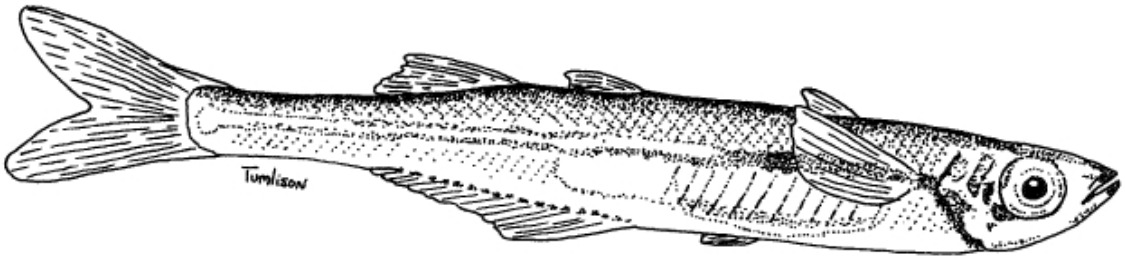
Waccamaw Silverside
(Menidia extensa)

5-Year Review:
Summary and Evaluation



Drawing by R. Tumlison

U.S. Fish and Wildlife Service
Southeast Region
Raleigh Ecological Services Field Office
Raleigh, North Carolina

*Please see Addendum 1 at the end of this, our original 5-year review document. The Addendum provides the limited new information we have gathered for our second 5-year review for his threatened fish that was initiated in the Federal Register on April 11, 2019 (84 FR 14669) and the analysis we have shared to explain the basis for continuing to recommend no change in status for this species.

5-YEAR REVIEW
Waccamaw Silverside (*Menidia extensa)*

I. GENERAL INFORMATION

A. Methodology used to complete the review: This review was completed by Dale Suiter and Sarah McRae of the U.S. Fish and Wildlife Service's Raleigh Field Office. All literature and documents used for this review are on file at the Raleigh Field Office and are cited in the References section. We used published literature; technical reports; data and information on the internet; unpublished data; and personal communications with land managers, biologists and researchers. Public notice of this review was given in the *Federal Register* on July 6, 2009, with a 60-day public comment period (74 FR 31972). We received information on the status of the Waccamaw Silverside from Sarah McRae, former Freshwater Ecologist with the N.C. Natural Heritage Program. None of this review was contracted to outside parties. The draft of this document was distributed for peer review (see Appendix A) and comments received were addressed where appropriate.

B. Reviewers

Lead Region - Southeast Region: Kelly Bibb, 404-679-7132

Lead Field Office - Raleigh, NC, Ecological Services: Sarah McRae, 919-856-4520, ext. 16.

C. Background

1. **Federal Register Notice citation announcing initiation of this review:** 74 FR 31972, July 6, 2009

2. **Species status:** Stable (2010 Recovery Data Call). The Waccamaw silverside is endemic to Lake Waccamaw in southeastern North Carolina, and was listed as threatened in 1987. In addition to its federal threatened status, the Waccamaw silverside is listed as state threatened by North Carolina Wildlife Resources Commission (Article 25 of Chapter 113 of the General Statutes; 1987). While population size is difficult to determine, this species continues to be commonly found in schools near the surface throughout Lake Waccamaw (Rohde et al. 1994; Heise and Jones 2010). However, the Waccamaw silverside remains vulnerable to threats to water quality and habitat degradation from man-made land-use activities, drought, physical constraints of its habitat, and natural and introduced predators.

   The following is a description of Lake Waccamaw from LeBlond (1995): Lake Waccamaw is a naturally-occurring lake within a geomorphic feature known as a Carolina bay. Carolina bays are found along the Atlantic Coastal Plain from

the Delmarva Peninsula to Georgia, and are most common in southeastern North Carolina. They are elliptically-shaped depressions usually oriented along a northwest/southeast axis and surrounded by a low sand ridge called a bay rim. Lake Waccamaw, covering an area of 14 square miles (8,934 acres), is the third largest natural lake in North Carolina (after Lake Mattamuskeet and Lake Phelps). The lake is shallow for its size, with a maximum depth of 11 feet and an average depth of five feet.

The lake is fed primarily by springs (groundwater) and drainages from swamps above the northeast shore. Big Creek is the largest of the swamp drainage streams entering the lake. The lake water is essentially clear but tea-colored, the result of tannic acids leached from decaying vegetation, a natural feature of coastal plain waters. Unlike most coastal plain water bodies, which generally have a low (acidic) pH, the waters of Lake Waccamaw have a neutral pH. This is likely caused by contact with surface and subsurface limestone ("marl") deposits. The spectacular aquatic animal diversity of Lake Waccamaw is due in part to this natural "sweetening" of lake waters. The lake serves as headwaters of Waccamaw River, which outflows at a small dam located along the south shore of the lake.

3. **Recovery achieved: 2** (26-50% recovery objectives achieved)

4. **Listing history:**

   Original Listing
   FR notice: 52 FR 11277
   Date listed: April 8, 1987
   Entity listed: Species
   Classification: Threatened

5. **Associated rulemakings:** None.

6. **Review History:**

   A previous 5-year review for this species was noticed on November 6, l991 (56 FR 56882). In this review, many species were simultaneously evaluated with no in-depth assessment of the Act's five threat factors as they pertained to the individual species. The notices summarily listed these species and stated that no changes in the designation of these species were warranted at that time. In particular, no changes were proposed for the status of the silverside in this review.

   Final Recovery Plan - 1993

   Recovery Data Call – 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, and 1998.

Shute et al. (2000) completed field surveys of imperiled fishes in Lake Waccamaw and the surrounding watershed in 1998 and 1999. They found Waccamaw silversides at four of seven lake sample sites and also just below the dam. They were most abundant on the north and northeast shores of the lake and occurred mostly in open, choppy water, rather than protected, vegetation margins of the lake. Other surveys have found that very young juvenile Waccamaw silversides frequent shallow areas nearer shore and vegetation (Wayne Starnes, NC Museum of Natural Sciences, 2010, pers. comm.). NC Wildlife Resources Commission (NCWRC) biologists Ryan Heise and Brena Jones (2010) conducted survey work for the fish and mollusk species in Lake Waccamaw on August 12 and 13, 2009 and found Waccamaw silversides at all sample sites. They were most abundant on the southwest shore of the lake near the dam with a catch per unit effort (CPUE) of 65.6 individuals per minute of seining. NCWRC capture data suggest that Waccamaw silversides continue to persist in high densities in Lake Waccamaw.

7. Species' Recovery Priority Number at start of review (48 FR 43098): 8. The "8" indicates a moderate degree of threat and high recovery potential.

8. Recovery Plan:
Name of plan: Waccamaw Silverside Recovery Plan
Date issued: August 11, 1993

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

1. Is the species under review a vertebrate? Yes.

2. Is the species under review listed as a DPS? No.

3. Is there relevant new information that would lead you to consider listing this species as a DPS in accordance with the 1996 policy? No.

B. Recovery Criteria

1. Does the species have a final, approved recovery plan containing objective, measurable criteria? No.

The recovery plan states that recovery of the Waccamaw silverside does not appear to be feasible unless other populations are found or established. Further, the plan states that it is unlikely that the Waccamaw silverside can be sufficiently protected from all of the threats associated with potential degradation or alteration of the water and/or habitat quality of Lake Waccamaw to allow the species to be

delisted. The plan does state that as additional data about the threats to the species are determined, it may be possible to develop recovery criteria.

Accordingly, the objective of this recovery plan is to protect and maintain a self-sustaining population of Waccamaw silverside in Lake Waccamaw and to protect its habitat from present and foreseeable threats. Currently, the species does appear to have a self-sustaining population. Several efforts to protect the habitat have been undertaken, most notably the designation of "Outstanding Resource Waters" by the NC Division of Water Quality (NCDWQ), thus providing additional protective measures for the water quality in the lake. All waters that drain to Lake Waccamaw are subject to the Lake Waccamaw Special Management Strategy (NCDWQ 2010). These waters have the same requirement as ORW waters because they are vital to protecting water quality in the lake [15NCAC 02B.0225 (c) (10)]. In addition, approximately 1/4 of the eastern and southern portion of lake has been protected as a state park under the NC Division of Parks and Recreation since 1976. Lake Waccamaw is also a registered Natural Heritage Area, which is a voluntary agreement with the NC Department of Environment and Natural Resources that requires coordination of management actions with the NC Natural Heritage Program.

Despite these protections, many threats remain unabated, including pressures from development and land use alteration upstream of, and surrounding the remaining 3/4 of the lake that is not under state ownership. These pressures result in substantial nutrient loading, which is a major concern for the overall water and habitat quality in Lake Waccamaw. Until all facets of nutrient loading are understood and potentially regulated, it is unlikely that the habitat for the Waccamaw silverside will be sufficiently protected from all threats associated with potential degradation or alteration of water and/or habitat quality.

C. Updated Information and Current Species Status

1. Biology and Habitat

Other than occasional surveys conducted for the Waccamaw silverside, there has been little research conducted on this species since it was listed in 1987.

a. Abundance, population trends, demographic features, or demographic trends:

According to Shute et al. (2000), Waccamaw silversides were found at four of seven sample sites in the lake and also just below the dam in the Waccamaw River. They were most abundant along the north and northeast shores of the lake, in open water. Shute et al (2000) believes that the population is similar to that observed in 1979-1981 (Shute et al. 1981). The specimens in the Waccamaw River were likely washed over the dam during high flows and do not represent an isolated, reproducing

population (Krabbenhoft et al. 2005). According to Wayne Starnes (NC Museum of Natural Sciences, 2010, pers. comm.) and Fritz Rohde (National Marine Fisheries Service, 2010, pers. comm.), these individuals are ephemeral in their occurrence in the dam tailrace (possibly often as matured larval washovers or maybe sometimes exiting the lake as adults during really high water when the dam is submerged) and then seek to re-enter the lake at any high water opportunity afforded thereafter.

During their 2009 field surveys, Heise and Jones (2010) collected Waccamaw silversides in all five fish sampling locations. Sampling sites were located in both shoreline and open water habitats. Based on their capture data, Waccamaw silversides continue to persist in high densities in both shallow and deeper open water areas of the lake. The majority of individuals collected were young of the year, indicating continued successful annual reproduction.

The N.C. Natural Heritage Program ranks the Waccamaw silverside population in Lake Waccamaw as "*Excellent*", indicating that it is likely to persist into the foreseeable future (i.e., at least 20 to 30 years), given current conditions; the population in the Waccamaw River just downstream of the dam is ranked as Extant, indicating that, while present, there is insufficient information to determine viability (Sarah McRae, NC Natural Heritage Program, 2009, pers. comm.).

b. Genetics, genetic variation, or trends in genetic variation: According to Wayne Starnes (NC Museum of Natural Sciences, 2010, pers. comm.), there have been comparative genetic studies with other atherinopsids (fish in the same family as the silverside) to study genetic relationships, but no population genetics level studies to date. Fritz Rohde (National Marine Fisheries Service, 2010, pers. comm.) indicated that Dr. Joe Quatto at the University of South Carolina has conducted some research on the genetics of Waccamaw silverside, but the results have not been published yet.

c. Taxonomic classification or changes in nomenclature: There have been no changes to the taxonomic classification or nomenclature since Waccamaw silverside was listed.

d. Spatial distribution, trends in spatial distribution, or historic range: The range of the Waccamaw silverside has not changed since listing. The species is known only from Lake Waccamaw, the lower stretch of Big Creek and a short stretch of the Waccamaw River just downstream from the Lake Waccamaw Dam in Columbus County, NC.

e. Habitat or ecosystem conditions: According to Sarah McRae (NC Natural Heritage Program, 2009, pers. comm.), 1,700 acres of land along

the lake shore are protected as Lake Waccamaw State Park. In addition, the lake itself occupies 8,934 acres (LeBlond 1995). Since Heise and Jones (2010) found Waccamaw silversides in all of their sampling locations, which were scattered across the lake in both shoreline and open water locations, it is assumed that the entire lake provides habitat for this species.

Lake Waccamaw is classified by the NC Division of Water Quality as an Outstanding Resource Water (ORW). The purpose of the designation is to protect the unique and special waters due to exceptional water quality and exceptional state or national ecological or recreational significance. This classification is meant to preserve water quality and to protect against degradation. All waters that drain to Lake Waccamaw are subject to the Lake Waccamaw Special Management Strategy (NCDWQ 2010). These waters have the same requirement as ORW waters because they are vital to protecting water quality in the lake [15NCAC 02B.0225 (c) (10)].

f. **Other:** According to J.R. Shute (Conservation Fisheries, Inc., 2010, pers. comm.), no one is currently propagating Waccamaw silverside or any other species of *Menidia*.

2. Five-Factor Analysis

a. Present or threatened destruction, modification or curtailment of its habitat or range: The recovery plan lists water quality degradation (discharge, runoff or leaching of contaminants) and the introduction of invasive species as the greatest threats to the Waccamaw silverside.

Nutrient loading in Lake Waccamaw has increased over the past 37 years (National Technical Information Service 1973; Lindquist and Yarbrough 1982; NCDWQ 2010). This trend, as well as the sensitive, unusual nature of this shallow lake, means that eutrophication is a possibility, and any increase in nutrient loading could precipitate water quality conditions that could threaten the species.

The shoreline of Lake Waccamaw is becoming densely developed (Chris Helms, Lake Waccamaw State Park, 2010, pers. comm.; Fritz Rohde, National Marine Fisheries Service, 2010, pers. comm.). Homes and cottages cover nearly three-fourths of the shoreline while the remaining one-fourth lies within Lake Waccamaw State Park. Coincident to this development is the potential for increase in nutrient loading in the lake (Shute 1997). Nutrient loading increases the potential for wide-scale algal blooms and corresponding eutrophication (Krabbenhoft et al. 2005).

There are several water quality and water quantity issues surrounding Lake Waccamaw. Fertilizers and herbicides from encroaching lawns and

gardens, sedimentation from nearby logging activities, pollution from recreational boaters, and antiquated sewer and septic systems seeping waste into the lake appear to be the biggest water quality threats. In addition, several drainage ditches contribute sediment and chemical pollution (i.e., herbicides) directly to the lake during storm events. In terms of water quantity, nearby ditches have been diverting water away from the lake to irrigate loblolly pine plantations (Chris Helms, Lake Waccamaw State Park, 2010 pers. comm.).

b. **Overutilization for commercial, recreational, scientific, or educational purposes:** There is currently no evidence to suggest that Waccamaw silverside is being overutilized for commercial, recreational, scientific or educational purposes.

c. Disease or predation: Rohde et al. (1994) indicate that the Waccamaw silverside is "one of the most abundant forage species in Lake Waccamaw." It is well adapted to heavy predation and frequent skipping over the water surface to avoid predators has been observed (Davis and Louder 1969). While this species is prey for larger fish, no signs of over-predation or disease have been observed in this species.

d. Inadequacy of existing regulatory mechanisms: Wetland permitting actions by the U.S. Army Corps of Engineers have the potential to impact this species and the habitat where it occurs. Permits for wetland alterations (Section 404 of the Clean Water Act) have the potential to adversely impact wetlands, headwaters, and streams that flow into Lake Waccamaw and wetlands along the lakeshore.

Lake Waccamaw is classified by the NC Division of Water Quality as an Outstanding Resource Water (ORW). The purpose of the designation is to protect the unique and special waters due to exceptional water quality and exceptional state or national ecological or recreational significance. This classification is meant to preserve water quality and to protect against degradation. Despite the ORW status, Lake Waccamaw is also on the 303(d), or "impaired waterbody" list for excessive levels of mercury (NCDWQ 2010).

e. Other natural or manmade factors affecting its continued existence: Because the Waccamaw silverside has an annual life cycle, it is susceptible to rapid extinction given reproductive failure for even a single year. Additionally, the recent invasion of the lake by the Brook silverside (*Labidesthes vanhyningi* (formerly *L. sicculus*, pending elevation) (Wayne Starnes, NC Museum of Natural Sciences, 2010, pers. comm.), is of concern. Shute et al. (2000) noted that the Brook silverside, a species previously unknown in the Waccamaw drainage was reported in this system in 1998. Historically, this species was not known north of the

Santee drainage in South Carolina. Shute et al. (2000) found the Brook silverside at nearly all sampling stations and believes that this species has "apparently invaded the Waccamaw drainage essentially to the headwaters." Habitat segregation appears to occur between the two silverside species, as Heise and Jones (2010) noted that "Waccamaw silversides were typically collected in open waters, and habitat use of the adults and juveniles do not appear to overlap with the brook silversides". Currently, the potential for negative interaction between the two silverside species is unknown.

In addition, recent droughts have impacted the Lake, and thus the habitat for the Waccamaw silverside. The drought has decreased incoming tributary flows, thus the typical "flushing" of the lake has not occurred. This has resulted in severe algal blooms, which impacts the overall water quality of the lake (Chris Helms, Lake Waccamaw State Park, 2010, pers. comm.).

According to NCDWQ (2010), the lake was placed on the 303(d) (i.e., "impaired waterbody") list in 2006 due to fish tissue samples that showed excessive levels of mercury. Mercury levels are a significant problem throughout the entire Lumber River Basin and is not reflective of a point source. There is an EPA National Atmospheric Deposition Program monitoring site located at the Lake Waccamaw State Park that records mercury deposition levels next to the lake. It is not known whether the mercury levels are affecting the Waccamaw silverside population.

D. Synthesis

Shute, et al (2000) believes that the population is similar in size to their observations in 1979-1981. Heise and Jones (2010) collected Waccamaw silversides in all five of their fish sampling locations in 2009. Approximately 1,700 acres of land along the lake shore as well as the 8,934 acres of the lake itself are protected as Lake Waccamaw State Park.

The recovery plan lists water quality degradation (discharge, runoff or leaching of contaminants) and the introduction of invasive species as the greatest threats to the Waccamaw silverside. The invasive Brook silverside was found in the Waccamaw River drainage in 1998. Impacts by this species on the Waccamaw silverside, if any, have not been determined.

Nutrient loading has increased over several decades, and this trend, as well as the sensitive, unusual nature of this shallow lake could lead to eutrophication, thus any additional increase in nutrients could "tip the uneasy balance" (Casterlin et al. 1984) and possibly threaten the species. The lake's environmental quality and its fauna could also be threatened by habitat alteration resulting from development and land use in Lake Waccamaw and its watershed if these activities are not planned and implemented with the protection of the Lake Waccamaw ecosystem in mind. The short life cycle of the fish and its dependence on the unique habitat conditions

present in Lake Waccamaw make it extremely vulnerable to any change in its environment. The continued increase in nutrient loading could result in serious deterioration of water quality which, even on a short-term basis, could precipitate the extinction of this fish (50 FR 46320).

Given that the range of the species is still limited to Lake Waccamaw, that there has been little research on the species since being listed in 1987, and that there are still concerns with water quality in the lake, we recommend that the status of the species remain as threatened.

III. RESULTS

Recommended Classification:

__X__ No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

- Develop clear recovery criteria and recovery objectives
- Determine any proposed or recent changes in land use that might affect water quality in Lake Waccamaw and work with local and state government to correct any such problems (Recovery Task 1.3)
- In coordination with NCWRC, develop captive propagation techniques and establish an *ex situ* population at the NC Zoo, NC Aquarium, hatchery or other facility (Recovery Task 3)
- Work with the Lake Waccamaw State Park and NC Aquarium at Fort Fisher to create an educational exhibit about the species (Recovery Task 1.3.3)
- Determine the number of individuals required to maintain a viable population, including a genetic study to determine the current effective population size and, from there, try to extrapolate that which would be needed to maintain the current level of variability (Recovery Task 2.4)

V. REFERENCES

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Waccamaw silverside (*Menidia extensa*)

Current Classification: Threatened

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X__ No change needed

Review Conducted By: Dale Suiter and Sarah McRae, Raleigh Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 2/6/11

REGIONAL OFFICE APPROVAL:

FOR
Lead Regional Director, Fish and Wildlife Service

Approve Aaron L Valdez Date 2-10-11

APPENDIX A
Summary of peer review for the five-year review of Waccamaw silverside (*Menidia extensa*)

A. Peer Review Method:
A draft copy of the five-year review was emailed to biologists at the North Carolina (NC) Natural Heritage Program and North Carolina Wildlife Resources Commission and independent fisheries biologists. Reviewers provided comments by email, and by modifications to the original document. All of the peer reviewers know the species, *Menidia extensa*, and are familiar with Lake Waccamaw where it occurs and the threats to the fish's long-term survival.

B. Peer Review Charge:
Peer reviewers were asked to provide written comments on the information presented in our analysis of the Waccamaw silverside and to provide comments on the validity of the data. Peer reviewers were asked not to provide recommendations on the legal status of the species.

C. Summary of Peer Review Comments/Report:
In general, the peer reviewers provided positive feedback and some specific comments. One reviewer from the NC Natural Heritage Program provided information about shoreline development around Lake Waccamaw as well as survey information and citations to support those comments. She also provided a good physical description of Lake Waccamaw and a source for that information.

Reviewers from the NC Wildlife Resources Commission clarified their sampling methodology that was summarized in the review. They commented that the need to establish and propagate captive populations was low, with the exception of those used for educational or display purposes. Further, they suggested that if we consider captive propagation, we should consult with them regarding genetic issues that may arise from captive stock.

One reviewer from the NC Museum of Natural Sciences suggested that the document include more background information about the lake and its environs. He provided more information about where Waccamaw silverside had been found during his surveys of Lake Waccamaw. He provided updated information on the specific epithet for brook silverside. Finally, he supported the idea of creating an educational exhibit on Lake Waccamaw endemics at the NC Aquarium at Fort Fisher.

One reviewer from the National Marine Fisheries Service provided information on the Waccamaw silversides that are sometimes observed below the dam. He also provided information on the development of the lakeshore and unpublished genetics studies.

D. Response to Peer Review:
The primary author was in agreement with all comments and concerns received from the peer reviewers and tried to address every comment as appropriate. The Service continues to work in collaboration with State agencies in NC to implement recovery for the Waccamaw silverside.

APPENDIX B
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5-YEAR REVIEW OF WACCAMAW SILVERSIDE (*Menidia extensa*)

Addendum 1. Summary of new information obtained since the 2011 5-year review.

Note: The following information updates the referenced sections of the 2011 Waccamaw Silverside (*Menidia extensa*) 5-year review (USFWS 2011). Sections of the 2011 5-year review not referenced herein do not contain any new information since the previous review. The *Federal Register* notice announcing the initiation of this 5-year review was published on April 11, 2019 (84 FR 14669). No comments were received during the 60-day public comment period following this notice. The U.S. Fish and Wildlife Service (Service) received information about the species from the North Carolina Wildlife Resources Commission (NCWRC) and biologists familiar with the species in response to requests for specific information. This information and recent research reports were used to prepare this addendum.

I. GENERAL INFORMATION

B. Reviewers

Lead Region: South Atlantic-Gulf Region, Atlanta Regional Office, Carrie Straight, 404-679-7226

Lead Field Office: Raleigh Ecological Services Field Office, Raleigh, North Carolina, Emily Wells, 919-856-4520 ext. 25.

C. Background

1. Federal Register Notice citation announcing initiation of this review: April 11, 2019 (84 FR 14669)

2. Species status: Stable

Biologists with NCWRC completed surveys in Lake Waccamaw annually since the 2011 5-year review. Their data is discussed below, and those data indicate that this species is stable.

6. Review History: The Service completed a 5-year review for the Waccamaw Silverside in 2011 (74 FR 31972). The 2011 review recommended the species remain classified as threatened given "that the range of the species is still limited to Lake Waccamaw, that there has been little research on the species since being listed in 1987, and that there are still concerns with water quality in the lake" (USFWS 2011).

II. REVIEW ANALYSIS

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Is there relevant new information regarding the species' abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g. age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends?

Yes. Since the 2011 5-year review, NCWRC biologists have conducted annual surveys (2011-2019) within Lake Waccamaw targeting endemic fishes, including Waccamaw Silverside, in addition to other rare aquatic species.

The NCWRC surveys found Waccamaw Silversides at all surveyed monitoring stations in all years (Jones 2019). There are four long-term annual monitoring stations: the southwest lakeshore near the dam (F1), the north shore near Dale's Seafood restaurant (F2), the southeast lakeshore near the mouth of Big Creek (F3), and the northwest shore near a private residence (F4). After the documented hydrilla (*Hydrilla verticillata*) infestation in this area of the lake in October 2012, the F4 monitoring site was added for the 2013 annual survey. This additional monitoring location assesses the presence and abundance of Waccamaw Silversides surrounding the hydrilla infested waters, and the efficiency of the multi-year Fluridone treatment in this area of the lake, which began in June 2013.

Waccamaw Silversides were consistently most abundant on the southwest shore of the lake near the dam (F1) with an eleven-year mean catch per unit effort (CPUE) of 13.3 individuals per minute of seining. The least abundant monitoring location remains Big Creek (F2) with an eleven-year mean CPUE of 4.2 individuals per minute of seining. The six-year mean CPUE at the newest monitoring location (F4) was 0.66 individuals per minute of seining.

The NCWRC 2019 monitoring report states that "The abundance of Waccamaw Silversides remains both temporally and spatially variable over the past eleven sampling years, but they are still relatively easy to collect (CPUE = 1.8 to 23.5 individuals per minute) and the population appears resilient. Multiple size classes still appear across the collected individuals, indicating continued successful reproduction and recruitment."

c. Is there relevant new information regarding disease or predation on the species?

Yes. Another non-native species which poses a threat to the Waccamaw Silverside by means of direct predation (Ashley and Rachels 1998, Pine et al. 2007) in Lake Waccamaw is the Flathead Catfish (*Pylodictis olivaris*).

It was officially documented to occur in the lake in June 2014 after multiple citizens reported the presence of this species (Jones 2019). Targeted catfish surveys in 2018 by NCWRC biologists did not result in additional Flathead Catfish findings. The threat may still be present in low numbers; therefore, continued monitoring will occur (Jones 2019). Additional discussion regarding the threat that the Flathead catfish poses to the Waccamaw Silverside can be found in Section II.C.2.c.

e. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Since the 2011 5-year review, the presence of the federal and State listed noxious weed, hydrilla, was reported in Lake Waccamaw (first reported in October 2012). Hydrilla tubers rooted in the lake bottom can form dense layers of vegetation in the water column, quickly reaching the water surface; this degrades habitat for the Waccamaw Silverside, which prefers open waters. The original infestation area was found immediately adjacent to a public boat ramp on the northwest shore of the lake, and the first treatment of a 960-acre area began in June 2013. The NCWRC added a fish survey location (monitoring site F4) within the infested area to monitor the multiyear chemical treatment for hydrilla management (Jones 2019). The 2018 data indicate that the infested area's vegetation density had been reduced to a treatment acreage of approximately 455 acres of the lake's total 8,934 acres. In 2019, no hydrilla was found during monitoring events (Jones, B. 2020. pers. comm.). The Lake Waccamaw Technical Advisory Committee (TAC) manages the treatment protocol, and they are currently working on a monitoring and early detection and rapid response plan to address future potential impacts from hydrilla. Fluridone will not be applied unless additional hydrilla locations are found.

Another plant species found to share hydrilla infested areas in the lake is black mat algae (*Lyngbya wollei*), which was found in 2013 in much smaller quantities (20-35 acres). This species has the ability to become invasive and can reduce available open water habitat for the Waccamaw Silverside as the dense mats grow and expand at the water's surface. A treatment plan is being discussed by the TAC for its management (Jones 2019).

f. Is there other new relevant information about the species (propagation, etc.)?:

Yes. Research involving three endemic fishes in Lake Waccamaw, including Waccamaw Darter *(Etheostoma perlongum),*Waccamaw Killifish *(Fundulus waccamensis),* and Waccamaw Silverside, was conducted to determine if these lake species had a more elongated morphology than their stream dwelling sister species. It was determined

that Waccamaw Silverside did show characteristics of elongated morphology compared to the stream sister species (Krabbenhoft et al. 2009).

2. **Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)**

a. Present or threatened destruction, modification or curtailment of its habitat or range:

In addition to the other threats mentioned in the 2011 5-year review, the federal and state-listed noxious weed hydrilla was reported in Lake Waccamaw in October 2012. Hydrilla poses a significant habitat degradation threat to the Waccamaw Silverside which prefers open waters. The original infestation area was found immediately adjacent to a public boat ramp on the northwest shore of the lake, and the first annual treatment of a 960-acre area began in June 2013. The 2018 data indicate that the infested area's vegetation density had been reduced to a treatment acreage of approximately 455 acres of the lake's total 8,934 acres. In 2019, no hydrilla was found during monitoring events (Jones, B. 2020. pers. comm). The Lake Waccamaw Technical Advisory Committee (TAC) manages the treatment protocol and they are currently working on a monitoring and early detection and rapid response plan to address future potential impacts from hydrilla. Fluridone will not be applied unless additional hydrilla locations are found. Another plant species found to share the previously hydrilla infested areas in the lake is black mat algae (*Lyngbya wollei*), which was found in 2013 but in much smaller quantities (20-35 acres) (Jones 2019).

c. Disease or predation

The non-native Flathead Catfish now poses a potential threat to the Waccamaw Silverside by means of direct predation (Ashley and Rachels 1998, Pine et al. 2007) since its first documented occurrence in the lake in June 2014. Targeted catfish surveys in 2018 did not document additional Flathead Catfish, although they may still be present in low numbers (Jones 2019). While direct impacts from predation of individuals are possible, there may be a low probability of the two species commonly interacting given their differing habitat preferences within the water column. The more likely threat would come from the Flathead Catfish feeding on substrates and surfaces where the Waccamaw Silverside eggs are attached (Jones, B. 2020. pers. comm.), reducing the potential population of individuals in the lake immediately and over time. The risk and potential threat to the Waccamaw Silverside eggs could increase if Flathead Catfish population density was to rise in the lake. NCWRC plans to continue targeted surveys to gauge possible increases in populations.

e. Other natural or manmade factors affecting its continued existence:

In the previous 5-year review, the Brook Silverside was noted as a non-native species with unknown impacts to the Waccamaw Silverside (USFWS 2011). While no direct research has been completed by NCWRC, it has since been observed that the Brook Silverside prefers more vegetated areas along the shorelines in contrast to the Waccamaw Silverside's preference for open water; therefore, the difference in the two species' lake use has not been observed to cause direct competition (Jones 2019).

Climate change is anticipated to threaten many rare species and the habitats where they occur in the coming years. While models of future climate scenarios are not available with fine detail, it is reasonable to expect shifts in temperature and precipitation patterns that are outside the climatic conditions to which Waccamaw Silverside is adapted. The species has been observed to move into deeper waters when water temperatures approach 30°C, such as in the summer of 2016 when the water temperature in Lake Waccamaw reached 37°C (Jones, B. 2020. pers. comm). Additionally, a 1980 study concluded that Waccamaw Silverside may reach a lethal upper temperature limit around 36 °C (Lindquist and Yarbrough. 1982. Pg. 6-8). If periods of hot water temperatures coincide with the species spawning season, this could be particularly concerning given their short lifespan (Jones, B. 2020. pers. comm).

Some models predict an increase in tropical storms and rainfall which could flood the surrounding low areas and wash individuals out of the lake if severe. Additionally, an increase in sedimentation and nutrient input into the lake could occur from upstream sources of runoff; potentially lowering dissolved oxygen to concerning levels. Conversely, droughts will continue to happen into the future; and thus the habitat for the Waccamaw Silverside will be impacted by decreasing incoming tributary flows causing reduced "flushing" of the lake, and potential algal blooms as reported in the previous 5- year review.

D. Synthesis

The most important factors that justify the threatened status of *Menidia extensa* have changed little since the 2011 5-year review. During the previous review the species was considered stable based upon the survey data. Given the range of the species is still and will always be limited to Lake Waccamaw and immediately below the dam, there are not opportunities to expand their range and population units. Research on the species has been limited since being listed, but there are

studies currently going on and proposed in the near future to continue data gathering about this species. The threat of invasive plant species (hydrilla and black mat algae) causing habitat loss is a current and future threat warranting annual monitoring and action plans by the TAC. The known presence of the non-native predatory Flathead Catfish in the lake could pose elevated concerns if increases in its density occur. Additionally, the uncertainties of climate change and its impacts on Lake Waccamaw water quantity, quality and temperature will be a continued area of concern for the species. The species' population remains stable based upon the recent survey information analyzed for this review. Based upon these existing and updated threats, which pose a risk to the entire inhabited range of the Waccamaw Silverside, we recommend that the status of the species remain as threatened.

III. RESULTS

A. **Recommended Classification**: No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

The recommended actions listed in the 2011 5-year review (page 9) remain important to the conservation and recovery of *Menidia extensa*.

Since the 2011 5-year review, progress has been made on several recommendations for future actions. For example: annual monitoring surveys for rare fishes and mollusks, including Waccamaw Silverside, have been conducted by NCWRC to assess the status of the species and habitat quality of Lake Waccamaw.

Additionally, Lake Waccamaw State Park is in the planning stage to re-construct their interactive educational exhibits, and Waccamaw Silverside exhibits are potential options. The Service is engaged in providing opportunities for Waccamaw Silverside educational outreach material when this renovation occurs.

While there are still no captive propagation efforts for the Waccamaw Silverside (Shute, J.R. 2020. pers. comm.), interest has been expressed in assisting the Service in this recovery goal. In 2019, Benjamin Parrot, an Assistant Professor at the Savannah River Ecology Lab and Odum School of Ecology, associated with the University of Georgia, volunteered lab space and staff for further exploring captive propagation of Waccamaw Silverside and the potential for temperature dependent sex determination (Parrot, B. 2019. pers. comm.). Further discussion will occur between the Service and NCWRC regarding Mr. Parrot's interest and willingness to work together. Further coordination with NCWRC and the TAC to continually address the hydrilla and black mat algae in the lake is an important future action for the Service.

Researchers Anthony Echelle and Peter Unmack plan to conduct genome-wide single-nucleotide polymorphisms research to study the phylogenetic relationships within the

Silversides genus *Menidia*, including the Waccamaw Silverside in 2020. Results will be shared with the Service and NCWRC.

The Service now uses Species Status Assessments (SSA) to evaluate biological information in terms of resiliency, redundancy and representation. No SSA has been conducted for Waccamaw Silverside to rigorously develop definitions of resiliency, redundancy and representation for the species against which to evaluate its current status **(**for which monitoring data indicate continued successful reproduction and recruitment), conservation measures realized, and current and future threats. As resources permit, the Service, NCWRC, and partners could synthesize cumulative species data, projections of habitat stability and stressors, and conservation actions implemented to date to complete an SSA to inform our current concept of status for this narrow-range endemic species.

V. REFERENCES

These references are in addition to the citations in the previous 2011 5-year review.

Ashley, K.W. and R.T. Rachels. 1998. Changes in redbreast sunfish population characteristics in the Black and Lumber rivers, North Carolina. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 52:29-38.

Krabbenhoft, T., M. Collyer, and J. Quattro. 2009. Differing evolutionary patterns underlie convergence on elongate morphology in endemic fishes of Lake Waccamaw, North Carolina. Biological Journal of the Linnean Society 98:636-645.

Jones, B.K. 2019. Endemic Fishes of Lake Waccamaw Monitoring Report. Attachment A from North Carolina Wildlife Resources Commission Final Performance Report on North Carolina Endangered Aquatic Species. Submitted to US Fish and Wildlife Service, Raleigh, NC.

North Carolina Natural Heritage Program. 2019. Element Occurrence Records for *Menidia extensa* (Waccamaw silverside). Unpublished report. As of June 26, 2019.

Pine, W.E, III, T.J. Kwak, and J.A. Rice. 2007. Modeling management scenarios and the effects on an introduced apex predator on a coastal riverine fish community. Transactions of the American Fisheries Society 136:105-120.

U.S. Fish and Wildlife Service. 2011. Waccamaw Silverside (*Menidia extensa*). 5-Year Review: Summary and Evaluation.

Bibliography

A complete bibliography for *Menidia extensa* was included in Appendix B of the 2011 5-year review.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW OF *WACCAMAW SILVERSIDE (MENIDIA EXTENSA)*

Current Classification: Threatened
Recommendation resulting from the 5-Year Review:

___Downlist to Threatened
___Uplist to Endangered
___Delist
_X_No change is needed

Review Conducted By: Emily Wells, Raleigh Ecological Services Field Office, Raleigh, NC

FIELD OFFICE APPROVAL:
Lead Field Supervisor, Raleigh Ecological Services Field Office, U.S. Fish and Wildlife Service

Approve: PETER BENJAMIN Digitally signed by PETER BENJAMIN Date: 2020.09.29 15:02:39 -04'00' Date: 9/29/2020

Pete Benjamin

* In 2014, Southeast Region Field Supervisors have been delegated authority to approve 5-year reviews that do not recommend a status change.

Field Supervisor signature on this document reflects:

1. ____We have no new information, received no new public comments, and the original five factor analysis remains an accurate reflection of the species current status.
2. __X_We have obtained a small amount of new information that we have summarized in Addendum 1, received no new public comments, and the original five factor analysis remains an accurate reflection of the species current status.