-48-R-19, Annapolis, MD.

Maryland Department of Natural Resources (MD DNR). 2012. Survey and management of Maryland's fishery resources, annual (2011) performance report. MD DNR, Federal Aid in Sport Fish Restoration, Project F-48-R-19, Annapolis, MD.

Markham, J.L., Cosden, D.T. and Schaefer, R.K. 2002. Use of GIS generated habitat maps for sampling Largemouth Bass in Maryland's tidal rivers. Pages 593–602 in D.P. Philipp and M.S. Ridgway (editors). Black Bass: Ecology, Conservation, and Management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Marler, B.J. and D.C. Jackson. 1992. Population characteristics of Largemouth Bass in riverine sections of the Tennessee-Tombigbee waterway. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 46:386-392.

Martin, W.E., F.H. Bollman, and R.L. Gum. 1982. Economic value of Lake Mead Fishery. Fisheries 7:20-24.

Meador, M.R. and W.E. Kelso. 1989. Behavior and movements of Largemouth Bass in response to salinity. Transactions of the American Fisheries Society 118: 409-415.

Meador, M.R. and W.E. Kelso. 1990. Growth of Largemouth Bass in low-salinity environments. Transactions of the American Fisheries Society. 119:545-552.

Mittelbach, G.G., Turner, A.M., Hall, D.J., Rettig, J.E., and Osenberg, C.W. 1995. Perturbation and resilience: a long-term, whole-lake study of predator extinction and reintroduction. Ecology 76:2347-2360.

Muoneke, M.I., and W.M. Childress. 1994. Hooking mortality: A review for recreational fisheries. Reviews in Fisheries Science 2: 123-156.

Nack, S.B., D. Bunnell, D.M. Green, and J.L. Forney. 1993. Spawning and nursery habitats of Largemouth Bass in the tidal Hudson River. Transactions of the American Fisheries Society 122:208-216.

Najjar, R.G., and 12 others. 2010. Potential climate-change impacts on the Chesapeake Bay. Estuarine, Coastal and Shelf Science 86:1-20.

Norris, A., D. DeVries, and R. Wright. 2010. Coastal estuaries as habitat for a freshwater fish species: Exploring population-level effects of salinity on Largemouth Bass. Transactions of the American Fisheries Society 139: 610-625.

Odenkirk, J. and S. Owens. 2007. Expansion of a northern snakehead population in the Potomac River system. Transactions of the American Fisheries Society 136:1633-1639.

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

Peer, A.C., D.R. DeVries, and R.A. Wright. 2006. First-year growth and recruitment of coastal Largemouth Bass (*Micropterus salmoides*): spatial patterns unresolved by critical periods along a salinity gradient. Canadian Journal of Fisheries and Aquatic Science 63:1911-1924.

Philipp, D.P. 1991. Genetic implications of introducing Florida Largemouth Bass, *Micropterus salmoides floridanus*. Canadian Journal of Fisheries and Aquatic Sciences 48:58-65.

Philipp, D.P., W.F. Childers, and G.S. Whitt. 1981. Management implications for different genetic stocks of Largemouth Bass (*Micropterus salmoides*) in the United States. Canadian Journal of Fisheries and Aquatic Sciences 38:1715-1723.

Pope, K.L. and G.R. Wilde. 2004. Effect of catch-and-release angling on growth of Largemouth Bass, *Micropterus salmoides*. Fisheries Management and Ecology 11: 39-44.

Post, D.M., J.F. Kitchell, and J.R. Hodgson. 1998. Interactions among adult demography, spawning date, growth rate, predation, overwinter mortality, and the recruitment of Largemouth Bass in a northern lake. Canadian Journal of Fisheries and Aquatic Sciences 55:2588-2600.

Powell, A.M. 1967. Historical information of Maryland Commission of Fisheries: with some notes on game. Maryland Department of Natural Resources, Annapolis.

Pribyl, A.L., J.S. Vile, and T.A. Friesen. 2005. Population structure, movement, habitat use, and diet of resident piscivorous fishes in the Lower Willamette River. In: Biology, Behavior, and Resources of Resident and anadromous Fish in the Lower Willamette River, Final Report of

Research, pages 139 - 184. T.A. Friesen (editor). Oregon Department of Fish and Wildlife, Clackamas, OR.

Quinn, S. 2002. Status of seasonal restrictions on black bass fisheries in Canada and the United States. Pages 455-465 in D.P. Philipp and M.S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Chinook salmon. U.S. Fish and Wildlife Service Biological Report FWS/OBS-82/10.122.

Richardson-Heft, C.A., A.A. Heft, L. Fewlass, and S.B. Brandt. 2000. Movement of Largemouth Bass in northern Chesapeake Bay: Relevance to sportfishing tournaments. North American Journal of Fisheries Management 20: 493-501.

Ridgway, M.S. 2002. Movements, home range, and survival estimation of Largemouth Bass following displacement. American Fisheries Society Symposium 31: 525-533.

Roloff, G.J. and B.J. Kernohan. 1999. Evaluating reliability of habitat suitability index models. Wildlife Society Bulletin 27:973-985.

Sammons, S.M., M.J. Maceina, and D.G. Partridge. 2003. Changes in behavior, movement, and home ranges of Largemouth Bass following large-scale *Hydrilla* removal in Lake Seminole, Georgia. Journal of Aquatic Plant Management 41:31-38.

Sass, G.G., S.R. Carpenter, J.W. Gaeta, J.F. Kitchell, and T.D. Ahrenstorff. 2011. Whole-lake addition of coarse woody habitat: response of fish populations. Aquatic Sciences 74:255-266.

Savitz, J., P.A. Fish, and R. Weszeley. 1983. Effects of forage on home-range size of Largemouth Bass. Transactions of the American Fisheries Society 112:772-776.

Saylor, R.K., N.W.R. Lapointe, and P.L. Angermeier. 2012. Diet of non-native northern snakehead (*Channa argus*) compared to three co-occurring predators in the lower Potomac River, USA. Ecology of Freshwater Fish 21:443-452.

Short, F.T. and H.A. Neckles. 1999. The effects of global climate change on seagrasses. Aquatic Botany 63:169-196.

Shuter, B.J., P.E. Ihssen, D.L. Wales, and E.J. Snucins. 1989. The effects of temperature, pH and water hardness on winter starvation of young-of-the-year Largemouth Bass, *Micropterus dolomieu* Lacèpéde. Journal of Fish Biology 35:765-780.

Siebold, S.E. 1991. Homing behavior of displaced Largemouth Bass (*Micropterus salmoides*) in the tidal Potomac River. Unpubl. Master's Thesis, University of Maryland, College Park, MD.

Siepker, M.J., S.J. Cooke, D.H. Wahl, and D.P. Philipp. 2009. Individual reproductive success of Smallmouth Bass and Largemouth Bass subjected to different components of competitive angling events. Transactions of the American Fisheries Society 138:818-825.

Slipke, J.W. and M.J. Maceina. 2007. Movement and use of backwater habitats by Largemouth Bass and White Crappie in Demopolis Reservoir, Alabama. Journal of Freshwater Ecology 22: 393-401.

Smagula, C.M. and I.R. Adelman. 1982. Day-to-day variation in food consumption by Largemouth Bass. Transactions of the American Fisheries Society 111:543-548.

Stang, D.L. 1996. Black bass movements after release from fishing tournaments in four New York waters. *In*: Multidimensional approaches to Research and Fisheries Management: Proceedings of the third national reservoir fisheries symposium, pages 163-171. L.E. Miranda, D.R. DeVries, and R.E. Miranda (editors). American Fisheries Society Symposium, volume 16.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53:577-588.
Stuber, R.J., Gebhart, G., and O.E. Maughan. 1982. Habitat suitability index models: Largemouth Bass. U.S. Department of the Interior Fish and wildlife Service FWS/OBS-82/10.16 32 pp.
Sule, M.J. 1981. First-year growth and feeding of Largemouth Bass in a heated reservoir. Illinois Natural History Survey Bulletin 32:520-535.
Suski, C.D., F.J.S. Phelan, M.F. Kubacki, and D.P. Philipp. 2002. The use of sanctuaries for protecting nesting black bass from angling. Pages 371 – 379 in D.P. Philipp and M.S. Ridgway, editors. Black Bass: Ecology, Conservation, and Management. American Fisheries Society, Symposium 31, Bethesda, MD.
Suski, C.D. and M.S. Ridgway. 2009. Winter biology of centrarchid fishes. Pages 264 – 292 in S.J. Cooke and D.P. Philipp, editors. Centrarchid Fishes, Diversity, Biology, and Conservation. Wiley-Blackwell Publishers, West Sussex, United Kingdom.
Todd, B.L. and C.F. Rabeni. 1989. Movement and habitat use by stream-dwelling Largemouth Bass. Transactions of the American Fisheries Society 118: 229-242.
U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau (USFWS). 2008. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation—Maryland. FHW/06-MD, Washington, D.C.
U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau (USFWS). 2013. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation—Maryland. FHW/06-MD, Washington, D.C.
Waters, D.S., R.L. Noble, and J.E. Hightower. 2005. Fishing and natural mortality of adult Largemouth Bass in a tropical reservoir. Transactions of the American Fisheries Society 134:563-571.
Wesche, T.A., C.M. Goertler, and W.A. Hubert. 1987. Modified habitat suitability index model for brown trout in southeastern Wyoming. North American Journal of Fisheries Management 7:232-237.
Wege, G.J. and R.O. Anderson. 1978. Relative weight (Wr): a new index of condition for Largemouth Bass. Pages 79-91 *in* GD Novinger and JG Dillard (editors). New Approaches to the Management of Small Impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, MD.
Wilde, G.R. 1998. Tournament-associated mortality in black bass. Fisheries 23:12-22.
Wilde, G.R. and K.L. Pope. 2008. A simple model for predicting survival of angler-caught and released Largemouth Bass. Transactions of the American Fisheries Society 137:834-840.
Winter, J.R. 1977. Summer home range movements and habitat use by four Largemouth Bass in Mary Lake, Minnesota. Transactions of the American Fisheries Society 106: 323-330.

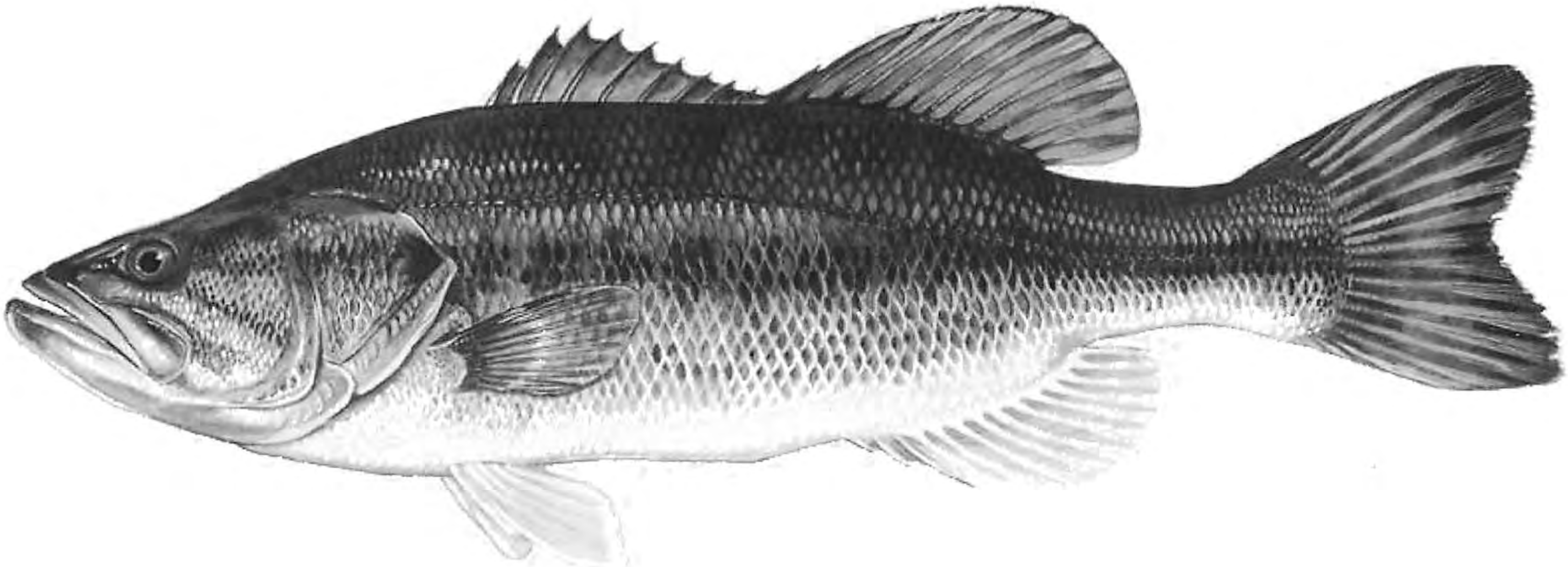

Figure 3.1.1. Largemouth bass (*Micropterus salmoides* Lacépède) is distinguished from other *Micropterus* by the extension of the upper maxilla bone beyond the rear margin o fthe eye and the lateral, dark strip along the body.

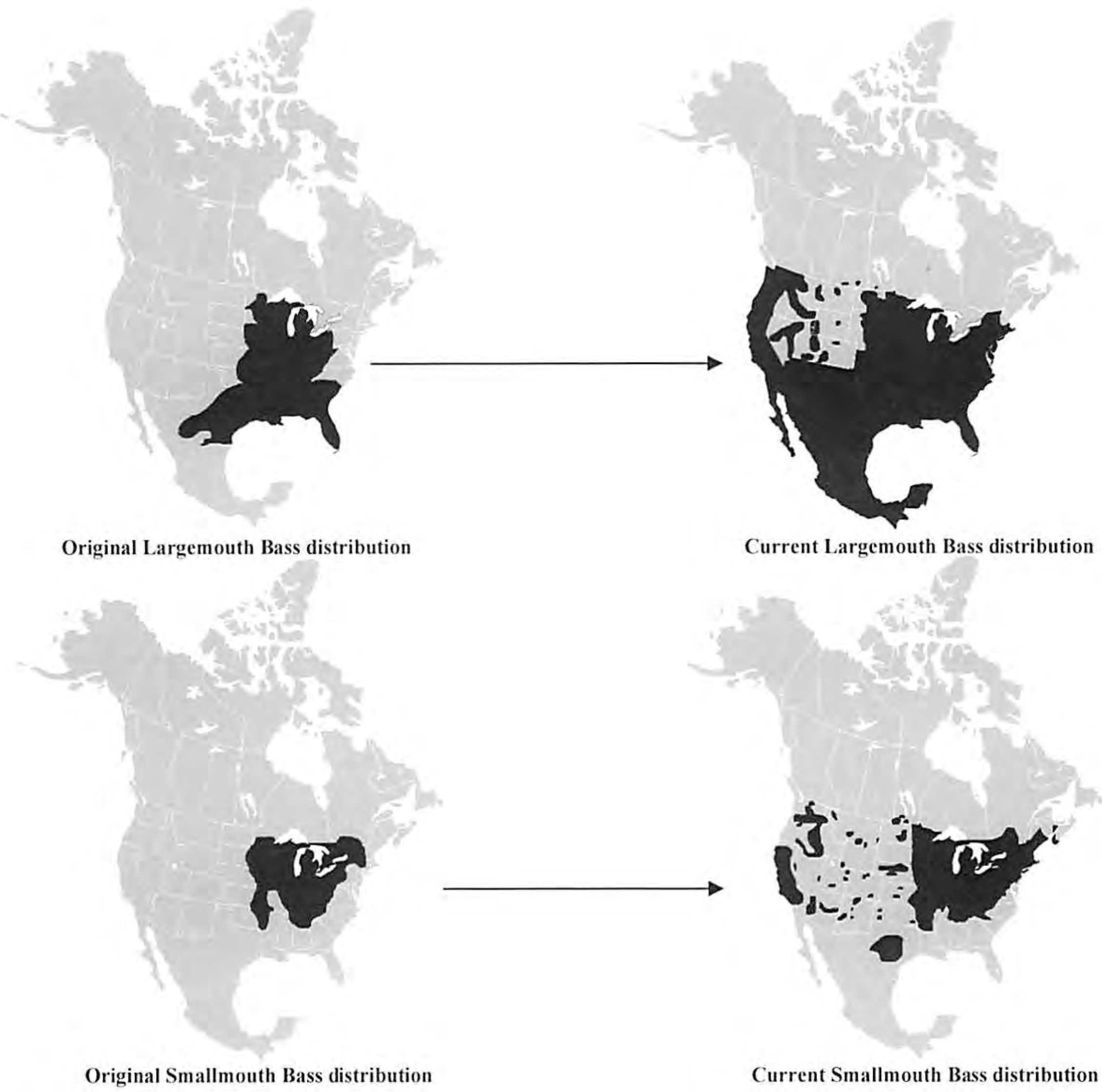

Figure 3.2.1. Original and current distributions (in black) of largemouth bass (*Micropterus salmoides*) and Smallmouth Bass (*M. dolomieu*) in North America. Adapted from Lee et al. (1980).

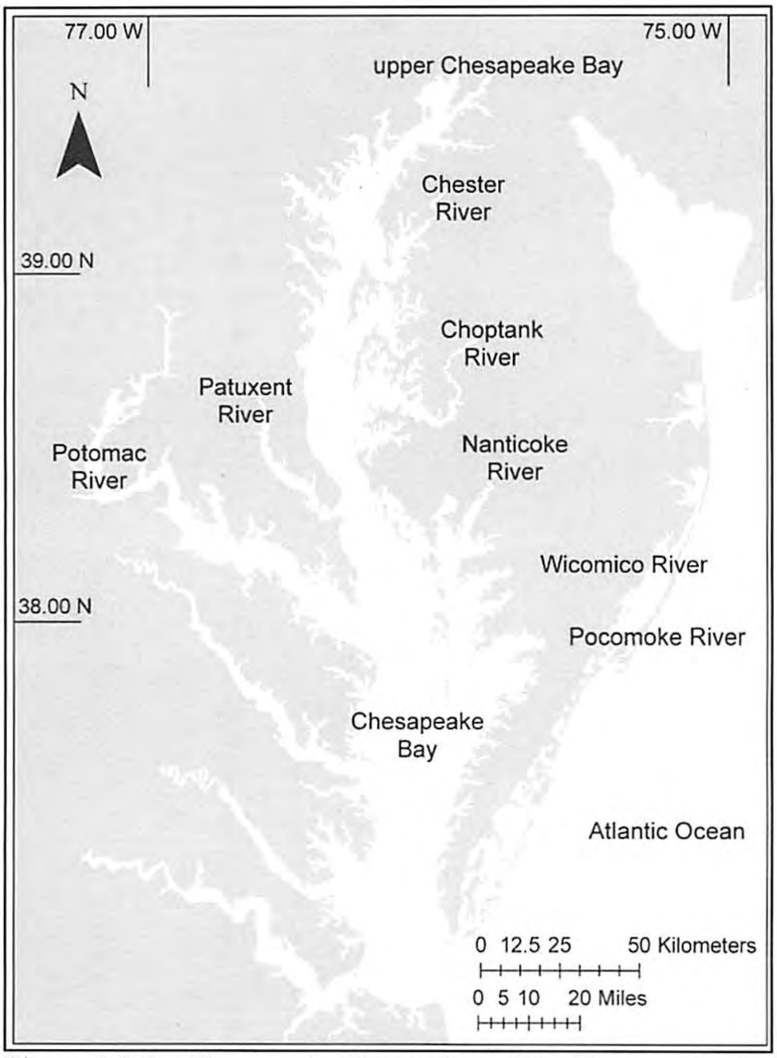

Figure 3.2.2. Chesapeake Bay and notable tidewater areas.

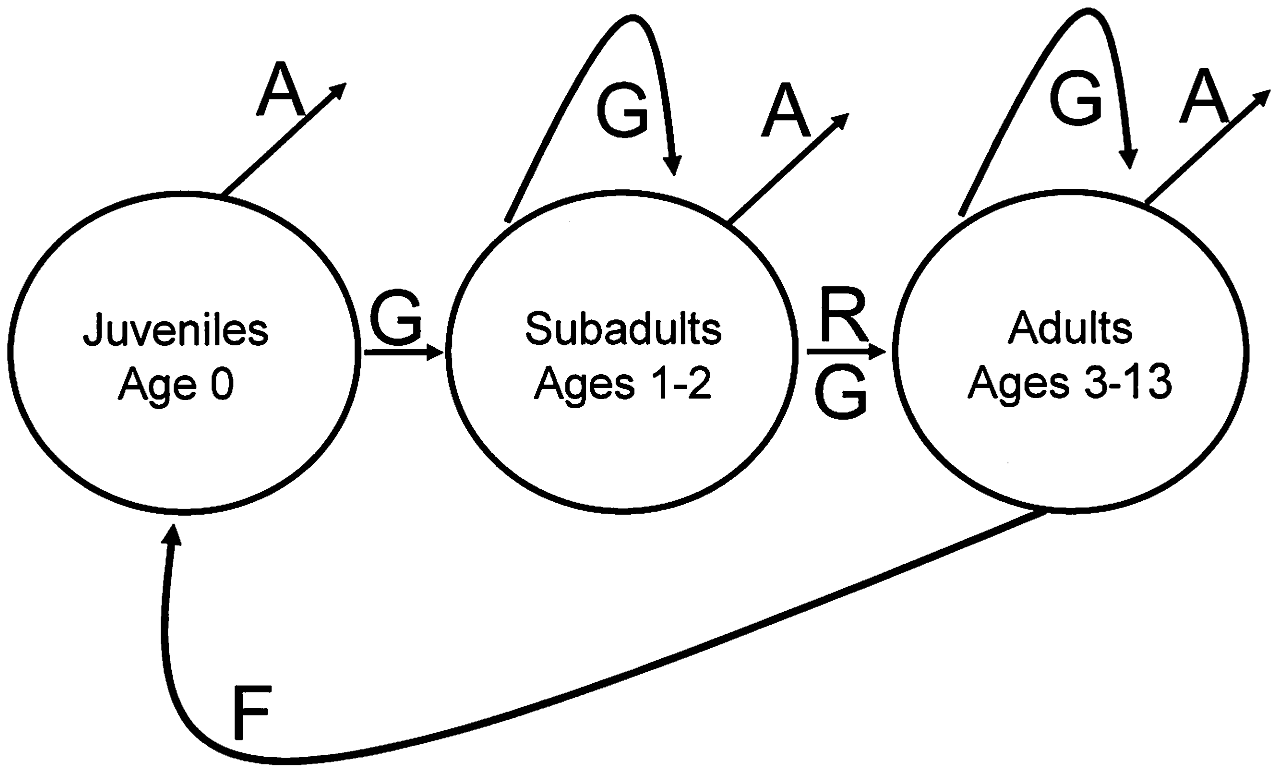

Figure 3.5.1. Life cycle for largemouth bass (*Micropterus salmoides*). Stages are linked by arrows depicting reproduction (F), recruitment (R), growth (G), and mortality (A).

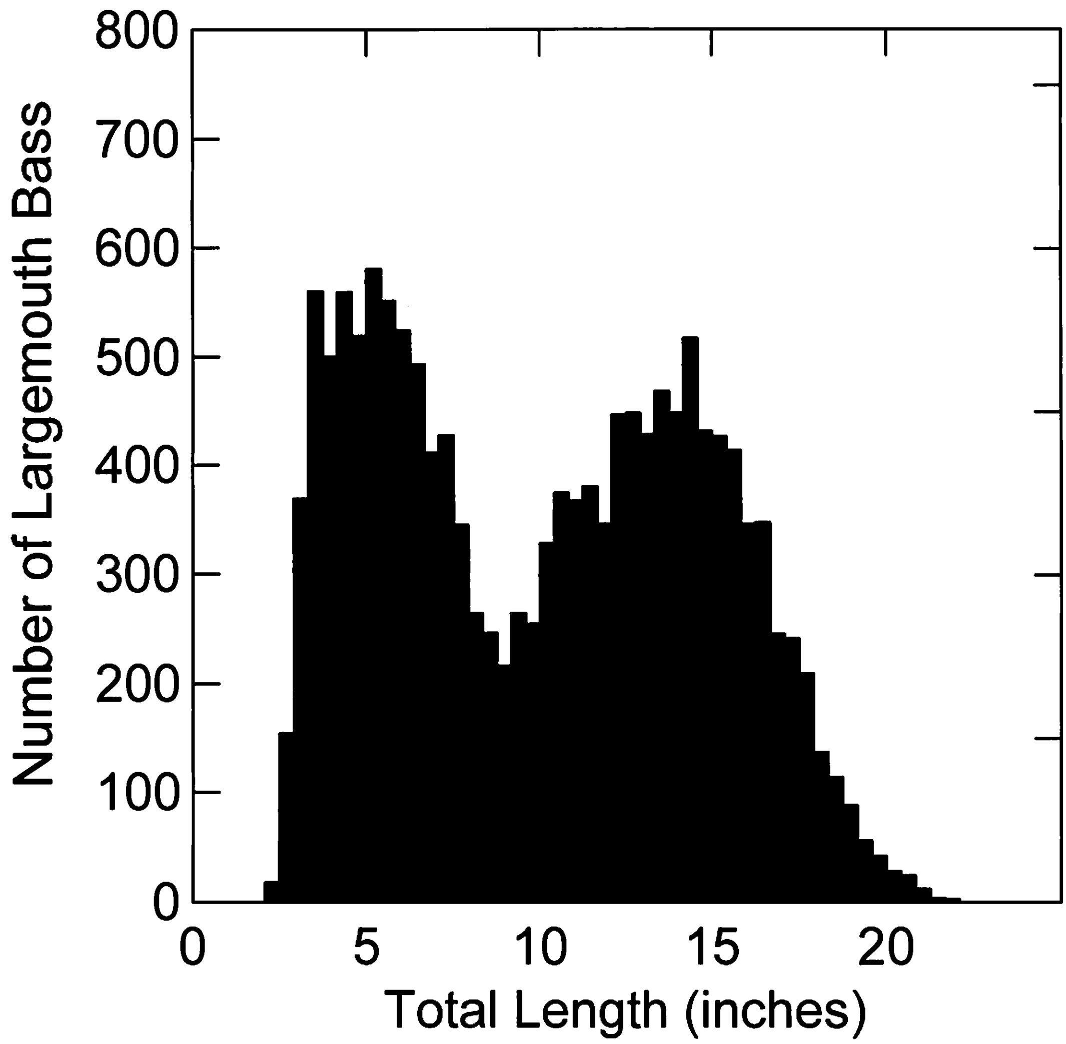

Figure 7.1.1. Length frequency distribution of largemouth bass (*Micropterus salmoides*) collected using a boat electroshocker from tidal rivers of the Chesapeake Bay watershed (1999 – 2009).

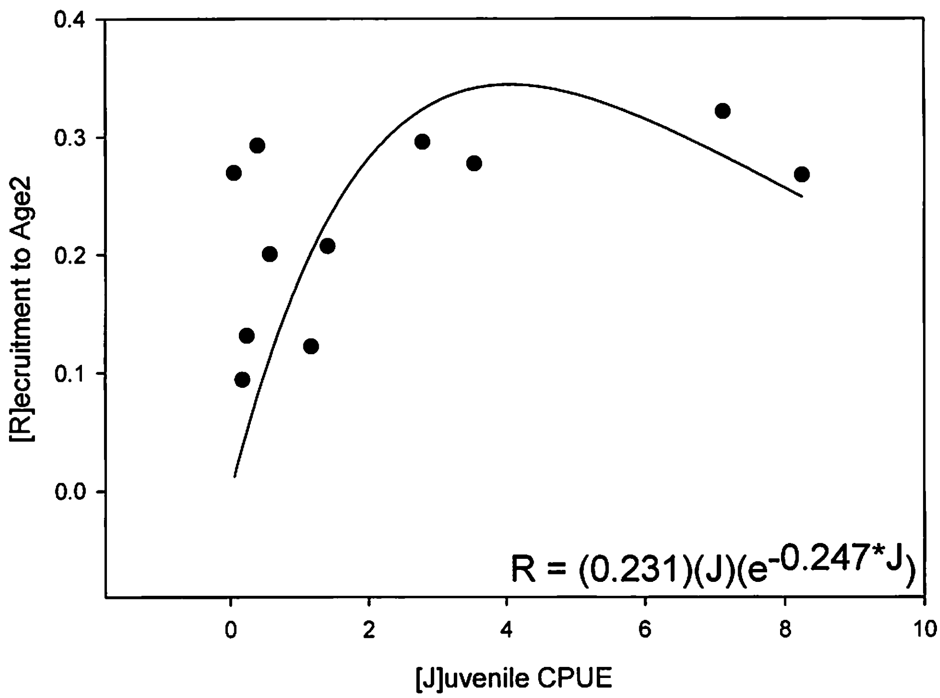

Figure 7.2.1. The relative abundance of juvenile largemouth bass (*Micropterus salmoides*)(geometric mean CPUE; catch (by electroshocking) per unit effort (hour)) predicts the proportion of fish that recruit age 2 in the upper Chesapeake Bay and Potomac River (1999 – 2009).

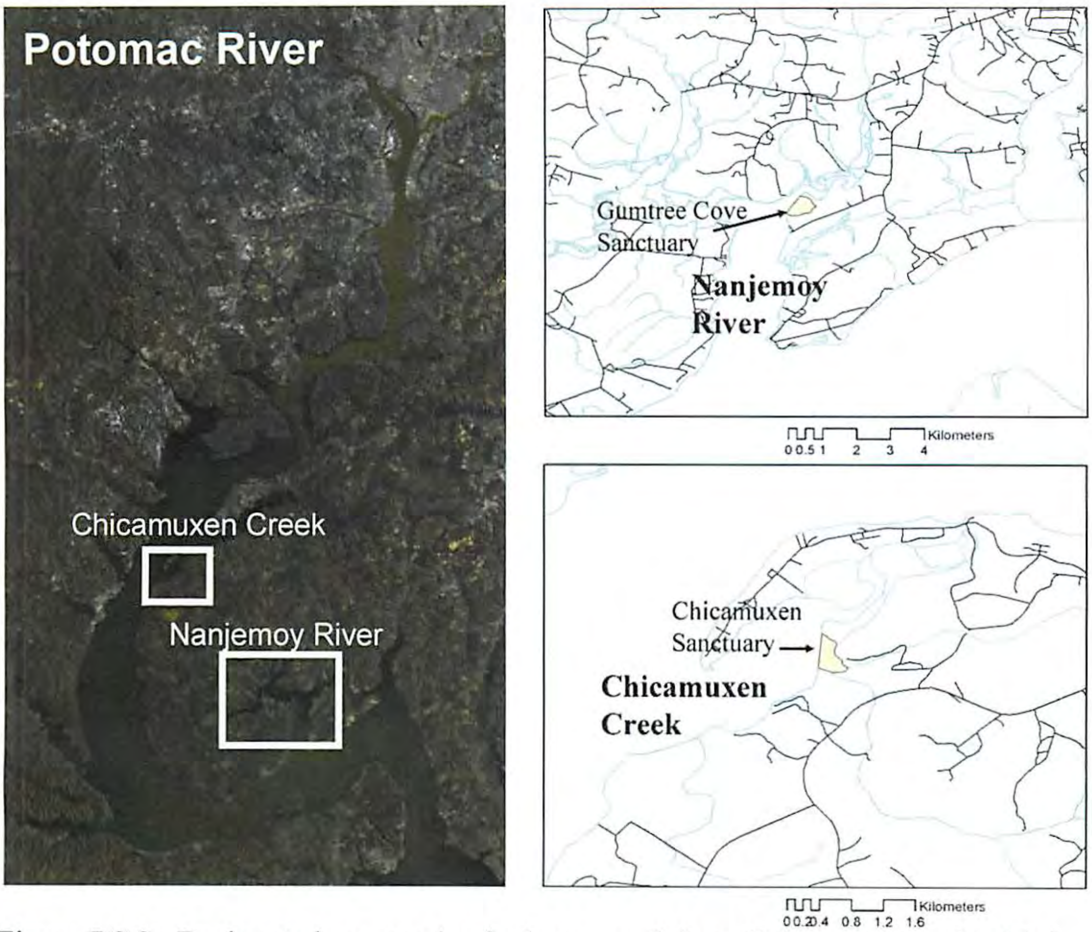

Figure 7.2.2. Designated sanctuaries for largemouth bass (*Micropterus salmoides*) are off-limits to any activities from 1 March – 15 June in the Potomac River drainage

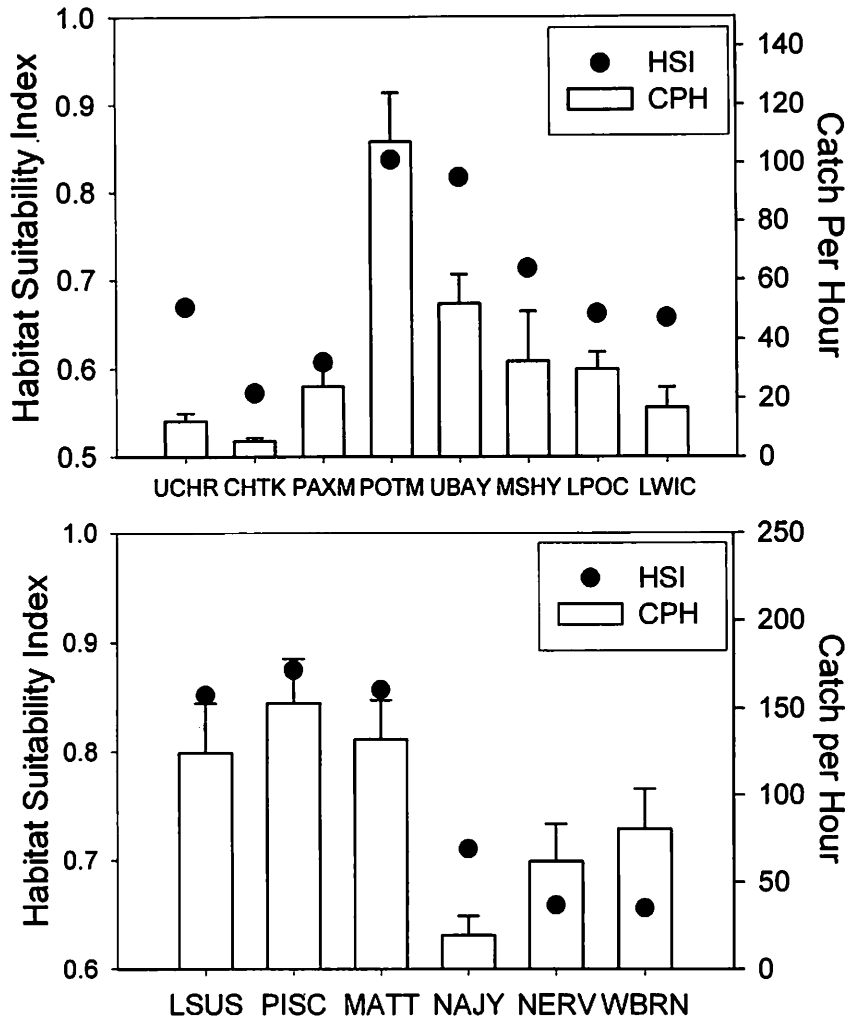

Figure 7.2.3. Habitat suitability index (HSI) adapted for Largemouth Bass (*Micropterus salmoides*) in the Chesapeake Bay watershed. The HSI is plotted with the average catch per hour (CPH) of largemouth bass from electrofishing surveys for drainages or tributaries (number of sites, year of most recent CPH assessment). Error bars of CPH are standard errors of the mean. Site abbreviations are given with the number of sampled areas within each site and the year of sampling: UCHR=Chester River (17,2007); CHTK=Choptank River (29,2009); MSHY=Marshyhope Creek (18,2009); LPOC=Pocomoke River (18,2009); LWIC=Wicomico River (23,2008); POTM=Potomac River (45,2009); PAXM=Patuxent River (34,2008); UBAY=upper Chesapeake Bay (30,2009); WBRN=Western Branch (5,2008); MATT=Mattawoman Creek (8,2009); NAJY=Nanjemoy River (2,2009); PISC=Piscataway Creek (9,2009); NERV = Northeast River (11,2009); LSUS = Susquehanna River (9,2009).

Table 3.4.1. Distances moved during a known period of time by marked and recaptured largemouth bass (*Microperus salmoides*) for Chester River of the Chesapeake Bay watershed (2001 – 2005). UNK = Unknown; NA = Not Available.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Length (mm; TL)
Chester River	3340	6	0.0	0.0	NA
Chester River	3389	240	0.0	0.0	314
Chester River	3393	150	0.0	0.0	229
Chester River	3269	240	0.0	0.0	390
Chester River	3347	240	0.0	0.0	445
Chester River	3280	240	0.0	0.0	283
Chester River	3304	365	0.0	0.0	391
Chester River	3385	5	0.0	0.0	340
Chester River	3369	210	0.0	0.0	417
Chester River	3421	210	0.0	0.0	352
Chester River	3431	270	0.0	0.0	361
Chester River	3561	300	0.0	0.0	325
Chester River	3401	365	0.3	0.0	410
Chester River	3583	1155	0.3	0.0	350
Chester River	3573	300	0.6	0.0	369
Chester River	3600	365	5.2	0.0	325
Chester River	3603	30	24.6	0.8	326
Average				*0.0*	*352*

Table 3.4.2. Distances moved during a known period of time by marked and recaptured largemouth bass (*Microperus salmoides*) for Choptank River of the Chesapeake Bay watershed (2001 – 2005). UNK = Unknown; NA = Not Available.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Length (mm; TL)
Choptank River	3130	134	NA	NA	387
Choptank River	3713	24	NA	NA	323
Choptank River	3221	9	0.0	0.0	453
Choptank River	3194	42	0.0	0.0	445
Choptank River	3154	194	0.0	0.0	393
Choptank River	3150	240	0.0	0.0	359
Choptank River	3202	240	0.0	0.0	370
Choptank River	3107	240	0.0	0.0	371
Choptank River	3123	240	0.0	0.0	300
Choptank River	3121	300	0.0	0.0	311
Choptank River	3124	300	0.0	0.0	311
Choptank River	480	300	0.0	0.0	415
Choptank River	3449	14	0.0	0.0	312
Choptank River	3452	14	0.0	0.0	428
Choptank River	3471	330	0.0	0.0	240
Choptank River	3542	330	0.0	0.0	331
Choptank River	3703	12	0.0	0.0	338
Choptank River	3705	12	0.0	0.0	479
Choptank River	4039	330	0.2	0.0	420
Choptank River	3099	210	1.1	0.0	230
Choptank River	3551	730	4.0	0.0	346
Choptank River	3476	1095	7.6	0.0	258
Average				*0.0*	*355*

Table 3.4.3. Distances moved during a known period of time by marked and recaptured largemouth bass (*Microperus salmoides*) for Potomac River of the Chesapeake Bay watershed (2001 – 2005). UNK = Unknown; NA = Not Available.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Lengtl (mm; TL)
Potomac River	251	194	NA	NA	391
Potomac River	270	2	NA	NA	435
Potomac River	271	19	NA	NA	457
Potomac River	290	351	NA	NA	340
Potomac River	290	3	NA	NA	340
Potomac River	366	254	NA	NA	417
Potomac River	369	365	NA	NA	298
Potomac River	8	330	0.0	0.0	427
Potomac River	26	180	0.0	0.0	NA
Potomac River	71	7	0.0	0.0	365
Potomac River	93	8	0.0	0.0	450
Potomac River	93	210	0.0	0.0	450
Potomac River	118	9	0.0	0.0	349
Potomac River	120	12	0.0	0.0	252
Potomac River	121	12	0.0	0.0	360
Potomac River	133	21	0.0	0.0	352
Potomac River	141	21	0.0	0.0	319
Potomac River	119	27	0.0	0.0	443
Potomac River	51	27	0.0	0.0	407
Potomac River	88	29	0.0	0.0	463
Potomac River	128	64	0.0	0.0	376
Potomac River	104	104	0.0	0.0	370
Potomac River	123	194	0.0	0.0	431
Potomac River	107	570	0.0	0.0	347
Potomac River	70	180	0.0	0.0	432
Potomac River	98	600	0.0	0.0	396
Potomac River	167	30	0.0	0.0	215
Potomac River	226	37	0.0	0.0	352
Potomac River	211	67	0.0	0.0	280
Potomac River	153	180	0.0	0.0	411
Potomac River	155	247	0.0	0.0	448
Potomac River	149	210	0.0	0.0	480
Potomac River	183	240	0.0	0.0	307
Potomac River	169	284	0.0	0.0	337
Potomac River	200	330	0.0	0.0	283
Potomac River	199	630	0.0	0.0	361
Potomac River	202	644	0.0	0.0	490
Potomac River	228	240	0.0	0.0	471
Potomac River	307	365	0.0	0.0	451
Potomac River	346	187	0.0	0.0	358
Potomac River	270	180	0.0	0.0	435
Potomac River	245	180	0.0	0.0	385
Potomac River	245	330	0.0	0.0	385

Table 3.4.3 cont.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Length (mm; TL)
Potomac River	271	330	0.0	0.0	457
Potomac River	267	300	0.0	0.0	314
Potomac River	344	379	0.0	0.0	281
Potomac River	333	390	0.0	0.0	385
Potomac River	333	284	0.0	0.0	385
Potomac River	282	180	0.0	0.0	405
Potomac River	289	210	0.0	0.0	399
Potomac River	343	247	0.0	0.0	410
Potomac River	350	254	0.0	0.0	355
Potomac River	318	321	0.0	0.0	392
Potomac River	365	365	0.0	0.0	210
Potomac River	291	120	0.0	0.0	356
Potomac River	283	210	0.0	0.0	283
Potomac River	285	NA	0.0	NA	396
Potomac River	366	90	0.0	0.0	417
Potomac River	369	234	0.0	0.0	298
Potomac River	416	390	0.0	0.0	223
Potomac River	397	307	0.6	0.0	223
Potomac River	223	21	0.7	0.0	305
Potomac River	52	2	4.2	2.1	335
Potomac River	227	1	6.3	6.3	363
Potomac River	26	330	24.1	0.1	NA
Potomac River	72	660	36.0	0.1	362
Potomac River	231	570	0.0	0.0	241
Potomac River	108	2	NA	NA	328
Potomac River	63	2	NA	NA	334
Potomac River	74	2	NA	NA	273
Potomac River	127	2	NA	NA	405
Potomac River	127	180	NA	NA	405
Potomac River	94	5	NA	NA	452
Potomac River	56	26	NA	NA	290
Potomac River	65	77	NA	NA	397
Potomac River	65	210	NA	NA	397
Potomac River	104	240	NA	NA	370
Potomac River	123	150	NA	NA	431
Potomac River	70	365	NA	NA	432
Potomac River	153	164	NA	NA	411
Potomac River	156	247	NA	NA	451
Potomac River	156	120	NA	NA	451
Potomac River	307	180	NA	NA	451
Potomac River	231	1	NA	NA	241
Average				*0.1*	*371*

Table 3.4.4. Distances moved during a known period of time by marked and recaptured largemouth bass (*Micropterus salmoides*) for areas in the upper Chesapeake Bay (Susquehanna River, Susquehanna Flats, Northeast River) watershed (2001 – 2005). UNK = Unknown; NA = Not Available.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Length (mm; TL)
Upper Bay	3081	510	NA	NA	360
Upper Bay	4786	180	NA	NA	448
Upper Bay	4856	210	NA	NA	274
Upper Bay	4761	210	NA	NA	227
Upper Bay	4928	270	NA	NA	297
Upper Bay	3007	744	NA	NA	451
Upper Bay	1681	50	NA	NA	383
Upper Bay	3033	UNK	0	NA	297
Upper Bay	3023	7	0	0.0	272
Upper Bay	3080	7	0	0.0	350
Upper Bay	3070	24	0	0.0	352
Upper Bay	3056	30	0	0.0	223
Upper Bay	3027	210	0	0.0	362
Upper Bay	3088	270	0	0.0	375
Upper Bay	4845	17	0	0.0	335
Upper Bay	4825	30	0	0.0	268
Upper Bay	1783	4	0	0.0	378
Upper Bay	1801	14	0	0.0	277
Upper Bay	1504	18	0	0.0	315
Upper Bay	1526	18	0	0.0	343
Upper Bay	1717	18	0	0.0	367
Upper Bay	1719	33	0	0.0	382
Upper Bay	1596	365	0	0.0	393
Upper Bay	4720	378	0.28	0.0	253
Upper Bay	4723	NA	0.28	NA	230
Upper Bay	1671	1	0.78	0.8	293
Upper Bay	1506	365	1.78	0.0	328
Upper Bay	1666	1	1.8	1.8	470
Upper Bay	4916	365	1.9	0.0	236
Upper Bay	4877	365	2.67	0.0	248
Upper Bay	1625	365	2.70	0.0	335
Upper Bay	1535	365	5.15	0.0	397
Upper Bay	1674	1	14.8	14.8	450
Upper Bay	1763	365	15.08	0.0	383
Upper Bay	1798	365	15.44	0.0	445
Upper Bay	4838	120	0	0.0	219
Upper Bay	1510	14	0	0.0	323
Upper Bay	1744	4	0	0.0	349
Average				*0.6*	*334*

Table 3.4.5. Distances moved during a known period of time by marked and recaptured largemouth bass (*Micropterus salmoides*) for areas in Patuxent River of the Chesapeake Bay watershed (2001 – 2005). UNK = Unknown; NA = Not Available.

River	Tag Number	Time Span (days)	Distance Moved (km)	Distance Moved (km/day)	Initial Total Length (mm; TL)
Patuxent River	2228	365	2.38	0.0	348
Patuxent River	2005	9	2.86	0.3	215
Patuxent River	2015	9	2.86	0.3	327
Patuxent River	2003	60	3.73	0.1	186
Patuxent River	2002	9	0.0	0.0	277
Patuxent River	2017	10	0.0	0.0	250
Patuxent River	2024	120	0.0	0.0	212
Patuxent River	2022	300	0.0	0.0	452
Patuxent River	2028	150	0.0	0.0	246
Patuxent River	2045	5	0.0	0.0	332
Patuxent River	2046	665	0.0	0.0	356
Patuxent River	3139	240	0.0	0.0	368
Patuxent River	2051	760	0.0	0.0	332
Patuxent River	2076	30	0.0	0.0	378
Patuxent River	2075	120	0.0	0.0	371
Patuxent River	2078	120	0.0	0.0	336
Patuxent River	2113	60	0.0	0.0	215
Patuxent River	2122	60	0.0	0.0	354
Patuxent River	2074	240	0.0	0.0	415
Patuxent River	2069	665	0.0	0.0	374
Patuxent River	2153	665	0.0	0.0	404
Patuxent River	2189	270	0.0	0.0	409
Patuxent River	2167	665	0.0	0.0	445
Patuxent River	2183	665	0.0	0.0	395
Patuxent River	2155	760	0.0	0.0	400
Patuxent River	2043	7	0.5	0.1	342
Patuxent River	2062	4	1.9	0.5	410
Average				*0.0*	*339*

Table 3.5.1. Length-at-age key for largemouth bass (*Micropterus salmoides*). For a fish measured with total length, the probabilities that it belongs to each age cohort (0 – 13) are given.

	Age													
Total Length (mm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13
<200	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
201-250	0.00	0.75	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
251-300	0.00	0.34	0.44	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
301-350	0.00	0.00	0.50	0.32	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
351-400	0.00	0.00	0.00	0.47	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401-429	0.00	0.00	0.00	0.15	0.39	0.22	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.00
430-450	0.00	0.00	0.00	0.00	0.32	0.27	0.19	0.10	0.03	0.02	0.00	0.00	0.00	0.00
451-500	0.00	0.00	0.00	0.00	0.15	0.33	0.23	0.13	0.05	0.02	0.04	0.01	0.01	0.00
501-550	0.00	0.00	0.00	0.00	0.05	0.16	0.16	0.16	0.21	0.21	0.00	0.00	0.00	0.05
>551	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.25

Table 5.5.1. History of hatchery-released largemouth bass (*Micropterus salmoides*) to tidewater of the Chesapeake Bay watershed (1982 – 2013).

River	Year (s)	Number Released	Stage Released
Back Creek	1982, 1984	42,880	Fry
Blackwater	1991-1994, 1997	181,353	Fingerlings
	1990	1352	Fry
Chester	1985, 1990-1997 2001, 2003, 2007	695,414	Fingerlings
	1982, 1986-1990	74,470	Fry
	2002	15,177	Unknown
Chicamocomico	1998	35,824	Unknown
Choptank	1991, 1994-1996 2006, 2009-13	284,242	Fingerlings
	1989-1990, 2009-13	719,334	Fry
	2007	21,791	Unknown
Little Choptank	1981, 1983-1984, 1986	64,390	Fry
Manokin	1989	10,400	Fry
Marshyhope	2003	15,000	Fingerlings
Middle	2001, 2003, 2009-10	25,189	Fingerlings
Patuxent	2008	150	Adults
	1982-2007, 2009-13	1,028,736	Fingerlings
	2004-2005, 2011	263,000	Fry
Pocomoke	1993-1994, 2003	47,942	Fingerlings
Potomac	2005-2006	399	Adult
	1993, 2003, 2005-07	73,069	Fingerlings
Transquaking	1994, 1996	40,837	Fingerlings
Upper Bay	1984 – 1986, 1993 – 1998, 2003	578,317	Fingerlings
	1980 – 1984, 1986 – 1988	456,034	Fry
	1988, 1994, 1998	59,482	Unknown
Wicomico	1995, 2003, 2012	36,471	Fingerlings

Table 7.3.1. Reference points of biological indices of largemouth bass (*Micropterus salmoides*) in tidal tributaries of the Chesapeake Bay were generated from Cleveland 25th and 75th percentiles for available years (N = number of years) of survey data (1999 – 2013) and creel data (2003 – 2013). Indices and additional reference points are explained in section 7.0. Abbreviations are: catch per unit effort (CPUE) for all Largemouth Bass and juveniles (Juv), proportional size distribution (PSD) for juveniles, 200-305 mm and 200-381 mm fish, proportional occurrence (OCC) of juveniles among sampled sites, relative weight (Wr), body condition (Kn), instantaneous mortality (Z), growth rates (GR) for exponential (EXP) and von Bertalanffy growth models (VBGF), the slope of the length-weight regression (LW), mortality at the weigh-in scale (IM) for small (Sm) and large (Lg) tournaments (TX), catch per angler hour (CPAH) for tournaments, and the habitat suitability index (HSI).

Fishery Independent		*CPUE*	*Cor-CPUE*	PSD_{305}	PSD_{381}	W_r	K_n	Juv_{CPUE}	$Juv_{\%OCC}$	Juv_{PSD}	*-Z*	*GR-EXP*	*GR-VBGF*	*LW-Slope*
CHESTER (N = 9)	25th	13.796	0.985	0.635	0.293	0.999	0.994	11.914	0.123	0.065	0.685	60.296	60.482	3.142
CHESTER (N = 9)	75th	41.756	4.555	0.823	0.379	1.003	1.003	25.575	0.631	0.219	0.605	65.394	65.582	3.230
CHOPTANK (N = 13)	**25th**	**14.232**	**1.079**	**0.630**	**0.295**	**0.997**	**0.993**	**10.481**	**0.279**	**0.149**	**0.774**	**64.124**	**64.292**	**3.218**
CHOPTANK (N = 13)	**75th**	**48.350**	**3.112**	**0.739**	**0.351**	**1.002**	**1.005**	**22.087**	**0.433**	**0.327**	**0.540**	**67.744**	**67.982**	**3.310**
POTOMAC (N = 14)	25th	70.415	8.051	0.556	0.255	0.999	0.986	18.532	0.571	0.327	0.884	61.885	62.116	3.134
POTOMAC (N = 14)	75th	101.315	17.159	0.796	0.345	1.011	1.000	38.552	0.833	0.580	0.653	69.800	69.605	3.301
UPPERBAY (N = 13)	**25th**	**63.458**	**5.409**	**0.697**	**0.310**	**1.002**	**0.990**	**22.011**	**0.500**	**0.621**	**0.767**	**64.083**	**64.336**	**3.168**
UPPERBAY (N = 13)	**75th**	**101.299**	**12.069**	**0.820**	**0.560**	**1.006**	**0.998**	**49.713**	**0.769**	**0.842**	**0.603**	**68.469**	**68.819**	**3.236**
Additional Reference		*na*	*na*	*≈ 0.572*	*≈ 0.245*	*≈ 1.000*	*≈ 1.000*	*na*	*na*	*na*	*≈ 0.57*	*≈ 68.44*	*≈ 68.44*	*≈ 3.00*

		Spawning Season			Non-Spawning Season		
Fishery Dependent		*Sm TX IM*	*Lg TX IM*	*TX CPAH*	*Sm TX IM*	*Lg TX IM*	*TX CPAH*
N		10	10	10	10	9	10
POTOMAC	25th	0.012	0.013	0.206	0.013	0.018	0.345
POTOMAC	75th	0.017	0.029	0.288	0.025	0.036	0.419
N		**9**	**5**	**10**	**10**	**7**	**9**
UPPERBAY	**25th**	**0.004**	**0.000**	**0.278**	**0.007**	**0.010**	**0.164**
UPPERBAY	**75th**	**0.018**	**0.022**	**0.307**	**0.034**	**0.027**	**0.219**
Additional Reference		*≤ 0.05*	*≤ 0.05*	*na*	*≤ 0.05*	*≤ 0.05*	*na*

Habitat		*HSI*
N		8
ALL RIVERS	25th	0.714
ALL RIVERS	75th	0.817
Additional Reference		*na*

Table 8.6.2. A table of potential fishery problems and several possible management actions that can be taken to mitigate the problem. There are 6 potential management actions: A) change in creel limits; B) change or enforce size limit; C) no possession (seasonal or spatial); D) fishing closure (seasonal or spatial); E) stocking; F) habitat enhancement or protection; and G) angler awareness strategies to include multimedia campaigns and seminars. In response to management actions, the indices that are likely to be responsive within 3 years are given. Indices are explained in section 7.0. Abbreviations are: catch per unit effort (CPUE) for all Largemouth Bass and juveniles (Juv), proportional size distribution (PSD) for juveniles, 200-305 mm and 200-381 mm fish, proportional occurrence (OCC) of juveniles among sampled sites, relative weight (Wr), body condition (Kn), instantaneous mortality (Z), growth rates (GR) for exponential (EXP) and von Bertalanffy growth models (VBGF), the slope of the length-weight regression (LW), mortality at the weigh-in scale (IM) for small (Sm) and large (Lg) tournaments (TX), catch per angler hour (CPAH) for tournaments, and the habitat suitability index (HSI).

Problem	Action(s)	Indices
Poor Recruitment	E, F	PSD_{305}, Juv_{CPUE}, $Juv_{\%OCC}$, JUV_{PSD}, CPUE, Cor-CPUE, HSI
Overfishing	A, B, C, D,G	CPUE, Cor-CPUE, Z, NS and SP CPAH indices for TXs, NS and SP IM indices for Lg and Sm TXs, PSD_{381}, PSD_{305}
Few Big Fish (overfished)	A, B, C, D, E, G	Z, PSD_{381}, CPUE, Cor-CPUE, Juv_{CPUE} SP CPAH for TX
Too Few Fish	A, C, D, E, G	CPUE, Cor-CPUE, NS and SP CPAH indices for TXs
Few Fat Fish	F	W_r, K_n, GR-VBGF, GR-EXP, L-W slope
Poor Habitat	F, G	W_r, K_n, GR-VBGF, GR-EXP, L-W slope Juv_{CPUE}, Juv_{PSD}, $Juv_{\%occ}$, HSI