CHAPTER 7: WEAKFISH

Populated from Amendment IV to the Weakfish FMP (2002)

Section I. General Description of Habitat

Weakfish are another sciaenid species that uses a variety of coastal and estuarine habitats throughout their life. Although spawning may take place closer to estuaries or in lower estuaries (as opposed to offshore), larval weakfish recruit to upper estuarine habitats but move down the estuary as they grow. Much work has been done on juvenile weakfish, particularly with respect to hypoxia, and like other sciaenids, weakfish exhibit a complex relationship with DO concentrations. Adults often move out of estuaries and spawn in nearshore habitats. Unlike other sciaenids, weakfish exhibit natal homing behaviors.

Part A. Spawning Habitat

Geographic and Temporal Patterns of Migration

The vast majority of age-1 weakfish are mature (Lowerre-Barbieri et al. 1996a; Nye and Targett 2008) and begin spawning in late winter in the south and progressively later in the spring in northern estuaries. Spawning typically peaks in May and June, and ends in the late summer, though temporal variability in eggs and larvae have been observed that suggest either multiple spawning peaks (Goshorn and Epifanio 1991) or an annual shift in peaks (Lowerre-Barbieri et al. 1996b). Regardless of the variability, weakfish are considered to have a protracted spawning period consisting of several months in most locations, with multiple reports of spawning (inferred from drumming) taking place in the evening (Connaughton and Taylor 1995; Luczkovich et al. 2008).

Spawning activities occur near the coast or within estuaries, many of which are natal estuaries (or adjacent estuaries) (Thorrold et al. 1998; 2001). In Delaware Bay, inshore, midwater, and offshore sites (all <6 km from shore) have reported spawning-associated drumming from mid-May to late-July (Connaughton and Taylor 1995). The drumming suggests the presence of large spawning aggregations in shallow waters earlier in the spawning season, with midwater and offshore drumming activity increasing later in the spawning season. It was hypothesized that the spawning aggregates were not just moving as a function of time, but as a function of increasing inshore temperatures, and that spawning may have continued past July in deeper waters than the study examined.

The spawning period in North Carolina is longer and begins in March and continues to September (Merriner 1976). This has led to clinal variability in life histories and reproduction (Shepherd and Grimes 1984). Weakfish that spawn in southern locations live shorter lives and reproduce at smaller sizes compared to weakfish living in northern locations. Shepherd and Grimes (1984) interpret this as ‘bet hedging’ (Stearns 1976) against cold spring waters that prevent weakfish egg from hatching. That is, northern weakfish have longer lives and more annual reproductive events because northern bays are more temperature variable, whereas southern bays are warm enough to ensure hatching. Unique spatial life histories combined with the strong evidence for natal homing suggests that while habitat for spawning and other life stages may be variable, spatial structuring exists, and estuary-specific habitat use and preference may be more important population-level structuring.

Salinity

Lower estuary and coastal spawning habitats experience moderate to high salinities. No studies have explicitly investigated salinity in relation to spawning habitat; however some studies have reported salinity values during inferred spawning events. Luczkovich et al. (1999) reported mean salinity to be 28.8 ppt (range 15.1–34.7 ppt). Another study found that weakfish were commonly heard in higher salinity habitats (mean 15.4 ppt, range 7.8–28.3 ppt).

Substrate

Although depth is considered an important spawning habitat variable (Luczkovich et al. 2008), no studies report on spawning habitat substrate. Additionally, weakfish eggs are pelagic and thus substrate and bottom features are considered minimally important during and after spawning.

Temperature

Photoperiod and temperature are thought to drive seasonal maturation (Epifanio et al. 1988), along with the hypothesized avoidance of cooler spring temperatures that pose a mortality threat to larval and juvenile weakfish (Shepherd and Grimes 1984). Luczkovich et al. (1999) reported weakfish drumming in a mean temperature of 20.7°C (range 19.1–22.6°C); another study reported bottom temperatures associated with weakfish drumming to average 25.3°C (range 17–31°C) (Luczkovich et al. 2008).

Dissolved Oxygen

DO is not well reported in adult and spawning weakfish, and based on spawning locations (deep estuaries and nearshore) low DO and hypoxic conditions are likely rare. Luczkovich et al. (2008) did measure bottom and surface DO and reported means of 7.9 and 7.6 mg L^{-1}, respectively. In the same study, only one sonobuoy reported any drumming noises at <4.0 mg L^{-1} DO, although other sciaenids (spotted seatrout and silver perch) both exhibited spawning-associated noises at low DO, even hypoxic conditions.

Feeding Behavior

No studies have reported the feeding habits of spawning weakfish, though it might be safely inferred that adult feeding habits apply to spawners, particularly because the duration of the spawning season suggests that spawning is integrated into their adult lives, rather than a small, discrete period of time that may necessitate a different foraging strategy.

Competition and Predation

No studies have examined competition or predation on spawning weakfish, though it might be inferred that adult competition and predation descriptions apply to spawning adults. Adults are commonly preyed on by bluefish and other estuarine predatory fishes.

Part B. Egg Habitat

Nursery habitats are those areas in which larval weakfish reside or migrate after hatching until they reach sexual maturity (90% by age 1, 100% by age 2). These areas include the nearshore waters as well as the bays, estuaries, and sounds to which they are transported by currents and hatch.

Geographic and Temporal Patterns of Migration

Mature weakfish spawn in the nearshore ocean and lower reaches of large east coast estuaries. Egg hatching occurs about 36–40 h post-fertilization (Welsh and Breder 1923) at 20–21°C. Spawning begins in the southern region of the distribution (e.g., North Carolina) early in the spring (March; Merriner 1976) and later in northern bays and estuaries. Because spawning can continue into the summer (July in the Mid Atlantic Bight) (Berrien and Sibunka 1999) and there are reports of two peaks in spawning (Delaware Bay: Thomas 1971; Goshorn and Epifanio 1991), it is likely that weakfish eggs experience a range of conditions and that local adaptation may influence differences in latitudinal environments. Additionally, Berrien et al. (1978) report weakfish larvae occurring from nearshore waters to 70 km offshore, suggesting that eggs may be found over a wide geographic area that extends away from the coast.

Salinity

Olney (1983) noted a distinct polyhaline distribution of sciaenid eggs, with high concentrations at the mouth of the Chesapeake Bay. Although he was not able to identify the eggs to the species level, the large number of eggs collected and the timing of collection strongly suggest that weakfish eggs were present, if not a substantial percentage of the sample. Olney (1983) reported that sampling across a range of salinities (11–31 ppt) resulted in 84% of sciaenid eggs collected in salinities >26 ppt. The Chesapeake Bay Weakfish and Spotted Seatrout Fishery Management Plan (Chesapeake Bay Program 1990) reports fertilized eggs collected between 12.1 and 31.3 ppt.

Substrate

Like many marine fish eggs, weakfish eggs are buoyant and the entire egg phase takes place in the pelagic zone of nearshore or lower estuarine waters, and thus substrate is not likely encountered.

Temperature

Minimum temperature is likely the main driver of weakfish reproduction and thus a necessary condition for egg development. Harmic (1958) reported a range of 12–16°C necessary for successful hatching; however, weakfish eggs have been collected across a range of temperatures (17–26.5°C) (Chesapeake Bay Program 1990), which likely reflects their broad geographic occurrence.

Dissolved Oxygen

DO is probably not an issue for short-lived weakfish eggs that remain buoyant and pelagic, and thus out of hypoxic and anoxic bottom waters. However, Harmic (1958) reported reduced hatching success at DO <4.3 mg L^{-1}.

Feeding Behavior

Weakfish eggs subsist entirely off the yolk sac prior to hatch.

Competition and Predation

Weakfish eggs likely do not enter into any meaningful ecological competition, as their habitat demands are basic (and largely met by the offshore conditions). Predation of eggs undoubtedly occurs and is likely dominated by gelatinous zooplankton (Purcell 1985; Olney and Boehlert 1988; Cowan et al. 1992). Although potentially large numbers of eggs are killed from predation, there is no initial reason to think that pelagic oceanic predators are targeting weakfish eggs over other, similar pelagic eggs.

Part C. Larval Habitat

Nursery habitats are those areas in which larval weakfish reside or migrate after hatching until they reach sexual maturity (90% by age 1, 100% by age 2). These areas include the nearshore waters as well as the bays, estuaries, and sounds to which they are transported by currents or in which they hatch.

Geographic and Temporal Patterns of Migration

Weakfish larvae are widely distributed and have been reported from nearshore waters to 70 km offshore (Berrien et al. 1978), as well as throughout estuaries. Wherever eggs hatch, larvae spend approximately three weeks moving toward or up estuaries. In both Delaware and Chesapeake Bays, larvae have been sampled throughout the estuary, suggesting relatively quick and even post-hatch dispersal, or substantial within-estuary reproduction. Additionally, the protracted spawning season, taking place over months in many locations, provides a constant source of larvae to estuarine habitats. Olney (1983) found weakfish larvae distributed throughout the lower Chesapeake Bay. Ribeiro et al. (2015) identified weakfish as a component of the summer larval fish assemblage in the York River estuary of the Chesapeake Bay.

Larval weakfish migration has been an active area of research. Rowe and Epifanio (1994a) report that in Delaware Bay larvae were more abundant at depth (2 and 7 m off the bottom) than at surface. They report no effect of tidal stage on yolk sac larvae, but greater abundance of post-yolk sac larvae during flood tide, suggesting that post-yolk sac may use selective tidal stream transport to migrate into upper estuarine regions. Rowe and Epifanio (1994b) report mean larval flux to be greater during flood phase for all early and late stage larvae, but not for yolk sac larvae. Together, these studies suggest that while yolk sac larvae are passively transported as part of general sub-tidal circulation, post-yolk sac larvae use selective tidal stream transport to migrate up estuaries.

Salinity

Owing to the wide distribution of weakfish larvae, a range of salinities is likely tolerated. In the lower Chesapeake Bay, Olney (1983) reported salinities during larval weakfish sampling to range from 11.2 to 31.5 ppt. Rowe and Epifanio (1994a) report salinities of migrating larvae to be 20.1–27.8 ppt.

Substrate

Larval weakfish are planktonic (Welsh and Breder 1923) and thus do not come in contact with the substrate over which they are dispersed.

Temperature

As with salinity, both Olney (1983) and Rowe and Epifanio (1994a) provide similar temperature ranges for larval weakfish, with a range of 18.1–28.1°C and 16.8–22.9°C, respectively.

Dissolved Oxygen

Due to the relatively short larval duration, the pelagic habitat, and the migratory behaviors of weakfish larvae, it is unlikely that they encounter any habitats in which DO imposes a limitation or threat currently.

Feeding Behavior
A number of studies have investigated the feeding behaviors of larval weakfish, both in laboratory settings as well as in the field. Goshorn and Epifanio (1991) found that larval weakfish began exogenous feeding 2 days post hatch at 20°C and that invertebrate eggs and tintinnids were important prey (larvae <0.5 mm notochord length, NL). Polycheate larvae were important for all size classes and dominant in weakfish >3.55 mm NL. Small copepods (*Acartia tonsa*) were also important for all weakfish larvae, but dominant at sizes >7.55 mm NL.

Competition and Predation
Little work has looked at competition and predation of larval weakfish. Some competition likely takes place when a high-density larval patch settles on limited habitat; however, the wide range of settled habitats and protracted spawning season suggest that widespread competition is unlikely. Furthermore, work on natal homing (Thorrold et al. 1998; 2001) suggests that adult weakfish return to natal estuaries to spawn, adding a level of population structure to mitigate against widespread competition.

No studies have explicitly reported on predation of larval weakfish, although larvae are likely subject to predation by a range of estuarine predators. Cowan et al. (1992) examined hydromedusa (*Nemopsis bachei*) and ctenphore (*Mnemiopsis leidyi*) predation on black drum, suggesting that high densities of hydrozoans could impact larval weakfish abundance.

Part C. Juvenile Habitat

Juvenile weakfish inhabit deeper waters of bays, estuaries, and sounds, including their tributary rivers. They also use the nearshore Atlantic Ocean as nursery areas. In North Carolina and other states, juveniles are associated with sand or sand/seagreass bottom. They feed initially on zooplankton, switching to mysid shrimp and anchovies as they grow. In Chesapeake and Delaware Bays, they migrate to the Atlantic Ocean by December.

Geographic and Temporal Patterns of Migration
The general pattern of habitat use by juvenile weakfish is estuarine-wide, but often beginning in late spring and early summer in upper estuarine habitats (or even freshwater) (Massman 1954) and moving down estuary during the fall to nearshore habitats.

Able et al. (2001) found high abundance of weakfish in June throughout Delaware Bay tidal creeks, and the large numbers of fish were attributed somewhat to high recruitment and that higher abundances were observed in upper bay sites over lower bay sites. Paperno et al. (2000) also reported that juvenile weakfish recruited to all parts of Delaware Bay, but higher abundances were observed in lower salinities. Higher temperature and lowers salinity habitats are preferred by juveniles early in the season or for earlier cohorts (Lankford and Targett 1994).

In the York River, Virginia, juveniles were caught in spring and summer, to which Chao and Musick (1977) attributed water temperature and DO as the most important factor driving distribution. Weakfish were abundant in late summer and fall with age 1 fish returning in the spring but young-of-year individuals absent until late summer. Inshore and nearshore of the Chesapeake Bay, a pattern of similar habitat use in early and late summer was discovered when comparing inner continental shelf and estuarine habitats, with an expected strong shift to inner continental shelf habitat use over estuary by fall (Woodland et al. 2012). Growth rates between habitats were similar, suggesting no growth advantage in either habitat, but in late summer larger fish were concentrated in the inner continental shelf while smaller fish were in estuary. Pincin et al. (2014) examined weakfish abundance in coastal Maryland bays and found no effect of seagrass and Olney and Boehlert (1988) observed that larval weakfish are rare in seagrass sites.

Salinity

Juvenile weakfish salinity preferences likely increase with size and age and is broad since weakfish use oligohaline to polyhaline habitats throughout the first year of life. Lankford and Targett (1994) found salinity effects on specific growth rates and gross growth efficiencies were optimal 20 ppt for 40–50 mm fish. Feeding rate was significantly higher at 5 ppt than at 19 ppt salinity.

Substrate

Weakfish are pelagic predators (Chao and Musick 1977; Horodysky et al. 2008) that are not expected to interact with the benthos so substrate type is not an ecologically important environmental variable for weakfish.

Temperature

Juvenile weakfish likely tolerate a wide range of temperatures, though temperature is considered to be an important variable driving their distribution. Although temperature has been documented in a number of descriptive studies, Lankford and Targett (1994) examined temperature effects on specific growth rates and gross growth efficiencies, and found significant effects at 27 and 29°C treatments. Overall, mean feeding rates increased with increasing temperature (from experimental treatments of 20–28°C).

Dissolved Oxygen

A relatively large body of research has been done on the effects of DO levels on juvenile weakfish. Tyler and Targett (2007) reported low weakfish densities in early morning (during diurnal hypoxic conditions) but relatively high weakfish densities later in the day and an avoidance threshold of 2.0 mg L^{-1}. A lower threshold of avoidance (<1.4 mg L^{-1} DO) was reported for hypoxia-acclimated fish (Brady and Targett 2013), supporting the idea that not only are these fish less inclined to swim to avoid hypoxia, but they can tolerate lower levels than fish that have never been exposed to hypoxia. Stierhoff et al. 2009 reported avoidance of low DO (≤1 mg L^{-1}), but no preference to DO levels > 2.0mg L^{-1}, suggesting weakfish are tolerant of low DO conditions.

Feeding Behavior

Juvenile weakfish experience ontogenetic diet shifts (Chao and Musick 1977; Nemerson and Able 2004; Deary 2015). In the Delaware Bay, mysid shrimp (*Neomysis americana*) dominated the diet (Grecay and Targett 1996a). Larger juvenile weakfish (67–183 mm) in the Chesapeake Bay consumed bay anchovy (*Anchoa mitchilli*) and mysid shrimp (*N. americana*) (Chao and Musick 1977), which highlights the transition from mysids to fish (piscivory) around 60 mm TL (Thomas 1971).

Competition and Predation

Due to the wide spatial distribution and extended temporal period of recruiting juvenile weakfish, it is unlikely that any large-scale competitive factors drive the population. Annual fluctuations in recruitment and micro-scale habitat and foraging competition probably result in patches of competition. Forage items are typically not limited, though in years of low prey abundance (and high turbidity) (Grecay and Targett 1996b) competition may result in decreased growth rates for less fit individuals.

Juvenile weakfish are likely preyed upon opportunistically by a range of estuarine and nearshore predators (fishes); however, Mancini and Able (2005) report silver perch and bluefish as the main documented predators. Large predators are typically less abundant or absent in oligotrophic, upper estuarine areas, yet as temperatures increase in summer, the interactions of temperature and salinity result in a suboptimal physicochemical environment (Lankford and Targett 1994; Lankford and Targett 1997).

Part D. Adult Habitat

Adult weakfish reside in estuarine and nearshore Atlantic Ocean habitats. Warming of coastal waters in the spring cues inshore migration and northward from the wintering grounds to bays, estuaries, and sounds. Larger fish move inshore first and tend to congregate in the northern part of the range. Catch data from commercial fisheries in Chesapeake and Delaware Bays and Pamlico Sound indicate that the larger fish are followed by smaller weakfish in summer. Shortly after their initial spring appearance, weakfish return to the larger bays and nearshore ocean to spawn. In northern areas, a greater portion of the adults spend the summer in the ocean rather than estuaries.

Weakfish form aggregations and move offshore as temperatures decline in the fall. They move generally offshore and southward. The continental shelf from Chesapeake Bay to Cape Lookout, North Carolina appears to be the major wintering ground at depths of 18–55 m. Some weakfish remain in inshore waters from North Carolina southward.

Geographic and Temporal Patterns of Migration

After juvenile weakfish overwinter in offshore environments, the vast majority (>90%) mature during their second year of life (age-1). The general pattern of adult habitat use is considered to be seasonal migrations south (toward Cape Hatteras, North Carolina) and offshore in fall and winter, and north and inshore during spring and summer (Able and Fahay 2010). Summer inshore habitats are shallow, averaging around 17 m, while offshore winter habitats average 59 m, but include depths up to 159 m (Able and Fahay 2010).

Off the New Jersey coast in the summer, weakfish occurred primarily inshore in shallow strata in coastal New Jersey (the Navesink River) during the summer. Tagged weakfish left the estuary when temperatures were above 28°C and when freshwater discharge was low (<2 $m^3 s^{-1}$). Smaller weakfish were more like to have longer overall residence times, although even large individuals (>400 mm TL) demonstrated estuarine habitat use ≥40 d (with some >60 d residence). These tagged weakfish were also found to leave the estuary when temperatures decreased below 23°C. Thorrold et al. (1998; 2001) concluded that 60–81% of weakfish exhibit estuarine fidelity as adults, despite the fact that the same fish from across the eastern U.S. were genetically panmictic.

Salinity

Adult weakfish occur primarily in nearshore or lower estuarine habitats where salinities are near full seawater. In a review of weakfish, Mercer (1989) report that adults were collected in salinities ranging from 6.6–32.3 ppt. Adult weakfish prefer higher salinities when inhabitating estuaries in the summer; Rountree and Able (1992) sampled adults in 22–32 ppt shallow sub- and intertidal marsh creeks in New Jersey. As with other habitat variables, salinity is probably tolerated at variable levels reflected in the variety of inshore and nearshore habitats populated by adult weakfish.

Substrate
In accordance with the variety of habitats used by adults, specific habitat use or habitat preference in adult weakfish has not been reported. Able and Fahay (2010) report the use of sandy or muddy substrates by adults in bays and estuaries, but substrates used are likely as variable as the overall habitats in which adult weakfish are found. In addition, weakfish are pelagic, open water foragers (Chao and Musick 1977; Horodysky et al. 2008), therefore substrate in not a significant environment variable.

Temperature
Temperature is likely a major driving in development of reproductive tissue and spawning behaviors in weakfish, though it is still an important habitat factor among resting (not reproductively active) adults. Weakfish have been captured in a wide range of temperatures (Mercer 1989). Contemporary studies of weakfish temperature occurrence or preference are lacking, likely due to their wide distribution, inferred tolerance for a range of temperatures, and the relatively high effort put into studying juvenile weakfish habitat. Temperatures above 28°C but below 23°C resulted in the egress of adult weakfish from coastal estuaries (Wuenschel et al. 2014).

Dissolved Oxygen
Adult weakfish likely experience normoxic conditions, as they typically avoid the upper estuary reaches inhabited by juvenile weakfish where hypoxia is most commonly reported. Without any explicit studies of adult weakfish DO tolerances or preferences, such values might be estimated from the extensive body of work conducted on juvenile weakfish. Later stage juvenile weakfish may have physiologies (and subsequent tolerances) similar to adults.

Feeding Behavior
Adult weakfish feed primarily between dawn and dusk on clupeid species, anchovies, blue crabs, and spot (Mercer 1989). More recent work has supported piscivory as the main adult weakfish feeding mode, but also note crustaceans, mollusks, shrimp, squid, and other common estuarine prey (Able and Fahay 2010). Overall diets vary in proportion to available prey but adult diets are relatively stable from June to October (Wuenschel et al. 2013).

Competition and Predation
Competition among adult weakfish is not well known. Silver perch and bluefish are commonly cited as the primary predators (Mancini and Able 2005), though predation of larger adults likely decreases with size and may include occasional larger coastal predators. Weakfish were consumed by summer flounder, bluefish, and other weakfish (Wuenschel et al. 2013). The same study noted that by October, summer flounder and bluefish predation was extensive (~25%).

Section II. Essential Fish Habitats and Habitat Areas of Particular Concern

Essential Fish Habitat
Habitats used by weakfish include spawning sites in coastal bays, sounds, and the nearshore Atlantic ocean, as well as nursery areas including the upper and lower portions of the rivers and their associated bays and estuaries (ASMFC 2002).

Identification of Habitat Areas of Particular Concern
There is no HAPC designation for weakfish.

Present Condition of Habitat Areas of Particular Concern

The quality of weakfish habitats has been compromised largely by impacts resulting from human activities. It is generally assumed that weakfish habitats have undergone some degree of loss and degradation; however, few studies quantify the impacts in terms of the area of habitat lost or degraded.

Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. The New York Bight is one example of an area that has regularly received deposits of contaminated dredged material, sewage sludge, and industrial wastes. These deposits have contributed to oxygen depletion and the creation of large masses of anoxic waters during the summer months.

Some losses have likely occurred due to the intense coastal development that has taken place during the last several decades, although no quantification has been done. Losses have likely resulted from dredging and filling activities that have eliminated shallow water nursery habitat.

Further functional losses have likely occurred due to water quality degradation from point and non-point source discharges. Intensive conversion of coastal wetlands to agricultural use also contributed to the functional loss of weakfish nursery area habitat. Other functional loss of riverine and estuarine areas may have resulted from changes in water discharge patterns due to withdrawals or flow regulation. Estuarine nursery areas for weakfish, as well as adult spawning and pre-spawning staging areas, may be affected by prolonged extreme conditions from inland water management practices.

Power plant cooling facilities continue to impact weakfish populations. The Environmental Protection Agency (EPA) estimates the number of age 1 weakfish lost as a result of entrainment at all transition zone cooling water intake structures in the Delaware Bay is over 2.2 million individuals. Other threats stem from the continued alteration of freshwater flows and discharge patterns to spawning, nursery, and adult habitats in rivers and estuaries. Additional threats arise from placement of additional municipal water intakes in spawning and nursery areas, although the impacts may be mitigated to some degree with proper screening (ASMFC 2002).

Section III. Threats and Uncertainties

Significant Environmental, Temporal, and Spatial Factors Affecting Distribution of Weakfish

The following is taken from Amendment IV to the Weakfish FMP, Section 1.4.2:

Habitat loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. For example, the New York Bight has regularly received deposits of contaminated dredged material, sewage sludge, and industrial wastes, which has led to oxygen depletion and large masses of anoxic waters during the summer months. Some losses have likely occurred due to the intense coastal development in the last several decades, including dredging and filling activities in shallow nursery habitats, point and non-point source discharges, and intensive conversion of coastal wetlands for agricultural use (ASMFC 2002).

Flow regulation may have also contributed to functional loss of riverine and estuarine areas due to possible changes in water discharge patterns. Estuarine pre-spawning staging areas, spawning, and nursery areas may be affected by prolonged extreme conditions resulting from inland water management practices. Power plant cooling facilities continue to impact weakfish populations through the entrainment of larvae and juveniles.

Unknowns and Uncertainties

Weakfish are pelagic fishes in estuarine systems and more common in the main channel of bays, sounds, and tributaries (Chao and Musick 1977). Therefore, perturbations to substrate and seagrass habitats through dredging, coastal development, and boating are not going to impact weakfish as much as benthic sciaenids. However, weakfish are visual predators (Horodysky et al. 2008) and human activities (e.g., dredging, eutrophication, sediment runoff) that increase turbidity are likely to reduce foraging efficiency for weakfish at all life stages. In addition, individuals are attracted to spawning aggregations through drumming but humans are increasing underwater noise pollution in coastal estuaries, which can increase stress and reduce the effectiveness of acoustic calls needed to initiate spawning (Slabbekoorn et al. 2010). It is not known how weakfish respond to increasing noise pollution and particular attention is needed in regards to the impacts of noise pollution on spawning adults as well as estimates of egg production.

Although weakfish are tolerant of low DO conditions (Stierhoff et al. 2009), other environmental variables are changing due to climate change. For weakfish, increasing acidification may be the more significant than other climate driven environmental changes since reduced pH decrease responsiveness to sensory cues, which can reduce foraging efficiency and predator avoidance (Dixson et al. 2010). Additional work, needs to be conducted to understand how ocean acidification may impact weakfish in estuarine systems at different life history stages.

Section IV. Recommendations for Habitat Management and Research

Habitat Management Recommendations

The following research recommendations are from Amendment IV to the Weakfish FMP, Section 6.1.1 and ranked high priority (H), medium priority (M), or low priority (L):

1. Collect catch and effort data including size and age composition of the catch, determine stock mortality throughout the range, and define gear characteristics. In particular, increase length-frequency sampling, particularly in fisheries from Maryland and further north. (H)

2. Derive estimates of discard mortality rates and the magnitude of discards for all commercial gear types from both directed and non-directed fisheries. In particular, quantify trawl bycatch, refine estimates of mortality for below minimum size fish, and focus on factors such as distance from shore and geographical differences. (H)

3. Update the scale – otolith comparison for weakfish. (H)

4. Define reproductive biology of weakfish, including size at sexual maturity, maturity schedules, fecundity, and spawning periodicity. Continue research on female spawning patterns: what is the seasonal and geographical extent of "batch" spawning; do females exhibit spawning site fidelity? (M)

5. Conduct hydrophonic studies to delineate weakfish spawning habitat locations and environmental preferences (temperature, depth, substrate, etc.) and enable quantification of spawning habitat. (M)

6. Compile existing data on larval and juvenile distribution from existing databases in order to obtain preliminary indications of spawning and nursery habitat location and extent. (M)

7. Identify stocks and determine coastal movements and the extent of stock mixing, including characterization of stocks in overwintering grounds (e.g., tagging). (L)

8. Biological studies should be conducted to better understand migratory aspects and how this relates to observed trends in weight at age. (L)

9. Document the impact of power plants and other water intakes on larval, post larval and juvenile weakfish mortality in spawning and nursery areas, and calculate the resultant impact to adult stock size. (L)

10. Define restrictions necessary for implementation of projects in spawning and overwintering areas and develop policies on limiting development projects seasonally or spatially. (L)

11. Develop a coastwide tagging database. (L)

12. Develop a spawner recruit relationship and examine the relationships between parental stock size and environmental factors on year-class strength. (L)

Habitat Research Recommendations

The following research recommendations are from Amendment IV to the Weakfish FMP, Section 6.1.4:

1. Conduct hydrophonic studies to delineate weakfish spawning habitat locations and environmental preferences (temperature, depth, substrate, etc.) and enable quantification of spawning habitat.

2. Compile existing data on larval and juvenile distribution from existing databases in order to obtain preliminary indications of spawning and nursery habitat location and extent.

3. Document the impact of power plants and other water intakes on larval, post larval and juvenile weakfish mortality in spawning and nursery areas, and calculate the resulting impacts on adult stock size.

4. Define restrictions necessary for implementation of projects in spawning and overwintering areas and develop policies on limiting development projects seasonally or spatially.

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