DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[Docket No. 130626570–6999–02]

RIN 0648–XC742

Endangered and Threatened Wildlife and Plants: Notice of 12-Month Finding on a Petition To List Alabama Shad as Threatened or Endangered Under the Endangered Species Act

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of 12-month finding.

SUMMARY: We, NMFS, announce a 12-month finding and listing determination on a petition to list Alabama shad (*Alosa alabamae*) as threatened or endangered under the Endangered Species Act (ESA). We have completed a comprehensive review of the status of Alabama shad in response to the petition submitted by the Center for Biological Diversity (CBD), Alabama Rivers Alliance, Clinch Coalition, Dogwood Alliance, Gulf Restoration Network, Tennessee Forests Council, and the West Virginia Highlands Conservancy (petitioners). Based on the best scientific and commercial information available on the status of Alabama shad, we have determined that the species does not warrant listing at this time. We conclude that the Alabama shad is not currently in danger of extinction throughout all or a significant portion of its range and is not likely to become so within the foreseeable future.

DATES: This finding was made on January 12, 2017.

ADDRESSES: The reference list associated with this determination is available by submitting a request to the Species Conservation Branch Chief, Protected Resources Division, NMFS Southeast Regional Office, 263 13th Avenue South, St. Petersburg, FL 33701–5505, Attn: Alabama shad 12-month finding. The reference list is also available electronically at:*http://sero.nmfs.noaa.gov/protected_resources/listing_petitions/species_esa_consideration/index.html*

FOR FURTHER INFORMATION CONTACT: Kelly Shotts, NMFS, Southeast Regional Office (727) 824–5312; or Marta Nammack, NMFS, Office of Protected Resources (301) 427–8469.

SUPPLEMENTARY INFORMATION:

Background

In 1997, we added Alabama shad to our Candidate Species List (62 FR 37562; July 14, 1997). At that time, a candidate species was defined as any species being considered by the Secretary of Commerce (Secretary) for listing as an endangered or a threatened species, but not yet the subject of a proposed rule (49 FR 38900; October 1, 1984). In 2004, we created the Species of Concern list (69 FR 19975; April 15, 2004) to encompass species for which we have some concerns regarding their status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA). Twenty-five candidate species, including the Alabama shad, were transferred to the Species of Concern list at that time because they were not being considered for ESA listing and were better suited for Species of Concern status due to some concerns and uncertainty regarding their biological status and threats. The Species of Concern status does not carry any procedural or substantive protections under the ESA.

On April 20, 2010, the Center for Biological Diversity (CBD), Alabama Rivers Alliance, Clinch Coalition, Dogwood Alliance, Gulf Restoration Network, Tennessee Forests Council, and the West Virginia Highlands Conservancy (petitioners) submitted a petition to the Secretaries of Interior and Commerce, as well as to the Regional Director of the Southeast Region of the U.S. Fish and Wildlife Service (USFWS), to list 404 aquatic, riparian, and wetland species from the southeastern United States as threatened or endangered under the ESA. The petitioners also requested that critical habitat be designated for all petitioned species. We notified the USFWS' Southeast Region by letter dated May 3, 2010, that the Alabama shad, one of the 404 petitioned species, would fall under NMFS' jurisdiction based on the August 1974 Memorandum of Understanding regarding jurisdictional responsibilities and listing procedures between the two agencies. We proposed to USFWS that we would evaluate the petition, for Alabama shad only, for the purpose of the 90-day finding and any required subsequent listing action. On May 14, 2010, we sent the petitioners confirmation we would be evaluating the petition for Alabama shad. On February 17, 2011, we published a negative 90-day finding in the **Federal Register** (76 FR 9320) stating that the petition did not present substantial scientific or commercial information indicating that the requested listing of Alabama shad may be warranted.

On April 28, 2011, in response to the negative 90-day finding, CBD filed a notice of intent to sue the Department of Commerce (DOC) and NMFS for alleged violations of the ESA in making its finding. CBD filed the lawsuit in the U.S. District Court for the District of Columbia on January 18, 2012. On June 21, 2013, CBD and DOC/NMFS settled the lawsuit. We agreed to reevaluate the original listing petition, as well as information in our files, including some additional information we acquired after the original 90-day finding published on February 17, 2011, and publish a new 90-day finding. On September 19, 2013, we published a 90-day finding with our determination that the petition presented substantial scientific and commercial information indicating that the petitioned action may be warranted (78 FR 57611).

Our 90-day finding requested scientific and commercial information from the public to inform a review of the status of the species. We requested information on the status of Alabama shad, including: (1) Historical and current distribution and abundance of this species throughout its range, including data addressing presence or absence at a riverine scale; (2) historical and current population sizes and trends; (3) biological information (life history, genetics, population connectivity, etc.); (4) landings and trade data; (5) management, regulatory, and enforcement information; (6) any current or planned activities that may adversely impact the species; and (7) ongoing or planned efforts to protect and restore the species and its habitat. We received information from the public in response to the 90-day finding, and we incorporated all relevant information into our review of the status of Alabama shad.

Listing Species Under the ESA

We are responsible for determining whether Alabama shad warrants listing as threatened or endangered under the ESA (16 U.S.C. 1531 *et seq.*) To be considered for listing under the ESA, a group of organisms must constitute a ''species,'' which is defined in section 3 of the ESA to include taxonomic species and ''any subspecies of fish, or wildlife, or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.'' Section 3 of the ESA defines an endangered species as ''any species which is in danger of extinction throughout all or a significant portion of its range'' and a threatened species as one ''which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.'' Thus, we interpret an ''endangered species'' to be one that is presently in danger of extinction. A ''threatened species,'' on the other hand, is not presently in danger of extinction, but is likely to become so in the foreseeable future (that is, at a later time). In other words, the primary statutory difference between a threatened and endangered species is the timing of when a species may be in danger of extinction, either presently (endangered) or in the foreseeable future (threatened).

Section 4(b)(1)(A) of the ESA requires us to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account efforts being made by any state or foreign nation to protect the species. Under section 4(a) of the ESA, we must determine whether any species is endangered or threatened due to any one or a combination of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence (Sections 4(a)(1)(A) through (E)).

We followed a stepwise approach in making this listing determination for Alabama shad. First we conducted a biological review of the species' taxonomy, distribution, abundance, life history, and biology. Next, using the best available information, we completed an extinction risk assessment using the general procedure of Wainwright and Kope (1999). Then, we assessed the threats affecting the status of each species using the five factors identified in section 4(a)(1) of the ESA.

In the next step, we evaluated the available information to determine whether there is a portion of the species' range that is ''significant'' in light of the use of the term in the definitions of threatened and endangered. We followed the final policy interpreting the phrase ''significant portion of its range'' (79 FR 37578; July 1, 2014). A portion of the range of a species is ''significant'' if the species is not currently endangered or threatened throughout all of its range, but the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range.

We describe each of the steps listed above in detail in the following sections of this finding.

Review of the Status of Alabama Shad

We have identified the best available scientific and commercial information in order to conduct a comprehensive review of the status of Alabama shad. Unlike many of our other 12-month findings, we have not developed a separate status review report. Instead we present all available relevant information for Alabama shad in this **Federal Register** notice.

Taxonomy

Alabama shad (*Alosa alabamae*) was first described by David Starr Jordan and Barton Warren Evermann in 1896 in the Black Warrior River near Tuscaloosa, Alabama (Jordan and Evermann 1896). Alabama shad was depicted earlier as ''white shad'' in documents from the U.S. Commission on Fish and Fisheries circa 1860 and was often confused with other shad even after it had been described (Daniels 1860, Barkuloo *et al.* 1993). Alabama shad belong to the family Clupeidae and are closely related to, as well as similar in appearance and life history to, the American shad (*A. sapidissima*). They also resemble the skipjack herring (*A. chrysochloris*), which occurs in the same areas as Alabama shad. Defining characteristics of the Alabama shad are an upper jaw with a distinct median notch, and the number of gill rakers (41 to 48) on the lower limb of the anterior gill arch. Alabama shad differ morphologically from other *Alosa* species that occur in the same area by a lower jaw that does not protrude beyond the upper jaw, black spots along the length of the lower jaw, and a dorsal fin that lacks an elongated filament.

Alabama shad are considered a separate species from the closely related American shad based on mitochondrial DNA molecular data (Bowen 2005, 2008, Kreiser and Schaefer 2009), in addition to the physical differences. There is limited genetic difference and it is theorized that the two species have only recently diverged from a common ancestor. Alabama shad is its own monophyletic group (a group of organisms descended from a single ancestor) due to limited genetic differences among the Clupeidae family and allopatric speciation (speciation by geographic isolation, Bowen 2008). There has been no significant genetic differentiation among different stocks of Alabama shad geographically and there is no evidence of hybridization between any of the other *Alosa* species and Alabama shad (Kreiser and Schaefer 2009).

Diet

Alabama shad are likely generalist insect feeders. Mickle *et al.* (2013) conducted stomach content analyses on individuals collected from the Pascagoula and Apalachicola Rivers. The stomach contents of the smallest juvenile Alabama shad (those less than 50 millimeters), collected exclusively from the Pascagoula River, were made up primarily of semi-decomposed algae and other unidentifiable organics, suggesting filter feeding or particulate feeding of smaller prey. As the size of Alabama shad taken from the Pascagoula River increased, the percentage of terrestrial and aquatic insects in the stomach contents increased. Mickle *et al.* (2013) found that terrestrial insects dominated the stomach contents of all size classes of Alabama shad taken from the Apalachicola River. Diet of Alabama shad from both the Apalachicola and Pascagoula Rivers changed as the size of the fish increased, with insects replacing unidentifiable organic matter. Ephemeroptera nymphs, an order of aquatic insects, dominated the diets of larger Alabama shad from both rivers. These nymphs produce aquatic juvenile larvae that emerge in open water in the same habitats where Mickle *et al.* (2013) collected the Alabama shad for their study. Mickle *et al.* (2013) noted that these observed ontogenetic dietary shifts seemed to coincide with habitat shifts and are consistent with a generalist strategy.

Age and Growth

Like many clupeids (the family of fish that include shad, herring, sardines, and menhaden), egg hatching period and growth of subsequent larvae varies by location and environmental factors. Mickle *et al.* (2010) found those Alabama shad that hatched in the Apalachicola River had a longer successful hatch window (mean of 58 days) compared to those in the Pascagoula River (mean of 33.8 days).

Juvenile Alabama shad exhibit rapid growth, although the size of juveniles varies across the range of the species. Typical juvenile Alabama shad increase in size from about 4.7 centimeters total length (cm TL, the length of the fish measured from the tip of the snout to tip of the tail fin) to about 10.1 cm TL over the summer but variation can occur depending on the river drainage. For example, juvenile Alabama shad from the Apalachicola River grew faster than those in the Pascagoula River despite similar environmental conditions (Laurence and Yerger 1967, Mickle 2010). In the Chipola River, Florida, juveniles move downstream at an average size of 6.5 cm TL, while those moving down the nearby Apalachicola River averaged 11.5 cm TL (Laurence and Yerger 1967).

In both the Apalachicola and Choctawhatchee Rivers, Florida, adult female shad were typically longer and heavier than the adult males (Laurence and Yerger 1967, Mills 1972, Mettee and O'Neil 2003). Age 1–3 males on average weigh 250 grams and age 1–4 females weigh around 650 grams before spawning (Mettee and O'Neil 2003, Ingram 2007).

Two studies have aged otoliths of Alabama shad but only one study has fit growth models to observed age data. In the Pascagoula River, maximum observed age was 6 years based on otoliths (Mettee and O'Neil 2003), while Ingram (2007) aged shad from the Apalachicola River to 4 years.

Reproductive Biology

Alabama shad is a euryhaline (adapted to a wide range of salinities), anadromous fish species that migrates between the ocean and medium to large flowing rivers to spawn (reproduce) from the Mississippi River basin to the Suwannee River, Florida. Alabama shad spawn in February to April at lower latitudes in the south and May to June in more northern latitudes, usually over sandy bottoms, gravel shoals, or limestone outcrops (Laurence and Yerger 1967, Mills 1972, Barkuloo 1993, Kreiser and Schaefer 2009, Mickle *et al.* 2010). Water temperatures between 18 and 22 °C and moderate current velocities (0.5–1.0 meters (m) per second) promote successful spawning (Laurence and Yerger 1967, Mills 1972). If environmental circumstances are unfavorable, mature Alabama shad will sometimes abandon their upstream spawning movement (Young 2010).

Spawning males range in age from 1 to 5 years and females from 2 to 6 years (Mickle *et al.* 2010). Some age-1 male Alabama shad move into fresh water for their first spawning, but the primary spawning age classes tend to be 2–3 years for males and 2–4 years for females; any age-4 Alabama shad present in rivers are almost always female (Laurence and Yerger 1967, Mettee and O'Neil 2003, Ingram 2007). Males arrive at spawning sites first and increase in abundance as the spawning season continues, while females appear in large groups slightly later in the spawning season (Mills 1972, Mettee and O'Neil 2003). It is unknown whether females arrive with ripened eggs, as suggested by Mills (1972), or if their gonads ripen as river temperatures increase (Laurence and Yerger 1967). Females tend to release their eggs in late April and early May when the water temperatures are 20–21 °C (Mettee and O'Neil 2003, Ingram 2007). Fecundity (reproductive capacity) is related to size, with larger females producing more eggs (Ingram 2007, Young 2010). Alabama shad produced 26,000–250,000 eggs per female in the Apalachicola River and between 36,000–357,000 eggs per female in the Choctawhatchee River (Mettee and O'Neil 2003, Ingram 2007). After spawning, the younger (age 2 and 3) Alabama shad migrate back to marine waters. The older spawners (age-4 and older) either die or are preyed upon by other piscivorous fish (Laurence and Yerger 1967).

Because of the age range among the spawning fish, it is believed that individuals may spawn more than once in a lifetime (Laurence and Yerger 1967, Mettee and O'Neil 2003, Ingram 2007, Mickle *et al.* 2010). Laurence and Yerger (1967) indicated that 35 percent of Alabama shad were likely repeat spawners and noted that 2–4 year old males from the Apalachicola River had spawning marks on their scales. Mills (1972) also observed 35–38 percent repeat spawners (mostly age-3) as well as discernable spawning marks on scales from the Apalachicola River population. In addition, Mettee and O'Neil (2003) noted that many Alabama shad collected from the Choctawhatchee River were repeat spawners, with age-3 and age-4 females comprising the majority of repeat spawners in 1994–1995, and age-2 and age-3 females the majority in 1999–2000. In contrast, Ingram (2007) has not observed spawning marks on the scales of Apalachicola River shad and most fish in the Apalachicola may die after spawning (Smith *et al.* 2011). Alabama shad appear to be philopatric and return to the same rivers to spawn, resulting in slight genetic differences among river drainages (Meadows 2008, Mickle 2010). These genetic differences may result in characteristics (*e.g.,* faster growth rates, higher temperature tolerance, etc.) that lead to variable spawning strategies among river drainages. Kreiser and Schaefer (2009) found slight genetic distinctions between populations from the Mississippi River basin and coastal Gulf of Mexico drainages due to Alabama shad straying from their natal rivers, at an estimated rate of about 10 migrants per generation.

Life History Strategy

On the spectrum of life history strategies, Alabama shad tend to be ''r strategists'', species that are typically short-lived, have small body size, reach sexual maturity at an early age, and have high natural mortality that is balanced by a high growth rate (Adams 1980). Species that are r strategists adapt to unstable, unpredictable environments by producing higher numbers of offspring as compared to k strategist species living in stable, predictable environments. Elliott and Quintino (2007) found that species living in unpredictable, variable, and even stressed environments are well-adapted to cope with these conditions without or with reduced adverse effects. Adapting to highly variable environments also produces high natural variability in r strategist populations. Adams (1980) noted that fisheries for r strategists can have very large catches some years, but are characterized by erratic, highly variable production levels overall. Most clupeoids (an order of soft-finned fishes that includes Alabama shad, other clupeids, and anchovies in the family engraulidae) have a short life span and show striking inter-annual or decadal variation in productivity and abundance (Mace *et al.* 2002). Fisheries for clupeoids can vanish for 50–100 years then undergo a remarkable recovery with the population growing as fast as 40 percent per year (Mace *et al.* 2002).

Sammons and Young (2012) noted that the population sizes of species in the *Alosa* genus commonly fluctuate widely. An Alabama shad researcher with the Georgia Department of Natural Resources (DNR) noted that as an r strategist, Alabama shad are prone to ''boom and bust'' years, but they are also highly fecund (capable of producing an abundance of offspring) and can recover quickly from even a small number of fish (based on the results of stocking efforts; T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). In fact, the speciation (evolutionary process by which reproductively isolated biological populations evolve to become distinct species) of Alabama shad likely occurred from a very small number of fish that dispersed around the Florida peninsula and became separated from other *Alosa* species during the Pleistocene (Bowen *et al.* 2008). Modeling conducted by Moyer (2012) indicated that the Pleistocene bottleneck for Alabama shad was intense. The effective population size for Alabama shad during the bottleneck was estimated to be between 76 and 398, meaning 76–398 individuals is the population size during the Pleistocene estimated to have been necessary to result in the relatively low genetic diversity observed in members of the species today. Moyer (2012) also noted that the bottleneck event was prolonged (145–987 shad generations), indicating that the species persisted at very low numbers for an extended period of time.

Habitat Use and Migration

Alabama shad are found in the Gulf of Mexico, although there is very little information about their marine habitat use. Only six records of Alabama shad collected in marine waters exist. The Florida Museum of Natural History reports one specimen was captured in July 1957 approximately 80 miles (mi) or 129 kilometers (km) south of Choctawhatchee Bay, Florida, in about 100 meters of water (Fishnet2 2015, Catalogue #28671). The National Museum of Natural History, Smithsonian Institution, reports another Alabama shad was captured just off Dauphin Island, Alabama, in December 1960 in 15 meters of water (Fishnet2 2015, Catalogue #293755.5174309). Two Alabama shad were collected approximately 115 km southwest of Cape San Blas, Florida in November 2007 (Fishnet2 2015, Catalogue #20627). An Alabama shad was collected by the Texas A&M University Biodiversity Research and Teaching Collections in a trawl about 25 mi (40 km) offshore of Florida, between Tampa Bay and the Charlotte Harbor Estuary (Fishnet2 2016, Catalogue #14540.07). In March 2013, an adult female Alabama shad was collected during a fishery independent monitoring survey approximately 15 km south of the Pascagoula River just north of Petit Bois Island in Mississippi Sound and approximately 5 km east of Horn Island Pass, which leads to the open Gulf of Mexico (Mickle *et al.* 2015). Microsatellite DNA analysis indicated that the fish was most genetically similar to Alabama shad originating from the Pascagoula River. She was observed to have well-developed ovaries, and Mickle *et al.* (2015) suggested she may have been preparing to make a spawning run. Stomach content analyses showed that the fish was full of small invertebrates. Previous studies (*e.g.,* Mills 1972) report few or no stomach contents in Alabama shad collected in riverine environments. The marine specimen with a full stomach collected by Mickle *et al.* (2015) supports that Alabama shad likely feed primarily in marine habitats, similar to other anadromous species.

As part of their anadromous life cycle, adult Alabama shad leave the Gulf of Mexico and move into rivers in the spring to spawn. First year (age-0) juveniles stay upriver in freshwater environments until late summer or fall and eventually migrate downstream to the Gulf of Mexico. Juveniles coming from natal rivers located at more northern latitudes (*e.g.,* Ouachita River in Arkansas) begin downstream movement throughout the summer, reaching the Gulf of Mexico by autumn. Juveniles located at more southern latitudes (*e.g.,* Pascagoula River in Florida) will remain in natal rivers as late as December before beginning their downstream movement to the Gulf of Mexico. Alabama shad do not overwinter in freshwater river systems (Mickle *et al.* 2010).

Alabama shad prefer cooler river waters with high dissolved oxygen (DO) and pH levels (Mickle *et al.* 2010). Although there have been no studies on the thermal tolerances of Alabama shad, other *Alosa* species cannot tolerate water temperatures greater than 32°C; it is likely that Alabama shad also cannot tolerate high water temperatures (Beitinger *et al.* 1999). Mickle *et al.* (2010) found spawning adults in waters as cold as 10 °C, but juveniles have been collected in waters as warm as 32 °C (Mickle *et al.* 2010, Young 2010).

Water velocity is also believed to be an important habitat feature, as this species is rarely found in the still or backwater portions of rivers. It is hypothesized that spring floods (increased river flows) are a vital environmental cue for spawning adults as well as an important aspect for successful hatching. Juveniles tend to occupy moderate to fast moving water (approximately 0.5–1.2 m per second) that is less than 1 m deep (Mickle 2010). Clear water with minimal benthic algal growth also appears to be preferred by this species (Buchanan *et al.* 1999).

Smaller, younger shad tend to prefer the slightly shallower, more protected areas over sandbars, while the older, larger shad can be found in channel and bank habitats. Sandbars within the bends of rivers that are less than 2 m deep often support juveniles in the early summer (Mickle 2010). As the fish grow, they move to bank (greater than 2.5 m deep) and channel (1.5–2.5 m deep) habitats, although the shift is not always consistent (Mickle 2010). Presumably, this allows the juveniles to avoid predators, fulfill foraging needs, or access cooler temperatures that might be present in deeper waters (Bystrom 2003, Mickle *et al.* 2010, Mickle 2010).

Distribution and Abundance

NMFS documented the current known distribution and abundance of Alabama shad in a technical memorandum published in August 2011 (Smith *et al.* 2011). In addition to conducting an extensive search of all publications, technical reports, and theses available, NMFS staff surveyed scientists at universities, state and Federal facilities, and non-profit organizations throughout the historical range of Alabama shad for any recent recorded captures. Surveys were sent by email, and information was requested on capture dates, location, and number of Alabama shad captured, if available. Additionally, capture information and observations were provided by state and Federal agencies during the public comment period on our 90-day finding.

Information on the historical and current distribution and abundance of Alabama shad is largely lacking. Alabama shad was never an economically important species, therefore information from fisheries statistics, such as landings data, is rare. Hildebrand (1963) noted that Alabama shad were considered unfit for human consumption, and the lack of demand produced no incentive to capture the species or record its presence and abundance. Very few directed research studies on Alabama shad have occurred, with the exception of recent studies in the Apalachicola Chattahoochee Flint (ACF) and Pascagoula River systems. The recent studies in the ACF River system have produced the only abundance estimates, either historical or current, for Alabama shad in any river system. The historical and current distribution of Alabama shad in other systems is based on capture data from general multi-species surveys, project monitoring, captures incidental to other research studies, and anecdotal information. Information received from state resource agencies (*e.g.,* during the public comment period on the 90-day finding and during development of this determination, presented in the sections below) corroborates that long-term, strategic studies of the species in their states are lacking. For instance, the Arkansas Fish and Game Commission stated in their comments on the Alabama shad positive 90-day finding they could not assess the status of Alabama shad in their state because of the scarcity of information on the species, the lack of targeted surveys, and the unknown detectability of the species (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013).

Mettee and O'Neil (2003) note that low numbers of recorded Alabama shad individuals may be due, at least in part, to insufficient sampling effort during appropriate times (*i.e.,* spawning migrations) and with the appropriate gear to target the species. Hildebrand (1963) noted the importance of proper gear, citing greatly increased catches of Alabama shad that occurred in Kentucky when surface-fishing seines were substituted for bottom-fishing seines. Short-term studies may also fail to accurately demonstrate the status of a given river population of Alabama shad since this r strategist species is prone to high natural variability and long-term studies would be necessary to reveal any population trajectory.

In reviewing data provided by the Florida Fish and Wildlife Conservation Commission (FFWCC) during the public comment period on the positive 90-day finding (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013), less than 50 Alabama shad were reported since 1999. The shad were collected during multispecies surveys not specifically targeting Alabama shad. The research with positive reports of Alabama shad was conducted using otter trawls, seines, and electrofishing during winter (December, January, February), spring (May), summer (June, July, August), and fall (September, October, November) months between 2002 and 2011. It is notable that none of the FFWCC surveys were conducted in March or April, when the largest catches of Alabama shad have occurred during targeted research in the ACF River system (Kern 2016, Sammons 2013, 2014). Further, although FFWCC caught less than 50 Alabama shad from 2002–2011, researchers targeting Alabama shad in the ACF River system captured 128–1,497 Alabama shad per year during an overlapping time period (2005–2011; Young 2010, 2011). This demonstrates the importance of the sampling gear and time of year in interpreting available data and why short-term and/or non-targeted research is not always a good indicator of distribution and abundance.

Even studies designed to target Alabama shad have yielded difficulties in detecting the species. Researchers studying Alabama shad in the ACF River system noted they had great difficulty finding Alabama shad in portions of the Flint River and expressed their surprise at the difficulty, given the small size of the river (Kern 2016; S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, Jim Woodruff Lock and Dam (JWLD) Fish Passage Year-End Summary Meeting, January 2014; S. Sammons, Auburn University, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2015). Large gaps in detections of Alabama shad were observed in the Flint River (Kern 2016; S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014; S. Sammons, Auburn University, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2015). Alabama shad were detected at upstream and downstream locations on acoustic receivers, but were not detected by receivers in between. Multiple methods were used with limited success to improve the detectability of Alabama shad, including passive (anchored receivers), boat, and airplane tracking of acoustically and radio-tagged shad (S. Sammons, Auburn University, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2015). Kern (2016) believed a combination of behavioral and environmental factors reduced the detectability of Alabama shad. Kern (2016) notes there are many ''blue hole'' springs along the river's length that are substantially deeper than the surrounding river and it is possible that Alabama Shad may use these features as refugia during the spawning migration. High water conditions were also experienced during portions of the sampling period. Kern (2016) stated that increased water depth during periods of high river discharge, swimming depth of Alabama Shad, and the presence of significantly deeper habitats than what is available in the rest of the river could lead to decreased detection probability by exceeding the detection range of passive and manual receivers. Kern (2016) also noted that Alabama shad are capable of long, rapid migration runs and if those migration runs occur at night, Alabama shad will not be detected by manual tracking (from boats and airplanes) that occurs exclusively during the day. The same detection problems (gaps in Alabama shad detection at receivers between two positive detection points) were experienced during Alabama shad conservation locking studies in the Alabama River system (Kern 2016; S. Sammons, Auburn University, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2015).

It is unknown to what degree the lack or low numbers of Alabama shad reported for many river systems accurately reflects the abundance in those systems or whether it is indicative of the lack of targeted studies or the detectability of this species.

Distribution and abundance information is summarized below by rivers, starting with the Apalachicola River where we have the most information regarding Alabama shad, then information is presented by rivers from west to east.

Apalachicola River Drainage

The Apalachicola River drainage is made up of the Apalachicola, Chattahoochee, and Flint Rivers and drains water from parts of Florida, Alabama, and Georgia. Alabama shad were known to have migrated from the Apalachicola River up the Chattahoochee River to Walter F. George Reservoir in the early 1970s (Smith *et al.* 2011), even with the construction downstream of the Jim Woodruff Lock and Dam (JWLD) in the early 1950s and George W. Andrews Lock and Dam in the early 1960s. Alabama shad were able to pass upstream and downstream when the navigation locks were open. Located at the confluence of the Chattahoochee and Flint Rivers, JWLD is the first major obstacle on the Apalachicola River to the upstream migration of Alabama shad to their historical spawning grounds. River traffic on the Apalachicola River resulted in the lock being operated frequently, allowing passage and sustaining reproduction of the resident Alabama shad population. Historically, JWLD was operated continuously 24 hours per day for commercial barge traffic (Sammons 2013). With the elimination of commercial traffic in the late 1960s, lock operation was reduced to 8 hours per day for on-demand passage of recreational boats, reducing the number of lockages to less than 100 per year from a high of 1200. Barge traffic decreased and lock operation became less frequent when navigational dredging ceased in 2001 (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013). Researchers believe Alabama shad spawn in shoal habitat downstream of JWLD based on observations of the species congregating over the shoals during spawning season, as well as usage by other spawning anadromous species, such as Gulf sturgeon (*Acipenser oxyrinchus desotoi;* T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016).

During the public comment period, the FFWCC reported collecting fewer than 50 Alabama shad in the lower Apalachicola River since 1999 (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013). In reviewing the data provided by FFWCC during the public comment period on the positive 90-day finding, the fewer than 50 Alabama shad reported since 1999 were collected during multispecies surveys (*i.e.,* Alabama shad were not specifically targeted). The research with positive reports of Alabama shad was conducted using otter trawls, seines, and electrofishing during winter (December, January, February), spring (May), summer (June, July, August), and fall (September, October, November) months between 2002 and 2011. It is notable that none of the surveys were conducted in March or April, when the largest catches of Alabama shad have occurred during research targeting Alabama shad in the ACF River system, which occurs annually between March and May to coincide with the spring spawning migration (Kern 2016, Sammons 2013, 2014). Further, although FFWCC caught less than 50 Alabama shad from 2002–2011, researchers targeting Alabama shad in the ACF River system captured 128–1,497 Alabama shad per year during an overlapping time period (2005–2011; Young 2010, 2011). This demonstrates the importance of the sampling gear and time of year in interpreting available data and why short-term and/or non-targeted research is not always a good indicator of distribution and abundance.

The ACF River system likely contains the largest spawning population of Alabama shad within its range, although the population may be several orders of magnitude smaller than historical levels (Schaffler *et al.* 2015). Because this population has remained self-sustaining even with apparent declines, a project to restore passage to upstream spawning habitats was initiated (Schaffler *et al.* 2015). Beginning in 2005, a cooperative study supported by multiple local, academic, state, and Federal conservation partners started tracking movements of Alabama shad and other fish species in the Apalachicola River (USFWS 2008, Ely *et al.* 2008, TNC 2010). The study also evaluated the feasibility of moving fish upriver of JWLD during the spawning season. The results of this collaborative study showed that the existing lock at JWLD could be operated to allow fish to move upriver through the lock where they could access additional spawning habitat. Based on these results, U.S. Army Corps of Engineers (USACE) began ''conservation locking'' (operating the lock at JWLD to provide Alabama shad access to upstream habitat) in 2005.

In 2012, the ''cooperator'' organizations (USACE, USFWS, NMFS, Georgia DNR, FFWCC, and TNC) signed a Memorandum of Understanding (MOU) clarifying their commitments and responsibilities in the continued implementation of fish passage at JWLD. The contents of the MOU are described in more detail in the ''Regulations on Dams'' section in ''*D. Inadequacy of Existing Regulatory Mechanisms.*'' In fulfillment of the cooperation outlined in the MOU, an annual meeting to discuss the issues and outcomes from the previous spring conservation locking cycle is held, usually in the early part of the following year (*i.e.,* January or February). At the annual meetings, the cooperators and other interested parties (*e.g.,* universities that are not signatories to the MOU, but are heavily involved in research activities associated with the conservation locking in the ACF River system) discuss lessons learned from the previous year and participate in planning the next cycle of spring conservation locking, including whether the locking operation and schedule can be improved. For example, during the planned lock maintenance that occurred during the 2013–2014 season, the cooperators were able to upgrade the method of delivering the attractant flow (a stream of high velocity water used to attract spawning fish) from a manual system to an electric pump as a more efficient way to direct shad through the lock when conservation locking resumed (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014).

Population abundance estimates for Alabama shad in the ACF River system were determined through mark-recapture methods from 2005–2016. The estimated abundances for 2005–2016 are listed in the following table (the asterisks indicate years in which no conservation locking occurred due to maintenance and upgrades to the lock at JWLD). The table also shows the catch per unit effort (CPUE) of adult and juvenile Alabama shad during spring and fall sampling, respectively.

TABLE 1—ADULT AND JUVENILE ALABAMA SHAD RESEARCH RESULTS IN THE ACF RIVER SYSTEM

Year	Adult population estimate (spring)	Confidence interval (spring)	Adult CPUE (spring)	Juvenile CPUE (fall)
2005	25,935	17,715–39,535	20.47	n/a.
2006	2,767	838–5,031	6.10	0.1.
2007	8,511	5,211–14,674	13.17	5.75.
2008	5,253	1,592–9,551	13.00	16.17.
2009	10,753	3,258–19,551	9.20	0.
2010	98,469	51,417–127,251	7.17	22.4.
2011	26,193	22,371–43,713	72.93	25.
2012	122,578	57,911–282,872	100.6	1.9.
2013*	2,039	618–3,706	17.2	1.33.
2014*	n/a	n/a [86 fish captured; no re-captures]	6.5	3.33.
2015	324	58–3,240	6.8	0.
2016	n/a	[0 fish captured]	0	CPUE not yet calculated [20 juveniles captured].

In the period of conservation locking, Alabama shad have been successfully passed through the navigational lock at the most downstream dam on the ACF, JWLD, providing upstream migration to higher quality spawning and juvenile rearing habitat, which has potentially improved recruitment and lead to population increases (Ely *et al.* 2008, Young *et al.* 2012, Schaffler *et al.* 2015). Since conservation locking began, Alabama shad have been reported above JWLD in both the Chattahoochee River and the Flint River (2008–2010) by the Georgia DNR (Smith *et al.* 2011). The USACE reported Alabama shad in Lake George W. Andrews in the Chattahoochee River during recent sampling of the area (Smith *et al.* 2011). Only a few Alabama shad have been found in the Chattahoochee River, with the vast majority being found in the Flint River (Young 2010). In years when conservation locking occurred, the locks were operated twice a day to correspond with the natural movement patterns of migrating fish during spawning seasons (February through May) each year. During conservation locking, acoustically tagged Alabama shad released below the dam have been found to pass upstream of the lock with 45 percent efficiency (Young 2010). Alabama shad can more easily access over 150 mi (241.4 km) of historical habitat and spawning areas in the ACF River system for the first time in more than 50 years now that the lock is operated to correspond with their natural spawning cues (TNC 2010).

Schaffler *et al.* (2015) completed a study on shad collected in 2010 and 2011 to determine whether fish passage efforts at JWLD were contributing recruits to the adult Alabama shad population. They evaluated otolith (inner ear bone) chemistry from spawning adult Alabama shad to determine the river reach within the ACF basin the fish originated from. They first examined the otolith chemistry of known-origin juveniles captured in freshwater reaches both upstream and downstream of JWLD. Then, they compared the distinct chemical signatures of the juvenile otoliths to those from returning spawning adults of unknown origin captured below the dam to assign river-reach natal origins. The results showed that the Flint River, inaccessible to Alabama shad prior to conservation locking, is the dominant source of recruits returning to spawn in the ACF River system making up 86 percent of the individuals captured. Schaffler *et al.* (2015) found no evidence that collection year, sex, or age impacted the origin of returning Alabama shad in the ACF River system, meaning the Flint River produced the majority of recruits in the ACF River system for the 2008–2010 cohorts of both males and females. The results from this study indicate that conservation locking is making a tremendous contribution to Alabama shad in the ACF River system, the bulk of the Alabama shad population in the ACF River system is spawning in the Flint River, and juvenile Alabama shad are able to successfully move downstream to contribute to the adult stock.

In 2005, the population estimate in the ACF River system was about 26,000 individuals, but decreased to less than 10,000 in both 2006 and 2007 (Ely and Young 2008). In 2008 and 2009, mark-recapture methods yielded an Alabama shad population estimate of approximately 5,200–10,700. However, one of the researchers noted that the Alabama shad population estimates for 2008 and 2009 (5,253 and 10,753 shad, respectively) are likely underestimates of the actual population numbers based on the results of a companion electrofishing study by Clemson University (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, February 8, 2016). Based on a predictive model developed by Clemson, the 2008 and 2009 Alabama shad population estimates would be closer to 8,500 and 26,000 shad, respectively.

Young (2010) estimated the number of Alabama shad in the ACF River system at 98,469 in 2010, almost 4 times larger than the previous high estimate of 25,935 in 2005 (Ely *et al.* 2008). Alabama shad were the most abundant species observed in the Apalachicola during spring sampling in 2010 (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016).

Within the ACF River system, the number of Alabama shad in 2011 was estimated at 26,193; this is lower than the 2010 value but slightly higher than the maximum abundance in the 2005–2009 period (Young 2011). The major difference between the 2010 and 2011 Alabama shad spawning runs was a lack of age-1 males in 2011. Ingram (2007) noted that fewer age classes and lower numbers of older, more mature, fish are indicative of a declining population. The 2011 run was dominated by older, larger adult females in excellent condition, a potential indicator of strong year classes in the future (Young 2011). Sammons and Young (2012) provided a report from the Apalachicola River, estimating the number of Alabama shad at 122,578 in 2012 (the largest since 2005). This spawning run was composed of many males presumed to be from the 2010 year class, as well as numerous older, larger adults of both sexes (presumably recruits from 2008 and 2009). In 2012, the abundance of 3- and 4-year-old fish made up the largest percentage of spawning Alabama shad, rather than 1- and 2-year-olds as in previous years (Ingram 2007), indicating a healthier population (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). Sammons and Young (2012) noted that a year of higher than average flows in 2009 may have contributed to spawning and recruitment successes in 2010 and 2012.

While conservation locking of Alabama shad at JWLD and monitoring of Alabama shad populations in the ACF River system continue to receive support and funding Alabama shad were not passed through the lock in 2013 and 2014 due to maintenance on the structure. However, 74 Alabama shad out of a total of 251 captured by researchers during 2013 were tagged and transported above JWLD and released (Kern 2016, Sammons 2013) in order to access habitat above the dam. Of the 74 tagged fish, 11 were verified as post-release mortalities, with another 3 suspected mortalities (Sammons 2013). It is unknown whether Alabama shad not captured by researchers successfully spawned at the shoal habitat below JWLD where they spawned prior to conservation locking (*Acipenser oxyrinchus desotoi;* T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). Also, during the maintenance period on the lock, the method of delivering the attractant flow (a stream of high velocity water used to attract spawning fish) was upgraded from a manual system to an electric pump as a more efficient way to direct shad through the lock when conservation locking resumed (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014).

Conservation locking appears to have enhanced spawning and recruitment of Alabama shad in the ACF River system (Young 2010, 2011, Sammons and Young 2012, Schaffler *et al.* 2015). Although the ACF population of Alabama shad has been the largest known population for decades (Laurence and Yerger 1967), the lack of conservation locking in 2013 and 2014, combined with environmental conditions (cold and flooding) and the poor condition of spawning fish (discussed below), likely produced the weakest year class since research began on Alabama shad in the ACF River System in 2005. However, environmental conditions (cold, flooding, and the presence of large debris) and funding levels also hampered researchers' ability to survey the Alabama shad population in the ACF River system in 2013–2015 to develop reliable population estimates.

The Alabama shad population sampled below JWLD during the 2013 spawning season was low compared to previous seasons (Sammons 2013). A total of 309 Alabama shad were captured below JWLD and of those fish, 87 fish were tagged and 1 was recaptured, resulting in a population estimate of 2,039 Alabama shad (Sammons 2013). Sammons (2013) noted that most Alabama shad collected below JWLD in 2013 were in poor physical condition, with visible wounds (this will be discussed further in ''C. Disease and Predation''). The wounds were observed only on adult fish and not on younger fish, indicating the source may have occurred in the Gulf of Mexico (Sammons 2013). The wounds were also not observed on other anadromous species, indicating Alabama shad are either more susceptible to the source of the wounds or they are distributed in areas that the other species are not (Sammons 2013).

The wounds remain unexplained, but Sammons (2013) cited a news article reporting gash wounds on fish potentially associated with the Deepwater Horizon Oil Spill resembling the wounds found on Alabama shad. Sammons (2014) also cited Murawski *et al.* (2014) noting the anecdotal reports of skin lesions in offshore fish species in 2010 and 2011, but the symptoms declined by 2012. The sores have not been observed in any Alabama shad captured since 2013 (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016).

The Alabama shad captured below JWLD were tagged and/or released approximately 5 km above the dam (Sammons 2013). Most of the Alabama shad were relocated (detected again after release) in Lake Seminole just above the dam, but some fish were detected moving into the preferred spawning habitat in the Flint River (Sammons 2013). Although fewer fish were detected making a spawning run than in previous years, Alabama shad traveled greater distances from the area they were released in 2013 than in previous years (Sammons 2013).

Reasons for the lack of fish found below JWLD are unknown, but unusually cold water temperatures due to cooler weather patterns present throughout the Apalachicola River Basin in 2013 may have been a contributing factor (Sammons 2013). Water temperature serves as one of the main cues for Alabama shad to enter the ACF River system to spawn (Kern 2016, Sammons 2013). The researchers suspect that many Alabama shad had not yet entered the Apalachicola River to spawn during their sampling effort in the river, and this factored into the low numbers captured during 2013.

In 2014, 102 Alabama shad were captured below JWLD; 86 were tagged and released above JWLD (Sammons 2014). No fish were recaptured and a population estimate could not be calculated (Sammons 2014). Since conservation locking did not occur in 2013 or 2014 due to maintenance of the lock, Alabama shad likely did not pass upstream except for those transported by researchers. Sammons (2014) noted that the Alabama shad captured in 2014 were smaller than shad captured in the previous two years, but that the fish were in better condition and did not exhibit the wounds as the majority of the population did in 2013. Although few adult Alabama shad were captured in the spring 2014, juvenile Alabama shad were collected in the fall sampling above JWLD in 2014 (CPUE of 3.3 in the table above), indicating that adult Alabama shad had successfully passed upstream and spawned (P. Freeman, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, February 2016). Despite no abundance estimate being produced, juvenile CPUE in 2014 was higher than CPUEs in the 2 previous years.

Given the low numbers, Sammons (2014) believes that weak year classes were produced in 2013 and 2014. However, Sammons (2014) stated that water levels and temperature may have factored in to the low catches in 2014. Water levels and discharge were much higher during Alabama shad sampling in 2014 than in the previous 2 years and the mean catch rate of Alabama shad below JWLD was inversely correlated with mean daily discharge over the past 5 years (Sammons 2014). High water and discharge may have hindered catch rates, but spawning population size was also likely low (Sammons 2014). Reasons for the lack of fish found below JWLD are unknown, but may have also involved unusually cold water temperatures. As in 2013, water temperature was generally more than 2–4 °C cooler throughout the spawning season than in 2011 or 2012 (Sammons 2014). Abnormally low water temperatures in the Apalachicola River throughout the spring in 2013 and 2014 may have inhibited the usual spawning migration cues of this species, resulting in fewer fish migrating upstream (Sammons 2014). Sammons (2014) stated it is possible that a significant spawning population of this species persists in the Gulf of Mexico waiting for more normal spring conditions to return to the river before initiating their spawning run.

In 2015, conservation locking resumed, but the Alabama shad population estimate remained low (324 fish). Due to the lack of conservation locking in 2013 and 2014, and potentially the lack of successful spawning due to the poor condition of the Alabama shad observed in 2013 (Sammons 2013, 2014), it is probable that the actual number of returning adult Alabama shad in 2015 was low. Similar to the previous year, researchers noted factors that may have reduced their capture rates, such as high water levels and large amounts of debris in the river that hampered sampling, potentially leading to the low number of recaptures and the low population estimate (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, February 3, 2016).

In 2016, high water levels occurred early in the sampling season, but later returned to normal levels (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). No Alabama shad were captured in the Apalachicola River in 2016, and therefore an abundance estimate could not be produced for that year (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). However, Alabama shad were observed lower in the Apalachicola River by another researcher conducting striped bass surveys (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). The Alabama shad survey occurred about 2 km downstream of JWLD (Sammons 2014) and therefore would not have encountered Alabama shad occurring downstream of that location. The gill-netting survey conducted in Lake Seminole above JWLD to detect juvenile Alabama shad occurred in mid-December 2016 and produced 20 juvenile Alabama shad. Even though no adults were captured in the spring survey, the collection of juvenile shad above JWLD indicates that some adult Alabama shad did successfully pass through the lock and spawn in the ACF system in 2016 (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, December 15, 2016). At the time this 12-month determination was prepared, the researchers had not yet calculated the CPUE for the juvenile survey.

Funding levels and research effort may also have contributed to the differences in abundance estimates between 2013–2016 (low number of fish captured) and 2009–2012 (large number of fish captured). Funding levels were much higher in 2009–2012 and researchers were pursuing additional research questions beyond population estimates that required them to capture more fish (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). From 2009–2012, researchers logged more research time on the Apalachicola River and targeted higher numbers of Alabama shad, which produced robust population estimates. As noted, environmental conditions greatly hampered research efforts in 2013–2015. It is unknown whether catch rates were influenced by environmental factors in 2016 or were strictly a reflection of very low population numbers, but reduced funding further exacerbated researchers' ability to increase survey efforts to offset research difficulties or to opportunistically take advantage of improved environmental conditions when they occurred (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). The differences in the trends in Alabama shad adult population estimates and the CPUE of adult Alabama shad between 2005–2016 can partially be explained by the differences in sampling effort levels due to both environmental conditions and funding levels (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016), although researchers believe the Alabama shad spawning populations in the ACF River system in 2013–2016 were smaller, especially compared to the 2009–2012 spawning populations.

As described above, low numbers of Alabama shad were captured in 2013–2015 and no adult Alabama shad were captured in 2016, producing low or no population estimates. From 2013–2016, the primary cause of low Alabama shad captures is likely that low numbers of Alabama shad returned to spawn in the ACF River system during those years (Sammons 2013, 2014, T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). Conservation locking did not occur in 2013 and 2014 due to maintenance and improvements on the lock. Some Alabama shad captured by researchers were transported and released above JWLD, but the remaining fish in the population likely only had access to any downstream spawning habitat (Sammons 2013, 2014). However, while conservation locking appears to have significantly increased spawning and recruitment success of Alabama shad and expanded the species' access to additional habitat in the ACF River system, the ACF population has been the largest known population of Alabama shad for decades (Laurence and Yerger 1967) even before conservation locking occurred. The poor condition of Alabama shad in 2013, when most fish collected had unexplained external wounds (Sammons 2013, 2014), potentially led to poor spawning success and fewer returning spawners in the following years. The CPUE of juvenile Alabama shad in the Flint River in the fall of 2013 was low, although not the lowest observed and similar to the CPUE for 2012, which had the highest adult population estimate recorded since research commenced in 2005.

Environmental conditions may have affected both shad spawning activities and the ability of researchers to detect shad. Cold temperatures in 2013 and 2014 may have postponed the spring spawning runs until temperatures increased later in the season (and after Alabama shad research had already ceased), or the majority of Alabama shad may have forgone their annual spawning run and remained in their marine habitat (Sammons 2014). Water levels and discharge were much higher during Alabama shad sampling in 2014 than in the previous 2 years and may have hindered catch rates. The mean catch rate of Alabama shad below JWLD was inversely correlated with mean daily discharge over the past 5 years (Sammons 2014). This is similar to observations in other systems, and can mean high river discharge delayed or hindered spawning runs or affected the ability of researchers to capture shad. Kern (2016) found that the number of detections of tagged Alabama shad in 2013 and 2014, as well as the extent of upstream migration by shad, appeared to be influenced by river discharge, with the lowest number of detections and least amount of upstream movement occurring during years with relatively high river discharges. Sammons (2014; citing Holman and Barwick 2011, and Pierce *et al.* 1985) noted that the inverse relationship between capture of fish by electrofishing results and high water level is well known. Alabama shad detection in general proved surprisingly difficult to researchers, in both the ACF River and the Alabama River systems, with large gaps in detections between areas where Alabama shad were known to have occurred (Kern 2016; S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014; S. Sammons, Auburn University, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2015). Funding levels and research effort may also have contributed to the differences in abundance estimates between 2013–2016 (low number of fish captured) and 2009–2012 (large number of fish captured), with higher funding levels and increased effort in 2009–2012 compared to the later years (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016).

To further evaluate potential causes and effects of the low capture rates in the ACF River system in 2013–2016, we compared the adult population estimates and CPUEs from spring sampling with the CPUE of juveniles sampled above JWLD in the fall. The CPUE for juvenile shad is a metric derived from surveys designed to assess the recruitment success of Alabama shad upstream of JWLD. Given the growth rate of Alabama shad, surveys for juveniles upstream of JWLD in the fall would indicate success of the spring spawning that occurred earlier in the year. Trends in juvenile CPUE did not appear to follow trends in the adult population estimates or the adult CPUEs. Further, the trends in juvenile CPUE did not appear to reflect the trends in adult population estimates either 1 or 2 years later, when juveniles would be of spawning age. Recapture rates of tagged adult Alabama shad ranged from 0 to 2.2 percent per year for tagged shad. There was not a strong relationship (r = 0.33) between population size and CPUE, nor between population size and the number of recaptured fish (r = 0.21). However, there was a strong positive relationship between population size and the number of fish tagged (r = 0.82). Interestingly, there is a very poor fitting relationship between the number of fish tagged and the number of fish recaptured (r = 0.15), which indicates the results are potentially heavily influenced by variability in the number of recaptures in a given year. The researchers' ability to capture, but not as easily recapture fish, may provide some indication that difficulties in detecting Alabama shad during research efforts factored into the low population estimates in addition to the actual population size being low.

The low catch rates of Alabama shad in 2013–2016, although potentially influenced by environmental conditions, detection ability, and research effort, primarily indicate that Alabama shad populations were much lower during those years than in the previous years of research since 2005. However, for an r strategist species such as Alabama shad that is inherently prone to high levels of natural variability, it is very difficult to interpret a population trend from 11 years of population estimates, with no historical abundances available for comparison. The abundance estimates for Alabama shad in the ACF River System demonstrate that the abundance in the system for the 11-year period is highly variable, and no population trend is apparent. The confidence intervals around each of the abundance estimates in the table show the wide range of uncertainty inherent in the abundance data.

Based on the life history strategy of the species and the short period over which abundance estimates have been available, we cannot discern a pattern or trend in the Alabama shad population in the ACF River system. As an r strategist, Alabama shad have high natural mortality that is balanced by a high growth rate (Adams 1980). R strategist populations are well-adapted to cope with unstable, unpredictable environments, and this also produces high natural variability in their populations (Elliott and Quintino 2007). Adams (1980) noted that fisheries for r strategists are ''boom or bust,'' and although catches can be very large some years, they will be characterized by erratic production levels overall.

Alabama shad belong to the clupeoids, an order of fish that show striking interannual or decadal variation in productivity and abundance, with the ability to persist at extremely low population numbers for 50–100 years then undergo a remarkable recovery with the population growing as fast as 40 percent per year (Mace et al. 2002). Sammons (2013) also noted that increases of Alabama shad populations can happen very quickly, as demonstrated by the rapid rise in population size between 2006–2009 and 2010–2012 (Sammons 2013). While the Alabama shad population appears to be much smaller based on the last 4 years of tag-recapture data as compared to the previous 7 years, we did not detect a discernable trend, the high interannual variability is not unexpected for this species, and the species is adapted to recover from very low numbers of fish, even if the population persists at depressed levels for long periods of time.

The studies in the ACF River system have produced the only abundance estimates, either historical or current, for Alabama shad in any river system. The following sections of the determination present the historical and current distribution of Alabama shad in other systems, which is primarily based on capture data from general multi-species surveys, project monitoring, captures incidental to other research studies, and anecdotal information.

Mississippi River

The Mississippi River is the largest river basin in North America and drains portions of Montana, the Dakotas, Nebraska, Minnesota, Wisconsin, Iowa, Illinois, Indiana, Ohio, West Virginia, Pennsylvania, Colorado, Kansas, Missouri, Kentucky, Tennessee, Texas, Oklahoma, Arkansas, Mississippi, and Louisiana. Alabama shad were historically found in parts of the Mississippi River and its tributaries and several small spawning populations remain.

Upper Mississippi River Mainstem

The Upper Mississippi River is the portion of the river upstream of Cairo, Illinois. In the Upper Mississippi River, Alabama shad were recorded in the 1994 Annual Status Report: ‘‘A Summary of Fish Data in Six Reaches of the Upper Mississippi River’’ (Gutreuter *et al.* 1997) as being captured in a long-term fish resource monitoring program. The report was compiled by the U.S. Geological Survey (USGS), Minnesota DNR, Wisconsin DNR, Iowa DNR, the Illinois Natural History Survey, and the Missouri Department of Conservation. However, the Gutreuter *et al.* (1997) report did not include specific data on Alabama shad and other species, such as the number of fish caught, gear used, the location of capture, etc. Presently, there are 10 locks and dams on the Upper Mississippi River (north of the confluence with the Ohio River) that border the state of Iowa and an additional seven locks and dams south of the state that could prevent Alabama shad from reaching historical spawning grounds within Iowa (Steuck *et al.* 2010). In 1915, 48 Alabama shad were collected from the Upper Mississippi River near Keokuk, Iowa, and it was reported that some of these fish were able to make it past the Keokuk Dam (Lock and Dam #19) farther upstream (Coker 1928). Iowa DNR has collected no Alabama shad in the Upper Mississippi River in the areas between Lock and Dams #16 and #19 in the last 25 years (Smith *et al.* 2011). Barko's study (2004b) in the Upper Mississippi River, near the confluence of the Ohio and Missouri Rivers, found no Alabama shad between 1994 and 2000. A species richness study conducted by Koel (2004) indicates that the Upper Mississippi River in the state of Illinois does not support Alabama shad. The Upper Mississippi River Conservation Committee also indicated that there are only historical records of Alabama shad in the Upper Mississippi River, and none have been caught in over 10 years (Steuck *et al.* 2010). However, Wilcox (1999) and Ickes (2014) both list Alabama shad as being present in the Upper Mississippi River.

Missouri River

The Missouri River is a major tributary of the Mississippi River and flows through Montana, North and South Dakota, Nebraska, Iowa, Kansas, and Missouri. The lower Missouri River and its tributaries, located in the center of Missouri, probably supported the greatest number of Alabama shad in the state, although the records are limited (Smith *et al.* 2011). The Missouri Fish and Wildlife Information System, maintained by the Missouri Department of Conservation (MDC), states that Alabama shad spawn in the Missouri River and two of its tributaries, the Gasconade and Osage Rivers (MDC 2015, Pflieger 1997). The MDC's earliest record of an Alabama shad in the Gasconade River was 23 fish collected in 1947 (C. Gemming, MDC biologist, pers. comm. to J. Rueter, NMFS, September 21, 2016). A study determining the habitat use of juvenile fish in the lower Missouri River did not identify Alabama shad as being present between 1987 and 1988 (Brown and Coon 1994). However, Galat (2005) recorded the presence of the species in the Lower Missouri River in 2005, and stated that Alabama shad are rare in the Ozark Plateaus region in southern Missouri. The MDC reported the collections, by trawl and electrofishing, of Alabama shad from the Gasconade River (41 fish in 1989, 4 fish in 1997, 17 fish in 2000, and 26 fish in 2012); the purposes and locations of those studies were varied (*e.g.,* project monitoring and fish surveys) and they were not directed at collecting Alabama shad (C. Gemming, MDC biologist, pers. comm. to J. Rueter, NMFS, September 21, 2016).

Meramec River

The Meramec River is a tributary of the Mississippi River whose confluence is just south of the confluence of the Missouri River. The entire length of the river is contained within Missouri. Alabama shad were known to spawn in the Meramec River prior to 1978 (Mills *et al.* 1978) and a second spawning location in the river was discovered in the Big River tributary (Mills *et al.* 1978). Between 1980 and 1997, 88 juvenile and 8 adult Alabama shad were captured in Missouri rivers, including the Meramec River (Pflieger 1997). The University of Tennessee reported the collection of 33 Alabama shad from the Big River shoals in 1990 (Fishnet2 2016, Catalogue #29.12) Burr *et al.* (2004) and Buchanan *et al.* (2012) list the Meramec as one of the remaining spawning rivers of Alabama shad. The Missouri Fish and Wildlife Information System, maintained by the Missouri Department of Conservation, also states that Alabama shad spawn in the Meramec River (MDC 2015).

Lower Mississippi River Mainstem

The Lower Mississippi River is the portion of the river downstream of Cairo, Illinois. Alabama shad historically used the Mississippi River as a means to reach many of its tributaries, but none have been found in the lower portion of the waterway in recent years. Surveys conducted by USACE on the Lower Mississippi River (north of Baton Rouge, Louisiana) in the early 1980s show a slow decline in the number of adult and juvenile Alabama shad (Pennington 1980, Conner 1983, Smith *et al.* 2011). From the Thibodaux Weir on Bayou Lafourche, between Donaldsonville and Raceland, Louisiana, a single Alabama shad was caught using a gillnet in March of 2006 (Dyer 2007). Three Alabama shad were caught in Louisiana just west of Atchafalaya Bay between 1992 and 1996 by the Louisiana Department of Wildlife and Fisheries (Smith *et al.* 2011). However, no records of shad have been reported in recent years in annual fish surveys conducted by USGS in other Louisiana streams and rivers (Smith *et al.* 2011).

Ohio River

The Ohio River is the largest tributary by volume of the Mississippi River and flows through Pennsylvania, Ohio, West Virginia, Kentucky, Indiana, and Illinois. Although the species was present and abundant enough to support a small and brief commercial fishery during the late 19th century and early 20th century in Ohio, by 1989 the majority of Alabama shad had been extirpated from the Ohio River (Pearson and Pearson 1989). The USGS has not collected any Alabama shad from the Ohio River since 1993 and the USFWS has no records of Alabama shad in its database (Smith *et al.* 2011). Hammerson (2010) cites that Etnier and Starnes (1993) recorded the collection of a large adult from the Tennessee River (which flows into the Ohio River) just below Kentucky Dam in Marshall County, Kentucky, in July 1986. However, there have been no recent observations or collections of the species in the Tennessee River (Smith *et al.* 2011). Although the species was once present in the Clinch and Stones Rivers (tributaries of the Tennessee River), no collections of Alabama shad were made in these systems after 1993 (Hammerson 2010, Etnier and Starnes 1993). Historically, the Wabash River, another tributary of the Ohio River, was said to have a ''very limited number'' of Alabama shad in its waters in the mid-1800s (Daniels 1860).

Arkansas River

The Arkansas River is a major tributary of the Mississippi River that drains Colorado, Kansas, Oklahoma, and Arkansas. Alabama shad have not been collected in the Arkansas River since an 1892 collection of one specimen in the Mulberry River tributary (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). A few specimens were captured from the Poteau River, a tributary of the Arkansas River, prior to the 1950s (Cross and Moore 1952), but Lindsey *et al.* (1983) stated the species' status was unclear. A compilation of 20 years of fish collection data from Arkansas riverine systems by Matthews and Robison (1988) indicated no records of Alabama shad. The species may have been extirpated from the watershed by the construction of dams in the McClelland-Kerr Arkansas River Navigation System in the early 1970s (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013).

Red River

The Red River, a major tributary of the Mississippi River, flows through Texas, Oklahoma, Arkansas, and Louisiana. The Washita, North Fork, Kiamichi, and Little Rivers, as well as Lake Texoma, are part of the Red River system. A compilation of 20 years of fish collection data from Arkansas riverine systems by Matthews and Robison (1988) indicated no records of Alabama shad in the Arkansas portion of the river. During a 6-year sampling period from 1996–2001, no Alabama shad were caught in the Red River (Buchanan *et al.* 2003). In a study on the effects of land alterations on fish assemblages, Rutherford *et al.* (1992) found no shad in the Little River. Presumably, Alabama shad are no longer able to reach their former spawning grounds in the Little River due to degradation of river habitat as a result of land modification (Buchanan *et al.* 2003). No Alabama shad were collected from Lake Texoma or any of its adjoining rivers (Red and Washita Rivers) between 1948 and 1958 (Riggs and Bonn 1959). The Denison Dam likely excluded the species from these areas. The Altus Dam also likely excluded the species from Red River tributaries, including the North Fork, Brier Creek, and Kiamichi River, since there are no longer reports of Alabama shad (Winston and Taylor *et al.* 1991, Matthews *et al.* 1988). In recent years, during general river surveys conducted by the University of Oklahoma, Alabama shad have not been collected in southeast and central Oklahoma (Smith *et al.* 2011).

Illinois and Marys Rivers

The Illinois and Marys Rivers are both minor tributaries of the Mississippi River contained solely within the state of Illinois. While there are historical records of shad within Illinois rivers (Smith *et al.* 2011), the historical abundance of Alabama shad in Illinois is not known. The first collection of Alabama shad from the Illinois River was 47 fish taken in 1950 (Moore 1973). In a thorough report of the biodiversity of the state's rivers and streams, Page (1991) found no evidence of Alabama shad. However, Burr *et al.* (1996) reported two juvenile Alabama shad, one near the mouth of the Marys River in 1994 and one in the Grand Tower in Devils Backbone Park in 1995. These two captures support the hypothesis that some adult shad were able to spawn in these areas during that time. Before these two captures, the last Alabama shad to be captured in Illinois was a juvenile in 1962 (Burr *et al.* 1996). Alabama shad appear to have been extirpated from many Illinois rivers and are considered rare in the state. Annual field studies conducted in the Illinois River by Illinois State University have resulted in no additional records of Alabama shad (Smith *et al.* 2011).

White River

The White River is a minor tributary of the Mississippi River that flows through Missouri and Arkansas and was recently discovered to contain a spawning population of Alabama shad (Buchanan *et al.* 2012). Matthews (1986) reported that no Alabama shad were found in White River tributaries from 1972–1973 or 1981–1983. However, the Arkansas Fish and Game Commission provided information during the public comment period on our 90-day finding that three Alabama shad were collected from the White River in 2006 (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). Buchanan *et al.* (2012) were the first to report the species in the White River drainage when they collected 3 juvenile Alabama shad over a sand-gravel bar in August 2006. The researchers believe the shad were spawned in the mainstem White River or one of its tributaries and they noted that the morphology and size of the White River specimens compared well with Alabama shad previously reported from other drainages in the state.

Ouachita River

The Ouachita River is a minor tributary of the Mississippi River and flows through Arkansas and Louisiana. The Ouachita River system includes the Little Missouri and Saline Rivers. The Ouachita and Little Missouri Rivers contain spawning populations of Alabama shad (Buchanan *et al.* 1999). Four pre-1900 records of Alabama shad from the Ouachita River are known: One specimen near Hot Springs and three at Arkadelphia (Buchanan *et al.* 1999). Buchanan *et al.* (1999) reported that 16 juvenile specimens were collected from the Saline River in 1972 and 3 juvenile specimens at the juncture of the Little Missouri and Ouachita rivers in 1982. Buchanan *et al.* (1999) collected over 300 juvenile Alabama shad from the Ouachita River and the Little Missouri River between 1997 and 1998, and noted that Alabama shad were abundant at the four sites where they were collected. Buchanan *et al.* (1999) also documented a 1.3-kilogram (kg) adult taken on an artificial lure in April 1997 in the Ouachita River below Remmel Dam. The Arkansas Fish and Game Commission provided information during the public comment period on our 90-day finding that 10 Alabama shad were collected from the Ouachita River in 2005 during a survey to evaluate the influence of increased minimum flows after the relicensing of the Remmel Dam (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). Several Alabama shad from the Ouachita River were also collected and photographed on October 12, 2012, for the purpose of illustrating a new edition of the ''Fishes of Arkansas'' (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013).

Although the Saline River in Arkansas is the only free flowing river left in the state, there have been no recent reports of Alabama shad (Buchanan 1999). The Monroe Museum of Natural History at the University of Louisiana has 16 Alabama shad that were collected from the Saline River in 1972 (Buchanan *et al.* 2012). During the public comment period on the 90-day finding, the Arkansas Fish and Game Commission provided information from Layher *et al.* (1999) that their targeted assessment of Alabama shad at 80 sites in the Saline River did not encounter the species in the 4,863 fish collected and that severe drought conditions may have influenced the results (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). Throughout the year, Arkansas State University conducts general fish sampling in the state's rivers and no captures of Alabama shad have been reported in recent years (Smith *et al.* 2011).

Lake Pontchartrain, Lake Maurepas, and the Tangipahoa River

Alabama shad are only caught sporadically in the state of Louisiana, and there are limited data for the species in its rivers (Smith *et al.* 2011). The Tangipahoa River begins in southwest Mississippi and drains into Lake Pontchartrain in Louisiana. Due west of Lake Pontchartrain, and connected by Pass Manchac and North Pass, is Lake Maurepas. No Alabama shad were caught in the Tangipahoa River in 1994 (Knight 1994) and none were collected in Lake Pontchartrain between 1996 and 2000. However, individuals were collected in Lake Maurepas from 1983 to 1984 and in 2009 using trawl and gillnets, indicating that some fish still pass through Lake Pontchartrain (Hastings 1987, O'Connell *et al.* 2004, O'Connell *et al.* 2009).

Pearl River

Multispecies studies of the Pearl River were conducted by Tulane University from 1963–1988 (Gunning and Suttkus 1990). Gunning and Suttkus (1990) looked at the relative abundance of 84 species over the course of the 25-year study, with sampling occurring at multiple stations in Louisiana and Mississippi either on a quarterly or annual basis. At stations where quarterly sampling was conducted, the spring survey occurred in February in the Mississippi portion of the river and April in the Louisiana portion of the river. Approximately 30 minutes were spent at each station unless the river was flooded and water depth limited sampling ability. Records from the Gunning and Suttkus (1990) sampling surveys show a steady decline in catches of Alabama shad. Sampling occurred in 16.1 km of the river above and below Bogalusa, Louisiana, for 25 years; a 64.4 km section of the West Pearl River was sampled for 16 years; and, a 64.4 km portion of the East Pearl River was sampled for 16 years. Between 1963 and 1965, 384 Alabama shad were caught from all river segments combined. Between 1965 and 1979, only 33 Alabama shad were captured. One Alabama shad was captured in the Pearl River between 1979 and 1988 (Gunning and Suttkus 1990). Gunning and Suttkus (1990) attributed the declining catch of Alabama shad to declining abundance of the species.

In the Gunning and Suttkus (1990) study, only one 30-minute multispecies survey was conducted during the spring once per year at some of their Pearl River stations. The studies targeting Alabama shad in the ACF River system are conducted over a 3-month period each year to ensure their collections encompass the peak spawning migration of Alabama shad, which can vary from year to year based on factors such as temperatures and river discharge (Sammons 2013, 2014, Kern 2016). Gunning and Suttkus (1990) state that the consistency of their methodology and the length of their study are sufficient to accurately indicate relative abundance. Gunning and Suttkus (1990) does provide one of the few long-term studies available for this species. However, as noted previously, low numbers of recorded Alabama shad individuals may be due, at least in part, to insufficient sampling effort during appropriate times (*i.e.,* spawning migrations) and with the appropriate gear to target the species (Mettee and O'Neil 2003). This was observed in the ACF in large differences in Alabama shad captured in multispecies surveys conducted by FFWCC (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013) versus studies targeting Alabama shad in ACF (Young 2010, 2011) during the same time period.

Smith *et al.* (2011) state no Alabama shad have been captured in the Pearl River since then, although FishNet contains records of Alabama shad captured from the Pearl River in 1996 by the Illinois Natural History Survey and 2004 by Tulane University (Fishnet2 2016, Catalogue #38236 and #198208).

Pascagoula River

The Pascagoula River system, made up of the Pascagoula, Leaf, and Chickasawhay Rivers, is the only system within the state of Mississippi inhabited by Alabama shad (Mickle *et al.* 2010, Mickle 2010). A total of 531 Alabama shad (all age classes) were captured in the Pascagoula River system between 2004 and 2007 (307 from the Pascagoula River, 200 from the Leaf River, and 24 from the Chickasawhay River; Smith *et al.* 2011). The Pascagoula River system has one of the remaining spawning populations of Alabama shad as evidenced by Mickle's (2006) collection of 193 age-0 Alabama shad from 10 sites between 2004 and 2005. The Leaf and Pascagoula Rivers contain the highest populations of Alabama shad within this system due to their unimpounded waters and variety of habitats, with a smaller Alabama shad population in the Chickasawhay River (Mickle *et al.* 2010, Mickle 2010). Between 2004 and 2006, Mickle *et al.* (2010) captured 133 juvenile Alabama shad (66 from the Leaf River, 55 from the Pascagoula River, and 12 from the Chickasawhay River). Small numbers of Alabama shad were also caught in Black Creek, a tributary of the Pascagoula River, in 1986 and the late 1990s (Adams *et al.* 2000).

Mobile Bay and the Mobile River Basin

The Mobile River basin spans Mississippi, Alabama, Georgia, and Tennessee. The Mobile River, which empties into Mobile Bay, branches upstream into the Alabama, Cahaba, Tallapoosa, Coosa, Tombigbee, and Black Warrior Rivers. The Alabama shad was first described as a species in 1896 in the Black Warrior River near Tuscaloosa, Alabama (Jordan and Evermann 1896). Alabama shad were once prevalent in the Mobile River basin (Evermann and Kendall 1897).

Numerous juvenile Alabama shad were recorded in the Alabama River in 1951, the late 1960s, and the early 1970s

(Boschung 1992, Mettee and O'Neil 2003). A single Alabama shad (15.3 cm) was also captured in Dog River (a small tributary draining into Mobile Bay) in 1964 (Williams and Gaines 1974, Boschung 1992, Hammerson 2010). On the Alabama River, Claiborne Lock and Dam was opened for navigation in 1969 (Freeman *et al.* 2005). Upstream from Claiborne Lock and Dam, Millers Ferry Lock and Dam was constructed for the purpose of both power generation and navigation, with the lock opening in 1969 and power coming on line in 1970. Sampling in Mobile Bay in 1972 yielded no Alabama shad. Two individuals were caught in the Alabama River in the 1990s: One in 1993 below Claiborne Lock and Dam, and one in 1995 below Miller's Ferry Lock and Dam (Smith *et al.* 2011). More recently, in February 2004, a single specimen (32.8 cm) was captured by the Alabama Department of Conservation and Natural Resources, Marine Resources Division, in Heron Bay (adjacent to Mobile Bay), presumably making its upstream spawning migration (Smith *et al.* 2011). The Alabama Division of Wildlife and Freshwater Fisheries conducted a year-long study in 2009 in the Alabama River that did not collect any Alabama shad.

Despite the existence of a thorough historical fisheries record of the Cahaba River system, no recent captures of Alabama shad from the upper reaches of the Cahaba River are documented. Both the Pierson *et al.* (1989) general fish faunal survey of the river from 1983–1988 and the Onorato *et al.* (1998 and 2000) sampling between 1995–1997 found no Alabama shad present in the upper region of the Cahaba River. The last Alabama shad collected was in 1968 and the only previously recorded fish reported in the Cahaba River at Centreville, Alabama, was in 1965 (Onorato *et al.* 2000, Boschung 1992). The last specimen to be captured from the Coosa River was in 1966 (Boschung 1992). No Alabama shad were captured during fish sampling in the Tallapoosa River by Freeman *et al.* (2001).

Mettee and O'Neil (2003) state that Alabama shad have not been found in the Tombigbee River since the 1901 construction of the Tombigbee lock system in the waterway. However, records provided by the Mississippi Museum of Natural Science during the public comment period on our 90-day finding showed that 5 Alabama shad were captured in the Tombigbee River in 1969 and one in 1971 (M. Roberts, Curator of Fishes, Mississippi Museum of Natural Science, pers. comm. to K. Shotts, NMFS, October 21, 2013). In the Black Warrior River of Alabama, where the species was first described in 1896, one Alabama shad was subsequently collected, over one hundred years later in 1998 (Mettee and O'Neil 2003).

Conservation locking, similar to efforts conducted in the ACF River system, was undertaken on the Alabama River at Claiborne Lock and Dam and Miller's Ferry Lock and Dam in 2009 by the Alabama Department of Conservation and Natural Resources, USACE, and Auburn University after USGS suggested the locks could be used as a means of fish passage (Simcox 2012). At that time, no efforts were made to quantify passage efficiency or even monitor which species may be passing upstream and downstream through the locks. Freeman *et al.* (2005) stated that substantial potential for restoring populations of migratory, large-river fishes such as Alabama sturgeon (*Scaphirhynchus suttkusi*), Gulf sturgeon, Alabama shad, and southeastern blue sucker (*Cycleptus meridionalis*) entailed modifying Claiborne and Miller's Ferry, the two downstream-most dams on the Alabama River. Enhancing fish passage at Claiborne and Millers Ferry Locks and Dams could restore connectivity between the lower Alabama River and the Cahaba River, encompassing over 400 km of riverine habitat from the Gulf to the fall line.

In 2014, a study was initiated to determine if conservation locking could be used to pass Alabama Shad upriver or downriver during spawning season through the navigation locks at Claiborne Lock and Dam and Miller's Ferry Lock and Dam. With support from the FFWCC and Georgia DNR, Alabama shad from the ACF River system were collected and tagged before being stocked in the Alabama River. Fifteen Alabama shad were tagged and released below Claiborne Lock and Dam, and an additional 38 Alabama shad were tagged and released above the dam. These fish were tracked both upstream and downstream of the dam. Of the Alabama shad released above the dam, 18 were later detected at 18 different locations, and 7 definite mortalities (no movement between successive locations) were eventually confirmed. The 7 confirmed mortalities occurred in the section of the Alabama River below Claiborne Lock and Dam to its confluence with the Tombigbee River. Kern and Sammons (2015) note that further research is necessary to determine whether Alabama shad found suitable spawning habitat in this location and halted downstream movements, or whether they died as a result of cumulative stress from handling and transport. One fish was detected approximately 53 mi (85 km) below Claiborne Lock and Dam, indicating successful downriver passage through the lock. Twenty fish were never detected. There were large areas where no tagged fish were detected, and some fish moved over 50 mi (80 km) in 2 days. ''Leap-frogging'' was also observed, with shad being detected at downstream and upstream locations, but escaping detection in between.

Of the 15 tagged fish released below Claiborne Lock and Dam, 3 were detected 93 times. One fish was detected 12 days after release below Gravine Island (just north of Mobile Bay) and was detected again upriver 6 days later, just below Claiborne Lock and Dam. This movement pattern indicated ''fallback'' (fish that move a great distance downriver shortly after stocking), but in this case, the fish eventually moved upriver. Another fish remained in the vicinity of Claiborne Lock and Dam for 9 days and was not detected thereafter. A third fish was detected several times moving downstream after release but not later. No tagged Alabama shad were detected above Claiborne Lock and Dam and researchers hypothesized this low number could have been due to high water events or mortalities.

In 2015, 27 Alabama shad from the ACF River system were tagged and stocked below Miller's Ferry Lock and Dam (and above Claiborne Lock and Dam). Detections of tagged fish were much higher in 2015 than 2014, likely due to higher river flows in 2014 (Kern and Sammons 2015), with 17 of the 27 fish detected for a total of 371 detections. Similar to 2014, large movements over short time periods were observed, with most of the movements being in a downstream direction. No fish were found to have successfully navigated upstream of Miller's Ferry Lock and Dam, although many of the fish passed downstream of Claiborne Lock and Dam.

Escambia River and Conecuh River

The Conecuh River begins in Alabama and becomes the Escambia River at the Florida border. Alabama shad were documented in the Escambia/Conecuh River system as early as 1900 (Evermann and Kendall 1900). This system contains one of the known remaining Alabama shad spawning populations (Smith *et al.* 2011). Bailey (1954) reported the capture of two individuals in the Escambia River in 1954. In 2009, two Alabama shad were caught in the Escambia River by FFWCC, one in spring and one in the fall (Smith *et al.* 2011; E. Nagid, FFWCC, pers. comm. to K. Shotts, NMFS, November 26, 2014). Studies indicate there are small populations of Alabama shad in southern Alabama, including within the Conecuh River (Barkuloo 1993, Adams *et al.* 2000, Mettee and O'Neil 2003). Smith *et al.* (2011) reported that 11 Alabama shad were captured in the Conecuh River in 2000 and one in 2010 by the Alabama Department of Wildlife and Fisheries.

Choctawhatchee River

The Choctawhatchee River begins in Alabama. As it flows south, it is joined by one of its tributaries, the Pea River, then continues through the Florida panhandle and into the Gulf of Mexico. Some studies indicate there are small spawning populations of Alabama shad in southern Alabama, including in the Choctawhatchee and Pea Rivers (Barkuloo 1993, Adams *et al.* 2000, Mettee and O'Neil 2003, Young 2010). Smith *et al.* (2011) reported the capture of 400 Alabama shad from the Choctawhatchee River system in 2000.

Ochlockonee River

Alabama shad were historically present in the Ochlockonee River, a fast running river that flows from Georgia into Florida. Smith *et al.* (2011) reported that the last specimens to be collected in the Ochlockonee River were captured in 1977 below Jackson Bluff Dam (Swift 1977). During the public comment period announced in the 90-day finding, FFWCC reported that 4 Alabama shad were collected near the Talquin (Jackson Bluff) Dam in 2011 (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013).

Econfina River

The Econfina River is a minor river draining part of the Big Bend region of Florida. It empties into Apalachee Bay. Historical data for Alabama shad are not available for this river, but, FFWCC reported during the public comment period that 1 Alabama shad was collected in the Econfina River in 2006 (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013).

Suwannee River

The Suwannee River originates from the Okefenokee Swamp in Georgia and runs south through Florida. Historically, the Suwannee River has been the easternmost boundary of the Alabama shad's range (Herald and Strickland 1946). There is still a spawning population of Alabama shad in the Suwannee River (Smith *et al.* 2011). Sporadic sampling in the Suwannee River has included Alabama shad (Mettee and O'Neil 2003). Records from the Florida Museum of Natural History and the FFWCC show that 3–27 Alabama shad were collected annually between 1990–1995 (FishNet2 2016; search terms ''*Alosa alabamae,*'' ''1990–2016,'' and ''Suwannee''). Mickle (2010) collected 6 fish. Smith *et al.* (2011) reported that FFWCC caught 15 Alabama shad on the Withlacoochee River, a tributary of the Suwannee River, in late November 2010 (Smith *et al.* 2011). The Florida Museum of Natural History also shows that 2 Alabama shad were collected in 2015 (FishNet2 2016; Catalogue #238044 and #238066).

Extinction Risk Assessment

We estimated both the current extinction risk for Alabama shad and the anticipated risk in the foreseeable future. We defined the ''foreseeable future'' as the timeframe over which threats or the species' response to those threats can be reliably predicted to impact the biological status of the species. First, we evaluated demographic factors associated with population viability (abundance, productivity, spatial distribution, and diversity) and how they are contributing to the extinction risk of Alabama shad. We then performed a threats assessment using the factors listed in Section 4(a)(1) of the ESA by identifying the severity of threats that exist now and estimating their severity in the foreseeable future.

We used the methods developed by Wainwright and Kope (1999) to organize and summarize our findings on the contributions of the demographic factors and threats listed in ESA Section 4(a)(1) to the extinction risk of Alabama shad. This approach has been used in the review of many other species (Pacific salmonids, Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, and black abalone, and foreign sawfishes) to summarize the status of the species according to demographic risk criteria. McElhany *et al.* (2000) examined short and long-term trends in abundance, productivity, spatial structure, and genetic variability as the primary indicators of risk. Populations that are more fragmented have less genetic exchange and therefore less connectivity, increasing the risk of extinction. Loss of fitness and loss of diversity can occur from random genetic effects and increase the risk of extinction for a species. We used the five-level qualitative scale from Wainwright and Kope (1999) to describe our assessment of the risk of extinction for Alabama shad for each demographic category, both currently and in the foreseeable future. We also used this scale to describe our assessment of each of the threats from ESA Section 4(a)(1). At the lowest level, a factor, either alone or in combination with other factors, is considered ''unlikely'' to significantly contribute to risk of extinction for a species. The next lowest level describes a factor that, on its own, is considered to be at ''low'' likelihood of contributing to the extinction risk, but could contribute in combination with other factors. The next level is considered a ''moderate'' risk of extinction for the species, but in combination with other factors contributes significantly to the risk of extinction. A ranking of ''likely'' means that factor by itself is likely to contribute significantly to the risk of extinction. Finally, the most threatening factors are considered ''highly likely'' to contribute significantly to the risk of extinction.

Both ''low'' and ''moderate'' rankings require that the demographic factor or threat be considered alone, as well as in combination with other factors. In this determination, we first consider each of the demographic factors and threats independently, then evaluate how they may interact in combination to contribute to the extinction risk of Alabama shad. Our rankings of demographic factors and threats do not translate directly to extinction risk conclusions. Ranking simply describes how we considered the information. For instance, one or more demographic factors could be ranked as ''highly likely'' to be contributing to the extinction risk of a species without concluding that the species is threatened or endangered. For example, low abundance may be considered to present a moderate threat to the extinction risk of Alabama shad, but is offset by the species' high productivity and wide spatial distribution.

In some cases, there was not enough information or too much uncertainty in pending outcomes to rank a threat's contribution to the risk of extinction for Alabama shad using the categories established by Wainwright and Kope (1999). In those cases, we classify the contribution of the threat to the extinction risk of Alabama shad as being ''unknown.'' Even for threats we ultimately classify as unknown, we provide and evaluate whatever information is available, in some cases providing information on how related surrogate species (*e.g.,* other *Alosas*) may be responding to the identified potential threat. NMFS recently issued updated ESA listing guidance (May 26, 2016) that states in order to list a species, the agency must affirmatively determine on the basis of a set of scientific facts that a species is at risk. The ESA does not allow for listings to be based on giving the species the benefit of the doubt. The guidance clarifies that in the absence of any information about threats to a species, the null hypothesis is that the risk is low (generally low, not as defined by Wainwright and Kope (1999). Specific supporting information must be cited in order to elevate the potential threat to a moderate or high risk category (again generally, not as defined by Wainwright and Kope (1999). In cases where we classified a threat as having an ''unknown'' risk to the species, we considered whether the ''unlikely'' or ''low'' category established in Wainwright and Kope (1999) was most appropriate. Because the ''low'' category by definition states that a threat could contribute to the extinction risk of a species in combination with other factors, per the listing guidance, we ultimately evaluated ''unknown'' threats as being ''unlikely'' to significantly contribute to the risk of extinction for Alabama shad.

We determined the extinction risk for the species as a whole by integrating the demographic risks and the threats assessment, including considerations of any uncertainty in the risks and threats. We made a determination as to whether the species warrants listing as threatened or endangered, or whether we believe listing is not warranted. Finally, we determined whether there was a significant portion of the species' range that may warrant listing as threatened or endangered.

Foreseeable Future

Per NMFS' May 2016 revised listing guidance, the ''foreseeable future'' describes the extent to which the Secretary can, in making determinations about the future conservation status of the species, reasonably rely on predictions about the future (Department of the Interior Solicitor's Memorandum M–37021, ''The Meaning of 'Foreseeable Future' in Section 3(20) of the Endangered Species Act'' (Jan. 16, 2009)). Those predictions can be in the form of extrapolation of population or threat trends, analysis of how threats will affect the status of the species, or assessment of future events that will have a significant new impact on the species. We believe that the appropriate period of time corresponding to the foreseeable future should account for the Alabama shad's life-history characteristics and the most significant threats facing the species.

The Alabama shad is an early-maturing species (Mickle *et al.* 2010) with high productivity (Mettee and O'Neil 2003, Ingram 2007). Like other members of the *Alosa* family, Alabama shad populations may fluctuate significantly from year to year (Sammons and Young 2012). The time period associated with the foreseeable future for Alabama shad should be long enough to assess population response while taking into consideration the high variability inherent in the species. Below, we discuss generation time in relation to our ability to reliably predict the species' conservation status.

In defining the foreseeable future, we considered generation time, specifically defined here as the time it takes for a sexually mature Alabama shad to be replaced by offspring with the same spawning capacity. Age-2 to age-4 fish make up the majority of spawning Alabama shad; therefore, using our definition, the generation time for Alabama shad is 4–8 years. Generation time is inversely related to productivity and/or resilience. Highly productive species with short generation times are more resilient than less productive, long-lived species, as they are quickly able to take advantage of suitable conditions for reproduction (Mace *et al.* 2002). Species with shorter generation times, such as Alabama shad (4–8 years), experience greater population variability than species with long generation times, because they maintain the capacity to replenish themselves more quickly following a period of low survival (Mace *et al.* 2002). We believe that the impacts from the threats on the biological status of the species can be confidently predicted within the 12- to 24-year (three-generation) timeframe. Given their high population variability, projecting out further than three generations could lead to considerable uncertainty in estimating the population trajectory for Alabama shad. The timeframe of three generations is widely used to assess trends in populations and has been applied to decision-making models by many other conservation management organizations, including the American Fisheries Society (AFS), the Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES), and the International Union for Conservation of Nature (IUCN).

The foreseeable future timeframe is also a function of the reliability of available data regarding the identified threats and extends only as far as the data allow for making reasonable predictions about the species' response to those threats. In our extinction risk assessment, we determined the abundance of Alabama shad and the presence of dams are the highest ranked threats, both contributing a moderate level of risk to Alabama shad. The remaining threats are ranked as either contributing a low or unknown level of risk to Alabama shad, or being unlikely to contribute to the species extinction risk.

Small populations may have less of a buffer against threats than large populations (McElhany *et al.* 2000). We ranked low abundance as posing a moderate threat to Alabama shad's extinction risk. Our consideration of generation time above discusses how the abundance of Alabama shad is variable, and the species can fluctuate widely from year to year. We determined projecting out further than three generations could lead to considerable uncertainty in estimating the population trajectory for Alabama shad.

We also consider the timeframe over which the effect of dams on Alabama shad populations can be predicted. Dams are believed to be the main cause of the initial decline of Alabama shad. Existing dams continue to block habitat and cause downstream effects today, but few new dams have been built since the mid-1980s (Graf 1999). The threat of dams to Alabama shad has not increased for the past 30 years, and is not expected to increase in the future due to the advent of environmental laws and public awareness that occurred after the era of big dam building (Doyle *et al.* 2003, Graf 1999). The threat of dams to Alabama shad is more likely to decrease in the future, as dams are either removed or additional fish passages are added. Environmental concerns are coinciding with a policy window in which many private dams are coming up for regulatory re-licensing with the Federal Energy and Regulatory Commission (FERC) and operational guidelines for publicly-operated dams are being reviewed (Doyle *et al.* 2003). Upstream effects from dams may be reduced through fish passage technology, which is becoming increasingly efficient (Roscoe and Hinch 2010). Fish passage may be voluntarily implemented at dams, or even required by Federal regulations in some instances. Downstream effects from dams are also becoming better understood and dam operators are becoming more willing and able (and may be required in some instances) to alter operations to minimize the ecological effects downstream (Poff and Hart 2002). Further, an estimated 85 percent of the dams in the United States will be near the end of their operational lives by 2020 (Doyle *et al.* 2003). Economic considerations and environmental concerns may result in dam removals, as maintenance, operation, repairs are often much costlier than dam removal (Doyle *et al.* 2003, Stanley and Doyle 2003).

It is unknown to what extent the implementation of fish passage, modifications to dam operations, or dam removal will occur in rivers inhabited by Alabama shad. The lack of new dam building in the past 30 years coupled with increased environmental regulation and public awareness makes it unlikely that the threat of dams to Alabama shad will increase and more likely that there could be a decrease of this threat to the species. However, we cannot predict where dam modifications or removal may occur, and how Alabama shad may be affected. Our ability to predict the response of Alabama shad populations to the threat is limited by the life history characteristics of the species (*i.e.,* its variability in response to all of the factors affecting the population) rather than any variability in the threat of dams itself.

In defining foreseeable future, we further considered the interaction of demographic characteristics (parameters describing the viability of a population, such as abundance and productivity) and the species' response to various threats, primarily dams. Smith *et al.* (2011) conducted a population viability analysis (PVA) on Alabama shad in the ACF River system. Researchers selected 20 years as the timeframe over which the PVA could reliably model population responses of Alabama shad based on the species' demographic characteristics and various combinations of natural and anthropogenic threat scenarios affecting their survival and growth. The 20-year timeframe used in the PVA falls within the three-generation timeframe discussed above. This timeframe takes into account aspects of the species' life history and also allows the time necessary to provide for the recovery of populations. Thus, we determined for the purpose of the extinction risk assessment, a 20-year timeframe, corresponding approximately to the three-generation time period, to be appropriate for use as the foreseeable future for Alabama shad.

Demographic Risks

Threats to a species' long-term persistence are manifested demographically as risks to its abundance, population growth rate, spatial structure and connectivity, and genetic and ecological diversity. These demographic risks provide the most direct indices or proxies of extinction risk. A species at very low levels of abundance and with few populations will be less tolerant to environmental variation, catastrophic events, genetic processes, demographic stochasticity, ecological interactions, and other processes compared to large numbers in many populations (*e.g.,* Meffe and Carroll 1994, Caughley and Gunn 1996). A population growth rate that is unstable or declining over a long period of time has less resiliency to future environmental change (*e.g.,* Lande 1993, Middleton and Nisbet 1997, Foley 1997). A species that is not widely distributed across a variety of well-connected habitats is at increased risk of extinction due to environmental perturbations, including catastrophic events, compared to a species that is widely distributed (Schlosser and Angermeier 1995, Hanski and Gilpin 1997, Tilman and Lehman 1997, Cooper and Mangel 1999). A species that has lost locally adapted genetic and ecological diversity may lack the ability to exploit a wide array of environments and endure short- and long-term environmental changes (*e.g.,* Groot and Margolis 1991, Wood 1995). Assessing extinction risk of a species involves evaluating whether risks to its abundance, population growth rate, spatial structure, and/or diversity are such that it is at or near an extinction threshold, or likely to become so in the foreseeable future.

Abundance

A small population faces a host of risks intrinsic to its low abundance while large populations exhibit a greater degree of resilience (McElhany *et al.* 2000). The only population estimates available for Alabama shad are from the ACF River system in Florida, Alabama, and Georgia. This system is believed to have the largest population of Alabama shad. Population estimates fluctuated widely from 2005 to 2015. For instance, 26,193 Alabama shad were estimated to be in the system in 2011. The following year, the estimate of Alabama shad peaked at 122,578. Sammons and Young (2012) noted that the population sizes of species in the *Alosa* genus commonly fluctuate widely. Researchers in the ACF River system believe that Alabama shad abundance may be a response to conservation efforts in the system (Schaffler *et al.* 2015). They also note that variability in population number may be linked to environmental conditions. Specifically, Sammons and Young (2012) believe that heavy rainfall in 2009 may have led to strong year classes in 2010 and 2012.

No population estimates are available for other rivers, although several hundred Alabama shad have been captured in studies conducted in the past 15–20 years in the Pascagoula (Mississippi), Choctawhatchee (Florida/Alabama), and Ouachita (Arkansas/Louisiana) River systems. The annual Alabama shad population estimates in the ACF River system were developed through mark-recapture studies. The initial capture of less than a hundred to over 1,000 Alabama shad resulted in population estimates of thousands to over 100,000 Alabama shad. Mark-recapture can be used to produce abundance estimates without capturing every individual in the population because in addition to counting the number of individuals captured during the study, they estimate the detection probability of individuals (*i.e.,* the probability that an individual will be captured during the study; Yoccoz *et al.* 2001). Detection probability can be influenced by population size, but can also be influenced by the sampling season and methodologies used, as well as a species' habitat affinities (Gu and Swihart 2004). Population estimates cannot be reliably developed from studies that collect a species, but do not consider its associated detection probability. Pellet and Schmidt (2005) note that it is often very difficult, if not impossible, to detect all individuals, populations, or species, and found during their surveys that the detection probability for a common species of tree frog was very high, while the detection probability of a common toad species was very low. Yoccoz *et al.* (2001) note that detection probability is generally less than 100 percent and usually variable. Although we cannot estimate the population abundance of Alabama shad in the Pascagoula, Choctawhatchee, and Ouachita Rivers, based on the likelihood that the species' detection probability is less than 100 percent, we can infer that the sizes of those Alabama shad populations are greater than the hundreds of fish collected in those systems. For instance, during the 2013 targeted study in the ACF, 251 Alabama shad were captured and 1 recaptured to yield the population estimate of 2,039 (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014).

Generally, the number of Alabama shad in rivers other than the ACF, Pascagoula, Choctawhatchee, and Ouachita is likely to be small. A multi-state, multi-agency report from 1994 (Gutreuter *et al.* 1997) indicates that Alabama shad were found in the Upper Mississippi River, but does not note the number or locations of fish caught. Smaller numbers (one to several dozens) of Alabama shad have been captured in the last 25 years in portions of the Lower Mississippi River, Mississippi River tributaries (Missouri, Marys, and

White Rivers), Mobile, Escambia, Conecuh, Ochlockonee, Econfina, and Suwannee Rivers.

Alabama shad was never an economically important species, and, therefore, information from fisheries statistics, such as landings data, is rare. Hildebrand (1963) noted that Alabama shad were considered unfit for human consumption, and the lack of demand produced no incentive to capture the species or record its presence and abundance. Most of the recent directed research studies on Alabama shad have occurred in the ACF and Pascagoula River systems. Capture data for other systems comes from general multi-species surveys, captures incidental to other research studies, and anecdotal information. Mettee and O'Neil (2003) note that low numbers of recorded Alabama shad individuals may be due, at least in part, to insufficient sampling effort during appropriate times (*i.e.,* spawning migrations) and with the appropriate gear to target the species. Hildebrand (1963) noted the importance of proper gear, citing greatly increased catches of Alabama shad that occurred in Kentucky when surface-fishing seines were substituted for bottom-fishing seines. The lack of data is echoed in the responses received from fish and wildlife agencies during the public comment period on our 90-day finding. The Arkansas Fish and Game Commission stated they could not assess the status of Alabama shad in their state because of the scarcity of information on the species, the lack of targeted surveys, and the unknown detectability of the species (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). It is unknown whether the lack or low numbers of Alabama shad reported for many river systems accurately reflects the abundance in those systems or whether it is indicative of the lack of targeted studies, but ultimately, the population abundance in these areas is still unknown.

The threshold abundance below which Alabama shad populations cannot rebound (quasi-extinction) is unknown. In conducting the PVA on Alabama shad from the ACF River system, Smith *et al.* (2011) conservatively assumed 420 females as the threshold for quasi-extinction based on the lowest recorded population abundance for the ACF River system at the time (from Ely *et al.* 2008). That assumption was not based on a minimum number of females needed to recover the population, but instead the lowest number of females observed in the viable population during previous studies. In fact, Smith *et al.* (2011) report that a viable spawning population persists in the Suwannee River at the eastern edge of the species' range, even though sporadic sampling since 2003 has only reported a total of 6–15 individual Alabama shad. We do not have historical abundances of Alabama shad, which can be indicative of abundance levels associated with low extinction risk. However, populations may also be at low risk of extinction at abundance levels below historical levels, and accurate estimates of historical abundance are not essential for evaluating extinction risk. Information from other species in the *Alosa* genus indicates that the species can rebound from extremely low abundance. The 12-month determination for 2 species of river herring (78 FR 48944; August 12, 2013), which determined that listing alewives (*A. pseudoharengus*) and blueback herring (*A. aestivalis*) under the ESA was not warranted, states that highly fecund, short generation time species like river herring may be able to withstand a 95 to 99 percent decline in biomass (Mace *et al.* 2002). The 12-month determination (78 FR 48944; August 12, 2013) states that both alewives and blueback herring may have declined by more than 98 percent from their historical baseline (Limburg and Waldman 2009), but that the abundance of each species is stable or increasing, indicating the species are self-sustainable and are at a low to moderate-low risk of extinction.

Directed studies and current data on Alabama shad abundance are mostly lacking. The available population estimates for the ACF River system since 2005 are relatively large and highly variable. Ely *et al.* (2008) compared Alabama shad and American shad. They noted that, given the similarities in life history characteristics of Alabama shad and American shad and the similarities in discharge, drainage area, and latitude between the Apalachicola River and other southeastern rivers, the populations of adult Alabama shad and American shad might be expected to be similar. Ely *et al.* (2008) cited the number of American shad reaching the first barrier to migration in the Savannah River, estimated as nearly 190,000 (Bailey *et al.* 2004), and the number in the Altamaha River system estimated as 133,000 (Georgia DNR 2005), and concluded that the population size of the Alabama shad in the Apalachicola River from 2005–2007 (approximately 2,700–26,000 shad) was relatively small. Subsequent to the Ely *et al.* (2008) study, the numbers of Alabama shad in the Apalachicola River generally increased, ranging from 2,000–122,500 from 2008–2012. It is not known what the historical abundance of Alabama shad was in the ACF River system, but the Alabama Shad Restoration Plan for the ACF River System (NMFS *et al.* 2012) projected that the carrying capacity (the maximum population of a species that can survive indefinitely in a given environment) for Alabama shad in the ACF is approximately 1.3 million adults. Capture data from other systems are limited or lacking but suggest low to moderate sized populations in some rivers and absence in others.

The only current population estimates available for Alabama shad are in the ACF River system. Because Alabama shad were never commercially or recreationally important, few historical records exist. There are no recorded historical population sizes in any river systems for comparison, although anecdotal information on observations and small, short-lived fisheries provide some historical context (*e.g.,* Coker 1929, 1930). However, many researchers recognize that Alabama shad populations have experienced decline from historical population sizes (*e.g.,* Gunning and Suttkus 1990, Buchanan *et al.* 1999, Mettee and O'Neil 2003, Mickle *et al.* 2010).

Declines have been estimated in other *Alosa* species with longer historical records. Hall *et al.* (2012) attempted to estimate historical alewife populations in Maine for the years 1600–1900 using analyses of nineteenth and twentieth century harvest records and waterway obstruction records dating to the 1600s and estimated that obstructed spawning access reduced the annual alewife productivity per watershed to 0–16 percent of pre-dam estimates. The 12-month listing determination for river herring (78 FR 48944; August 12, 2013) reported that of the riverine stocks of alewife and blueback herring for which data were available and were considered in a stock assessment, 22 were depleted, 1 was increasing, and the status of 28 stocks could not be determined because the time-series of available data was too short. In most recent years, 2 riverine stocks were increasing, 4 were decreasing, and 9 were stable, with 38 rivers not having enough data to assess recent trends. Both alewives and blueback herring may already be at or less than 2 percent of the historical baseline. Because historical landings data are available for alewife and blueback herring, population modeling was feasible and used to determine the stability of the stocks in light of the declines. The conclusion of the 12-

month determination (78 FR 48944; August 12, 2013) was that listing alewife and blueback herring under the ESA was not warranted because the abundance of each species is stable or increasing, indicating the species are self-sustainable and are at a low to moderate-low risk of extinction.

Population sizes of Alabama shad and other *Alosa* species are known to be variable and the species can quickly rebound from low population numbers. Alabama shad are spawning and persisting in river systems along the Gulf Coast and in tributaries of the Mississippi River. Even smaller populations are considered to be self-sustaining (*e.g.,* eastern Alabama rivers, Mettee and O'Neil 2003, Suwannee River, Smith *et al.,* 2011). The range of Alabama shad appears to be stable (Smith *et al.* 2011). However, low abundance in combination with other factors could contribute significantly to the risk of extinction since smaller populations have less of a buffer against threats than larger populations. This aligns with the definition of a ''moderate risk'' under the risk classification system by Wainwright and Kope (1999).

For comparison, the next highest ranking under Wainwright and Kope's (1999) classification system is for a threat that is presently low or moderate, but is likely to increase to high risk in the foreseeable future if present conditions continue. Although based largely on anecdotal information rather than population estimates and trends, we believe there is sufficient evidence to indicate that there have been declines in the abundance of Alabama shad and their low abundance could contribute significantly to their long-term risk of extinction. However, we do not have information suggesting that threats to Alabama shad populations are likely to lead to further decline to the point that their abundance would present a high risk to the species. The primary threat that led to the initial decline of the species was the installation of dams that block access to upriver spawning habitat (evaluated under Factor A of this listing determination). Although most dams are still in place and represent an obstacle to spawning Alabama shad, very few dams have been built in the last 30 years (Graf 1999). Few environmental laws were in existence when the dams were originally built, but the development and implementation of conservation measures in the last 20 years (Doyle *et al.* 2003) are likely to lessen the effect of dams on Alabama shad rather than to pose an increasing threat to the species. Other threats evaluated in this listing determination are ranked as either contributing a low or unknown level of risk to Alabama shad, or being unlikely to contribute to the species extinction risk. As discussed in each of these sections evaluating these threats, we do not have information that they will increase in the foreseeable future. Therefore, we ranked abundance throughout its range as contributing a moderate level of risk to the overall current and foreseeable extinction risk of Alabama shad.

Productivity

Population growth rate (productivity) and factors that affect productivity provide information on how well a population is responding in the habitats and environmental conditions it is exposed to during its life cycle (McElhany *et al.* 2000). Whether a species' productivity has declined, or is declining, toward the point where populations may not be sustainable and whether habitat quality restricts productivity to non-sustainable levels are key pieces of information in assessing a species' extinction risk (Wainwright and Kope 1999). In assessing the productivity of Alabama shad, we considered life history traits, the number of spawning populations, and trends in abundance over time.

Several life history traits make Alabama shad a relatively productive species (Smith *et al.* 2011). They reach sexual maturity quickly. Males start spawning as early as 1 year old, and females start spawning at 2 years old (Mickle *et al.* 2010). Female Alabama shad are known to release large numbers of eggs. Individual females in the Apalachicola River produce from 26,000–250,000 eggs and from 36,000–357,000 in the Choctawhatchee River (Mettee and O'Neil 2003, Ingram 2007). Females may have multiple spawning periods within the same spawning season (Mettee and O'Neil 2003). Because of the age range among spawning Alabama shad (1–5 years for males, 2–6 years for females), individuals may spawn multiple times in a lifetime (Laurence and Yerger 1967, Mettee and O'Neil 2003, Ingram 2007, Mickle *et al.* 2010). Recent information from the ACF River system suggests that female Alabama shad may spawn only once during their lifetime, but may release several batches of eggs during the weeks that they are spawning (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, November 2015).

We also considered the number of Alabama shad spawning populations to assess the productivity of Alabama shad. The largest spawning population of Alabama shad is in the ACF River system, with smaller spawning populations believed to exist in the Missouri/Gasconade/Osage, Meramec, White, Ouachita/Little Missouri, Pascagoula/Leaf/Chickasawhay, Escambia/Conecuh, Choctawhatchee/Pea, and the Suwanee River systems. The life history traits of Alabama shad combined with the presence of multiple spawning populations contributes to the productivity potential of Alabama shad. Highly productive species with short generation times, like Alabama shad, are more resilient than less productive, long lived species, as they are quickly able to take advantage of suitable conditions for reproduction (Hutchings and Reynolds 2004, Mace *et al.* 2002, Musick 1999). Species with shorter generation times, such as Alabama shad (4 to 8 years), experience greater population variability than species with long generation times, because they maintain the capacity to replenish themselves more quickly following a period of lower survival (Mace *et al.* 2002). This resilience was observed in the ACF River system when Alabama shad populations quickly increased when access to upstream spawning habitat was re-established by conservation locking through an existing dam.

Alabama shad populations are generally believed to have declined in many areas where they were historically found. However, it is difficult to quantify any declines because of a lack of historical abundance data for most river systems and the lack of current population estimates for populations other than the ACF River system. Records of Alabama shad in the Pearl River are fairly complete and show a steady decline of the species. This decline was based on the total number of fish captured over time; it did not include estimating population numbers through the use of mark-recapture methods, like those used in the Apalachicola River. In the Pearl River, consistent sampling occurred in several sections of the river over 16–25 years: 384 fish captured 1963–1965; 33 captured 1965–1979; and 1 individual captured 1979–1988 (Gunning and Suttkus 1990). Since then no records of shad have been reported during annual fish surveys conducted by several of the state's universities in the Pearl River (Smith *et al.* 2011). Surveys conducted by USACE on the Lower Mississippi River (north of Baton Rouge, Louisiana) in the early 1980s also recorded the number of individuals encountered and showed a slow decline in the number of both adult and juvenile Alabama shad (Pennington 1980, Conner 1983, Smith *et al.* 2011). We can use the low numbers or lack of Alabama shad captures/observations throughout the rest of their range to indicate declines from historical abundances. But it is hard to relate those numbers with the estimates for the Apalachicola that were calculated using mark-recapture techniques. However, it is clear that while once abundant enough to support small commercial fisheries in Alabama, Arkansas, Kentucky, Indiana, Ohio, and Iowa, Alabama shad are rarely collected throughout much of their former range (Adams *et al.* 2000, Daniels 1860). Alabama shad are believed to possibly be extirpated from the Ohio River since 1989 (Pearson and Pearson 1989). Alabama shad are considered rare in the state of Illinois and appear to have been extirpated from many rivers in the state (Smith *et al.* 2011).

Declines have been estimated in other *Alosa* species with longer historical records. Hall *et al.* (2012) attempted to estimate historical alewife populations in Maine for the years 1600–1900 using analyses of nineteenth and twentieth century harvest records and waterway obstruction records dating to the 1600s. They estimated that obstructed spawning access in 9 watersheds reduced the annual alewife productivity per watershed to 0–16 percent of pre-dam estimates, equaling a cumulative lost fisheries production of 11 billion fish from 1750 to 1900 (Hall *et al.* 2012).

Attempts have been made to estimate past abundances of Alabama shad and habitat carrying capacity for conservation planning by using examples from other *Alosa* species. Comparisons have been made between Alabama shad and American shad. Ely *et al.* (2008) noted that, given the similarities in life history characteristics of Alabama shad and American shad and the similarities in discharge, drainage area, and latitude between the Apalachicola River and other southeastern rivers, the populations of adult Alabama shad and American shad might be expected to be similar. Ely *et al.* (2008) cited the number of American shad reaching the first barrier to migration in the Savannah River, estimated as nearly 190,000 (Bailey *et al.* 2004), and the number in the Altamaha River system estimated as 133,000 (Georgia DNR 2005), and concluded that the population size of the Alabama shad in the Apalachicola River from 2005–2007 (approximately 2,700–26,000 shad) was relatively small. Subsequent to the Ely *et al.* (2008) study, the numbers of Alabama shad in the Apalachicola River generally increased, ranging from 2,000–122,500 from 2008–2012 (as noted earlier, the 2013–2015 data was considered to be skewed by sampling difficulties). Additionally, Ely *et al.* (2008) noted that fluctuations in abundance of American shad are well documented (citing Hattala *et al.* 1996, Atlantic States Marine Fisheries Commission 1998, Moring 2005) and variations in year-class strength typically observed in this genus suggest that populations of Alabama shad are capable of recovering quickly to historical levels under favorable conditions. A multi-agency Alabama Shad Restoration Plan for the Apalachicola-Chattahoochee-Flint River System (NMFS *et al.* 2012) calculated that the carrying capacity for the system is 1.3 million adult Alabama shad (700,000 in the Chattachoochee and 600,000 in the Flint), derived from the amount of free-flowing habitat in the mainstem and major tributaries of the Flint and Chattahoochee Rivers and using American shad population indices as a surrogate.

In summary, we find the productivity potential for Alabama shad is relatively high, given its life history characteristics and the presence of multiple spawning populations within the species' range. This relatively high productivity potential of Alabama shad was confirmed in the ACF River system when population numbers greatly increased when access to historical spawning habitat was provided. Available data suggest a decline in abundance in many systems. Other *Alosa* species with longer and more complete historical records, such as alewife, have also shown declines in abundance. A comparison with American shad populations at similar latitudes and a habitat study indicate that the Alabama shad population in the ACF River system may be smaller than expected and below carrying capacity in the system. Managers and researchers note that low numbers of recorded Alabama shad individuals may be due, at least in part, to insufficient sampling effort during appropriate times (*i.e.,* spawning migrations) and with the appropriate gear to target the species. We ranked productivity, on its own, to be at low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

Spatial Distribution

McElhany *et al.* (2000) stated that spatial structure is an important consideration in evaluating population viability because it affects evolutionary processes and can affect a population's ability to respond to environmental change. Wainwright and Kope (1999) stated that it is important to determine whether existing populations adequately represent historical patterns of geographic distribution and biodiversity and whether population fragmentation poses a risk. The historical distribution of Alabama shad spanned the Gulf Coast from the Suwannee River, Florida, to the Mississippi River, Louisiana. Within the Mississippi River and its tributaries, the species spanned north to Illinois and Iowa, westward to Oklahoma, and eastward to Kentucky and Ohio. The species is believed to be extirpated in some of the farthest reaches of its historical range, such as the Upper Mississippi River and Mississippi River tributaries in Oklahoma, Illinois, and Kentucky/Ohio. However, Alabama shad can still be found in river systems in Arkansas, Missouri, and along the Gulf Coast. The current range of Alabama shad encompasses a diverse array of habitats, which potentially contributes to population stability. Smith *et al.* (2011) state that the current range of Alabama shad is believed to be stable.

Maps displaying the best available information on the historical and current range (presence) of Alabama shad by river, including where the species continues to spawn, can be found at: *http://sero.nmfs.noaa.gov/protected_resources/listing_petitions/species_esa_consideration/index.html* (see Figures 1 and 2 for the eastern and western portions of the range, respectively). Historical and current range, as well as spawning rivers, are based on reports of the species presence from the literature (see the ''Distribution and Abundance'' section), but the maps do not represent the number of fish reported from a river system. In most cases, we do not have information on the exact portion(s) of river systems historically or currently inhabited by Alabama shad, or where spawning habitat is located. In the ACF River system (where the majority of recent directed research on Alabama shad is occurring), the map shows that Alabama shad likely do not pass above dams at Albany and George Andrews Lake. In other systems, it is unknown to what degree locks and dams and/or low head dams block upstream passage or allow some shad to move upstream and downstream. This is discussed in greater detail in the ''Dams'' section under ''A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range.'' In cases where no information is available on the specific extent of Alabama shad or its spawning habitat within a river system, we included the entire river system as part of the range of Alabama shad.

In developing the maps reflecting the historical and current range of Alabama shad, we determined we would include positive reports of Alabama shad over the last 24 years. The 24-year time frame was selected because dams within the geographic range of Alabama shad were completed 30 or more years ago (mid-1980s; Graf 1999). Since dams have the ability to alter the range of shad within rivers, older/pre-dam studies reporting shad would not reflect any alterations of the species' distribution due to the dam. Further, any alterations in the distribution of Alabama shad may not happen immediately after construction of a dam. Therefore we considered the maximum age observed in Alabama shad (6 years; Mettee and O'Neil 2003). We only included reports of Alabama shad that occurred at least 6 years after the era of dam-building ended (*i.e.,* 24 years ago or less). Positive reports of Alabama shad in a river system in the last 24 years would indicate that new generations of shad persisted in the river system after the end of the dam-building era, even if a dam was constructed in the system. Therefore, positive reports collected during the 24-year time frame accounted for the presence of dams with the range of Alabama shad. We also used information from the literature on where the species is potentially extirpated to indicate the historical versus current range. In many instances, the information demonstrating persistence during the last 24 years is limited to just one or several verified identifications of Alabama shad. However, in view of the high productivity of shad, the challenges associated with detecting the species in non-targeted studies, and the episodic, anecdotal nature of available information, we believe it is reasonable to extrapolate from information confirming presence during the last 24 years that Alabama shad continue to occur in these systems.

In some cases, such as the Mississippi River, Alabama shad are shown to inhabit a tributary but not the river mainstem. Although the mainstem is not included as part of the historical range, this does not necessarily indicate Alabama shad are not present in the mainstem, only that we did not find a positive report of their presence in the last 25 years. In the example of the Mississippi River, the river mainstems are often not the subject of research surveys as high river flows and high vessel traffic raise concerns for human safety. Also, as noted earlier in this determination, Alabama shad can be difficult to detect, in both non-targeted or targeted surveys. Positive reports in the tributaries without reports from the mainstem could indicate the presence of landlocked populations or it could simply indicate that shad were present in the mainstem, but not surveyed or detected. Given the pelagic nature of Alabama shad, and their migratory life style, we believe that Alabama shad likely inhabit the mainstem of the rivers adjacent to the tributaries where they were reported.

Spatial structure contributes to the resiliency of populations to various disturbances, which can occur across a range of spatial scales, from localized disturbances affecting a few miles of stream and therefore only a portion of a population, to regional impacts from events such as droughts that affect multiple populations (Williams *et al.* 2008). Hilborn *et al.* (2003) state there is growing recognition that many fish stocks consist of multiple combined geographic components. Spatial diversity in populations can lead to greater stability in fish species (Jorgensen *et al.* 2016). Schindler *et al.* (2010) referred to this as a ''portfolio effect'' that is analogous to the effects of asset diversity on the stability of financial portfolios. Hilborn *et al.* (2003) reported a ''portfolio effect'' in the resilience of sockeye salmon in Bristol Bay, Alaska, which the researchers attributed to the maintenance of diverse geographic locations and life history strategies that comprise the sockeye salmon stock. At different times during the 1900s, different geographic regions and different life history strategies contributed to the productivity of the stock, and Hilborn *et al.* (2003) concluded this likely buffered the stock against large-scale environmental conditions, providing long-term stability. Jorgensen *et al.* (2016) studied Chinook salmon populations from the Columbia River and also observed differential contributions of populations to species productivity, noting differences in migratory corridors, climate, and geology as potential factors.

The current range of Alabama shad (the species' portfolio) encompasses a diverse array of habitats, which potentially contributes to population stability. Many Federal agencies and non-governmental organizations classify terrestrial and aquatic systems based on ecoregions, large areas of similar climate where ecosystems recur in predictable patterns (USFS 2016). Ecoregions are a widely recognized and applied geospatial unit for conservation planning, developed to represent the patterns of environmental and ecological variables known to influence the distribution of biodiversity features at broad scales (Abell *et al.* 2008). The boundaries of an ecoregion encompass an area within which important ecological and evolutionary processes most strongly interact (Abell *et al.* 2008). Conservation of blocks of natural habitat large enough to be resilient to large-scale disturbances and long-term changes are essential for large river systems in particular (Abell *et al.* 2008).

Under several widely used ecoregion classification systems, Alabama shad populations inhabit heterogeneous habitats across multiple diverse ecoregions. Alabama shad occupy six ecoregion ''divisions'' that the U.S. Forest Service classifies based on precipitation, temperature, and vegetation or other natural land cover. The Environmental Protection Agency (EPA) identified four levels of ecoregions by analyzing patterns of biotic and abiotic phenomena, both terrestrial and aquatic. These phenomena include geology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology (EPA 2016). Even at the coarsest level, the EPA's Level I ecoregion, which highlights major ecological areas, Alabama shad populations occupy 2 of the 12 ecoregions in the continental United States: The Eastern Temperate Forests and the Great Plains. The species occupies 4 of the 25 Level II ecoregions, and 14 of the 105 Level III ecoregions. The Nature Conservancy (TNC) uses a terrestrial ecoregion classification system similar to the EPA Level III ecoregions. Alabama shad populations occupy nine TNC terrestrial ecoregions.

TNC also uses freshwater ecoregions with boundaries describing broad patterns of species composition and associated ecological and evolutionary processes (Abell *et al.* 2008). Along the Gulf Coast, Alabama shad occupy four freshwater ecoregions: The Apalachicola (containing the ACF River system and the Econfina River), the West Florida Gulf (includes the Escambia and Choctawhatchee River systems), Mobile Bay (containing the Mobile River system), and the Lower Mississippi (includes portions of the White River). In the northern part of their range, Alabama shad occupy three freshwater ecoregions: The Central Prairie (containing the Missouri River and its tributary, the Osage River), the Ozark Highlands (including a portion of the White River), and the Ouachita Highlands (including the Ouachita River and its Little Missouri River tributary). The ecoregions along the Gulf Coast are similarly defined by humid subtropical climates, but diverge in other characteristics. The Apalachicola ecoregion lies entirely within the coastal plain, but the variety of habitats found in its rivers provide the foundation for a diverse freshwater fauna. Rivers in the Apalachicola ecoregion flow through shaded ravines with cool spring inputs, resembling habitats of more northerly regions. This ecoregion supports more species than adjacent lowland ecoregions. The West Florida Gulf ecoregion is defined by the lowland drainages that flow through extensive floodplain oak-hickory-pine forests. This ecoregion does not boast the same fish richness as the neighboring Mobile Bay. The Mobile Bay ecoregion has the highest level of aquatic diversity in the eastern Gulf. This is largely due to the variety of physiographic provinces occurring in this ecoregion, its size, and its escape from Pleistocene glaciation. This ecoregion is centered in central Alabama and includes eastern Mississippi, western Georgia, and a small area in southern Tennessee. The northern part of the ecoregion is characterized by Appalachian Blue Ridge and Appalachian mixed mesophytic forests, considered some of the most biologically diverse temperate forests in the world. These grade into Southeastern mixed forests, which are demarcated from conifer forests in the south by the fall line of the Atlantic Piedmont. Historically, rivers and streams in this ecoregion stretched over 1000 mi. Today, flow in the Mobile River is regulated by a series of upstream reservoirs on the Etowah, Coosa, and Tallapoosa rivers, and to a lesser extent by the locks and dams of the Tombigbee River. The Lower Mississippi ecoregion is also distinguished by its species richness, particularly in fish. The entire Mississippi basin has served as a center for fish distribution as well as a glacial refugium, and as such it is home to many of the species found in surrounding drainages. As a result, it is the second richest ecoregion in North America.

Compared to other ecoregions, Alabama shad experience different climatic conditions in the Central Prairie, which has hot continental summers and cold winters, with periodic arctic blasts. Most of the streams and rivers in the ecoregion are meandering with low to moderate flow. The diversity of species in this ecoregion is high relative to adjacent ecoregions due to the presence of diverse habitats that were not interrupted during glacial periods. The Ozark Highlands ecoregion is part of the western Mississippi River drainage but is distinctive because of its relative biogeographical isolation. It is a region of high gradient headwater streams surrounded by coastal plains and prairie. The Ozark Highlands contain a diversity of freshwater habitats, including fens, sinkholes and springs, which feed the clear headwaters of larger, free-flowing streams. Many of these habitats served as refugia during periods of glacial maximas. The Ozarks are home to a unique assemblage of species. Like the Ozark Highlands, the Ouachita Highlands ecoregion is distinguished by its relative biogeographic isolation. The ecoregion is a source area for several larger streams and is an area of high-gradient and spring-fed springs, and can almost be considered an island surrounded by the Great Plains, coastal plains, and prairie. The ecoregion is characterized by oak-hickory-pine forests, which are some of the best developed in the United States.

Habitat heterogeneity is considered to be important for the stability of populations, and Oliver *et al.* (2010) found that heterogeneous landscapes containing a variety of suitable habitat types were associated with more stable population dynamics in a butterfly species. Oliver *et al.* (2010) noted that many studies have suggested that the beneficial effects of heterogeneity may buffer a broad range of taxa against environmental change. Based on common ecoregion classifications, the watersheds inhabited by Alabama shad populations contain a diverse array of landscapes, vegetation, geology, hydrology, and climate.

We also considered the spatial structure of the spawning populations of Alabama shad. In assessing the viability of salmonid populations, which are anadromous and exhibit homing tendencies like Alabama shad, McElhany *et al.* (2000) stated that it is practical to focus on spawning group distribution and connectivity because many of the processes that affect small population extinction risk depend on the breeding structure. The spatial arrangement of suitable spawning and rearing habitat within a watershed can be dynamic through time as a result of periodic disturbances that create a mosaic of varying habitat conditions (Reeves *et al.* 1995). Efforts to understand population diversity have focused on population connectedness, through the analysis of DNA collected from individuals across the landscape or tagging data to quantify dispersal between populations (Jorgensen *et al.* 2016). Alabama shad continue to spawn in river systems in Florida, Alabama, Georgia, Mississippi, Louisiana, Arkansas, and Missouri. While most Alabama shad spawn in their natal rivers, Waters *et al.* (2000) proposed that shad species may stray more than other anadromous fishes and estimated that American shad are expected to have over 10 effective migrants per generation. In fact, Mickle *et al.* (2006) and Kreiser and Schaefer (2009) found slight genetic distinctions between populations from the Mississippi River basin and coastal Gulf of Mexico drainages. Kreiser and Schaefer (2009) attributed this to Alabama shad straying from their natal rivers at a rate of about 10 migrants per generation, consistent with the estimate by Waters *et al.* (2000) for American shad. This indicates the possibility that Alabama shad could enhance and repopulate nearby river systems within their range. This was also observed in anadromous Pacific salmon. Similar to Alabama shad, these species exhibit high spawning site fidelity, but are well-adapted to dynamic environments through straying by adults (to connect populations) and high fecundity (also similar to Alabama shad; Reeves *et al.* 1995, Jorgensen *et al.* 2016).

The historical range of Alabama shad has contracted and this species is believed to be extirpated from some river systems. Few targeted research studies were conducted since the time a majority of dams may have altered Alabama shad's distribution, therefore we can rely only on anecdotal reports from monitoring activities and multispecies surveys from the last 24 years to determine their current range. However, the remaining spawning populations of the species appear to be geographically widespread. Their range appears to have become stable once dam building ended, and lost access to spawning habitat is likely to be restored through dam removal and fish passage, and protections under environmental laws have increased. Although spawning populations in some places are small, the species exists in multiple ecoregions, representing a diverse array of ecosystems that has the potential to buffer the species against environmental changes and promote population stability. Genetic studies (Kreiser and Schaefer 2009, Waters *et al.* 2000) show that exchange between river populations is occurring at higher rates than is expected for other anadromous species. Therefore, we ranked spatial distribution throughout its range, on its own, to be at low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

Diversity

In a spatially and temporally varying environment, genetic diversity is important for species and population viability because it (1) allows a species to use a wider array of environments than they could without it, (2) protects a species against short-term spatial and temporal changes in the environment, and (3) provides the raw material for surviving long-term environmental changes (McElhany *et al.* 2000). Small populations may be at risk from random genetic effects, Allee effects, and directional effects (Wainwright and Kope 1999).

Alabama shad are believed to be philopatric and generally return to the same rivers to spawn, which has resulted in slight genetic differences among river drainages (Meadows *et al.* 2008, Mickle 2010). These genetic differences could result in characteristics (*e.g.,* faster growth rates, higher temperature tolerance, etc.) that lead to variable spawning strategies among river drainages. Kreiser and Schaefer (2009) also noted slight genetic differences between Alabama shad from the Mississippi River basin and coastal Gulf of Mexico drainages; however, they determined there has been no significant genetic differentiation among different river populations of Alabama shad.

Moyer (2012) evaluated the genome of Alabama shad collected from the ACF River system to assess the influence of genetic factors on their extinction risk, including whether the construction of JWLD blocking access to upstream spawning habitat affected their genetic diversity. Genetic diversity of Apalachicola River shad was calculated based on the average number of alleles (the possible forms in which a gene for a specific trait can occur), observed heterozygosity (having different alleles in regard to a specific trait), and expected heterozygosity. Moyer (2012) found no evidence of fine-scale population structure in the ACF River system. The observed genetic variation found in Alabama shad was lower than expected based on other shad studies. These findings suggest that the genetic variation of Alabama shad in the ACF River system has been severely reduced by a bottleneck event. Moyer (2012) concluded that the bottleneck likely did not result from the construction of JWLD or from any other anthropogenic activity. Moyer (2012) stated the reduced genetic diversity appears to be the result of past events that occurred during the Pleistocene. Bowen *et al.* (2008) made a similar determination for Alabama shad while studying the phylogenetic relationships across North American *Alosa* species. Their study also indicated that the genetic bottleneck occurred when the originating ancestor(s) of Alabama shad traveled around the Florida peninsula into the Gulf of Mexico during or after the Pleistocene and became geographically separated from Atlantic populations.

Loss of genetic diversity can reduce an organism's adaptive capacity to respond to differing environmental conditions and increase a species' extinction risk. However, population bottlenecks can also have positive outcomes on a species' genetic diversity, fitness, and extinction risk (Bouzat 2010). Moyer (2012) noted that populations or species that have undergone population bottlenecks throughout their evolutionary history may have reduced genetic load. Genetic load is the combination of harmful genes that are hidden in the genetic make-up of a population and may be transmitted to descendants. The genetic load of a population reduces the fitness of that population relative to a population composed entirely of individuals having optimal genotypes. Hedrick (2001) stated that a population with reduced genetic load resulting from a bottleneck may have increased viability and be more likely to recover from near-extinction than a population that has not experienced such an evolutionary bottleneck.

Modeling conducted by Moyer (2012) indicated that the Pleistocene bottleneck for Alabama shad was intense. The maintenance of genetic variability in a finite population can be understood through the concept of effective population size, which is not an actual abundance estimate but an estimate of the number of individuals in an ideal population that would give the same rate of random genetic drift (change in the frequency of a gene variant) as in the actual population (Lande 1988). The effective population size for Alabama shad during the bottleneck was estimated to be between 76 and 398, meaning 76–398 individuals is the population size during the Pleistocene estimated to have been necessary to result in the relatively low genetic diversity observed in members of the species today. Moyer (2012) also noted that the bottleneck event was prolonged (145–987 shad generations) and he concluded that it may have purged much of the species' genetic load, making the population less prone to fitness decreases in the event of another bottleneck. Moyer (2012) concluded the risk of population decline and extinction in Alabama shad from the ACF River basin due to reduced genetic diversity appears to be low and is not of immediate importance to the short- or long-term persistence of Alabama shad in the ACF River system.

In summary, we found no significant genetic differences between Alabama shad from different river populations, based primarily on information provided in Kreiser and Schaefer (2009) and Moyer (2012). A genetic evaluation of Alabama shad from the ACF River system (Moyer 2012) showed genetic diversity is low, likely resulting from a bottleneck that occurred during the Pleistocene rather than any recent anthropogenic factors. Moyer (2012) stated that the reduced genetic diversity resulting from the Pleistocene bottleneck potentially reduced the genetic load of Alabama shad, which decreases their extinction risk and increases their viability and chances of recovery. We ranked diversity, on its own, to be at low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

Threats Assessment

Next we consider whether any of the five factors specified in section 4(a)(1) of the ESA are contributing to the extinction risk of Alabama shad.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Effects to Alabama shad's riverine habitat are contributing to the species' extinction risk now, and are likely to continue into the foreseeable future. The primary cause for declines in Alabama shad populations is believed to be the presence of dams, which can block access to upstream spawning habitats (NMFS *et al.* 2012, Mettee and O'Neil 2003). Existing literature cites other threats to Alabama shad, including dredging (Mettee and O'Neil 2003), sedimentation (Mettee and O'Neil 2003), and water quality degradation (Mettee *et al.* 1996), although there is little specific information on how Alabama shad populations may be responding to those threats. Recently identified and ongoing potential threats to Alabama shad include water allocation issues, climate change, and the Deepwater Horizon (DWH) oil spill.

Dams

The construction of dams that block access to upstream habitat has long been considered the primary reason for declines of Alabama shad and other anadromous fish species (NMFS *et al.* 2012). Dynesius and Nilsson (1994) list three of the river systems inhabited by Alabama shad (the Mississippi, Apalachicola, and Mobile Rivers) as being strongly affected by the presence of dams. Despite a lack of species-specific data, the proliferation of impassable structures constructed on rivers within its range is believed to have restricted adult Alabama shad from reaching their historical spawning grounds, which severely reduced or eliminated their ability to reproduce (Pflieger 1997, Mettee and O'Neil 2003). Most surveys and studies of Alabama shad focused on fish below dams (Laurence and Yerger 1967, Mills 1972), while collection records from state and Federal agencies, as well as ichthyological collections, indicate a rarity of specimens collected upstream of dams (Coker 1930, Etnier and Starnes 1993). In addition, similar declines in American shad populations have resulted from dam construction (Limburg and Waldman 2009). Pringle *et al.* (2000) note that *Alosa* species, such as river herring and American shad, have established themselves outside their native ranges and in landlocked populations when dams blocked their natural habitat. In the Mississippi River system, Alabama shad are shown to inhabit several tributaries but have not been recently reported within the river mainstem. Positive reports in the tributaries without reports from the mainstem could indicate the presence of landlocked populations of Alabama shad or it could indicate that shad were present in the mainstem, but not surveyed or detected.

Within the state of Iowa there are 10 locks and dams on the Upper Mississippi River (north of the confluence with the Ohio River) and an additional 7 locks and dams to the south that could prevent Alabama shad from reaching historical spawning grounds (Steuck *et al.* 2010). Noting that large numbers of Alabama shad congregated below Keokuk Dam, Iowa, but few were ever captured above it, Coker (1930) reasoned that the dam likely limited the upstream passage of the species in the Upper Mississippi River. Dams in Mississippi River tributaries also block Alabama shad from reaching spawning habitat. Construction of dams in the McClelland-Kerr Arkansas River Navigation System in the early 1970s may have led to the extirpation of Alabama shad in that system (M. Oliver, Chief of Fisheries, Arkansas Fish and Game Commission, pers. comm. to K. Shotts, NMFS, November 5, 2013). The Denison and Altus Dams block access to habitat in the Red and Washita Rivers (Smith *et al.* 2011).

Dams have been constructed at or below the fall line in many river systems along the Gulf Coast and prevent spawning migrations into the Piedmont (NMFS *et al.* 2012). In Georgia and Alabama, there is evidence that Alabama shad historically occurred above the fall line in the Flint and Chattahoochee Rivers (Mettee and O'Neil 2003, Couch *et al.* 1996) and in the upper Coosa and Tallapoosa River systems (Freeman *et al.* 2005). An Alabama shad record exists above the fall line into the Piedmont from the Cahaba River, Alabama (Mettee *et al.* 1996). There are many locks, dams, and other impoundments in the Mobile River basin that cumulatively impound approximately 44 percent of the river mainstem length in the basin as well as portions of many tributary streams (Pringle *et al.* 2000). Only a few Alabama shad have been found in the Tombigbee River, a tributary of the Mobile River, since the construction of the Tombigbee lock system in the waterway in 1901 (M. Roberts, Curator of Fishes, Mississippi Museum of Natural Science, pers. comm. to K. Shotts, NMFS, October 21, 2013). On the Alabama River, Claiborne Lock and Dam was opened for navigation in 1969 (Freeman *et al.* 2005). Upstream from Claiborne Lock and Dam, Millers Ferry Lock and Dam was constructed for the purpose of both power generation and navigation, with the lock opening in 1969 and power coming on line in 1970. Numerous juvenile Alabama shad were recorded in the Alabama River in 1951, the late 1960s, and the early 1970s (Boschung 1992, Mettee and O'Neil 2003). However, only two individuals have been caught in the Alabama River in more recent years, one in 1993 below Claiborne Lock and Dam and one in 1995 below Miller's Ferry Lock and Dam (Smith *et al.* 2011). In 2009, conservation locking during spawning season was instituted at Claiborne Lock and Dam and Miller's Ferry Lock and Dam (Simcox 2009). In 2014 and 2015, conservation locking coupled with stocking of Alabama shad was undertaken to provide access above Claiborne and Miller's Ferry Locks and Dams and to enhance Alabama shad populations in the river system.

Legislation focused on flood control, navigation, and hydropower passed in the late 1920s through the mid-1940s resulted in the development and construction of over a dozen major impoundments on the mainstem Missouri River, but there are approximately 17,200 minor dams and reservoirs on the river and its tributaries, most of which are small, local irrigation structures (USACE 2006). Alabama shad spawn in the Missouri River, as well as two of its tributaries, the Gasconade and Osage Rivers (Smith *et al.* 2011). The Powersite Dam, a hydroelectric dam, was constructed far upstream in the Missouri portion of the White River in 1913. In 2006, researchers collected the first Alabama shad in the White River (Buchanan *et al.* 2012); the collected specimens were juveniles believed to have been spawned in the river. The Remmel Dam was constructed on the Ouachita River in 1924 to provide electrical power for southern Arkansas and surrounding states. While the dam blocks access to upstream habitat for most of the year, Alabama shad are successfully spawning in the Ouachita and Little Missouri Rivers (Buchanan 1999). Buchanan *et al.* (1999) note that during March and April of most years, the peak months of the spring spawning run, high water frequently flows over and around the structure, allowing Alabama shad to move into habitats upstream of Remmel Dam.

The Elba-Pea River Dam was constructed for power generation on the Pea River tributary of the Choctawhatchee River in the early 1900s. Studies indicate there are small spawning populations of Alabama shad in the Choctawhatchee and Pea Rivers (Barkuloo 1993, Adams *et al.* 2000, Mettee and O'Neil 2003, Young 2010). Dams were constructed on the Conecuh/Escambia (Point A Dam) and Apalachicola Rivers (JWLD) beginning in 1929 and 1947, respectively. River traffic on the Apalachicola River resulted in the lock being operated frequently, allowing passage and sustaining reproduction of the resident Alabama shad population. Historically, JWLD was operated continuously 24 hours per day for commercial barge traffic (Sammons 2013). With the elimination of commercial traffic in the late 1960s, lock operation was reduced to 8 hours per day for on-demand passage of recreational boats, reducing the number of lockages to less than 100 per year from a high of 1200. Barge traffic decreased and lock operation became infrequent when navigational dredging ceased in 2001 (J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013). Recently, conservation locking on the Apalachicola River has given Alabama shad access to previously blocked habitat upstream of JWLD, although 15 other impoundments/reservoirs currently exist upstream on the Chattahoochee and Flint Rivers (NMFS *et al.* 2012). Populations of Alabama shad continue to use the Conecuh/Escambia and ACF River systems for spawning.

Dams are believed to be the primary reason for declines in all three of the anadromous species native to the Gulf of Mexico (USFWS 2009a). In addition to Alabama shad, anadromous Gulf sturgeon and striped bass (*Morone saxatilis*) have also been blocked by dams from accessing upstream habitat in river systems draining into the Gulf. Gulf sturgeon were listed as threatened in 1991 (56 FR 49653) and occur in river systems from Louisiana to Florida, in nearshore bays and estuaries, and in the Gulf of Mexico. While overfishing caused initial declines in Gulf sturgeon populations, the listing determination cited dams as a current threat to the species. Striped bass were native to Gulf of Mexico rivers from the Suwannee River in Florida to the rivers draining into Lake Pontchartrain in eastern Louisiana and southwestern Mississippi. Striped bass populations began declining in the early 1900s, and by the mid-1960s had disappeared from all Gulf rivers except for the ACF River system of Alabama, Florida, and Georgia (USFWS 2009a). In addition to blocking upstream habitat, it is believed that downstream effects from the dam, such as impaired water quality and channelization may have prevented successful spawning (USFWS 2009a). The USFWS and Gulf states began cooperative efforts to restore and maintain Gulf striped bass populations in the late 1960s, mainly through stocking of hatchery-raised fingerlings, and this effort continues today (USFWS 2009b). Related anadromous *Alosa* species on the East Coast, such as the American shad, have also experienced declines due to dams blocking access to upstream habitat (Limburg and Waldman 2009).

Spawning populations of Alabama shad inhabit the Meramec, Gasconade, Suwannee, and Pascagoula River systems, all of which are free-flowing systems unmodified by dams (Heise *et al.* 2005, MDC 2001, 2015, Mickle *et al.* 2010; J. Wilcox, FFWCC, pers. comm. to K. Shotts, NMFS, November 12, 2013). However, other spawning populations of Alabama shad, including the largest known spawning population in the ACF River system, use river systems that have been dammed since the early to mid-1900s. Recent conservation locking is currently having a positive effect on Alabama shad in the ACF River system, and this population has been considered to be the largest population since at least 1967 (McBride 2000).

While dams are known to impede upstream access to habitat, access may still be possible under certain conditions. Fish may be able to pass upstream and downstream during high water conditions at ''low head'' dams, which are low vertical structures that have been constructed across rivers or streams to raise the water level, normally producing vertical water surface drops of one to several feet. Fish may also pass through navigation locks when they are open for vessel traffic. Coker (1929) noted lack of observation in locks. However, Zigler *et al.* (2004) note that there is considerable opportunity for fish to use some locks for upstream and downstream movement. Ickes (2014) states that all of the dams on the Upper Mississippi River are ''semi-permeable'' to fish passage in that they all have locks that fish could use to move upstream and downstream. With the exception of two of the locks, all are open and run-of-the-river for part of the year, up to as much as 35 percent of the time annually (Ickes 2014).

Zigler *et al.* (2004) found that the dams on the Upper Mississippi River are typically low head dams that allow fish passage under certain conditions. Downriver fish passage can occur through the locks and gated sections of the dam, as well as over the top of the dam (Wilcox 1999). Fish can sometimes swim over low head dams when water levels in the river are high enough, although Wilcox (1999) notes that most upriver passage on the Upper Mississippi River occurs through the gated sections of the dams. Zigler *et al.* (2004) observed that navigation dams are operated with partially closed dam gates during most of the year to increase dam head and maintain water levels in navigation pools. Fish can likely pass downstream through partially closed dam gates unharmed (Zigler *et al.* 2004, Moen *et al.* 1992). Upstream passage is possible, but likely impeded to some degree, when gates are partially closed due to increased current velocity, which increases with increasing dam head (Zigler *et al.* 2004). In a tagging study of paddlefish, a species selected as representative of migratory fish species whose movements have likely been adversely affected by dams, Zigler *et al.* (2004) showed 12–33 percent of the tagged fish moved upstream, downstream, or both during years with high river discharge through the low head dams, but no movement was observed during time periods with a weak flood pulse. Studies by Brooks *et al.* (2009) and Tripp and Garvey (2011) in the Upper Mississippi River found that the degree to which upriver movement was impeded by lock and dam structures varied among species, but that each of their 5 study species had the capability to negotiate dams whether the lock gates were closed or open. Wilcox (1999) found similar results in that strong swimming species (*e.g.,* sturgeon, bass, and herrings) had the most success moving upriver through structures, but Alabama shad and other migratory fish species included in the study were also able to move upstream through Upper Mississippi River locks and dams when hydraulic conditions were favorable. Wilcox (1999) described the difference in hydraulic conditions when gates are in the open and closed positions. Velocities through the gated sections of the dams are highest when dam gates are in the water (closed). When the dam gates are raised from the water (open) during higher levels of river discharge, uncontrolled conditions exist, and open channel flow occurs in the gate bay openings. Opportunity for upriver fish passage through dams is greatest during uncontrolled conditions due to the lower velocities through the dam gate openings. Dams with lower controlled discharge capacity may therefore present more frequent and longer windows of opportunity for upriver fish passage than dams with higher discharge capacity (Wilcox 1999).

USFWS (2012) conducted a 2-year study starting in 2010 to determine whether Lock and Dam #1 (a low head dam) creates a barrier to fish passage on the Osage River, which supports a spawning population of Alabama shad. USFWS (2012) determined through captures of pallid and hybrid sturgeon marked in other studies that Lock and Dam #1 was passable at certain flows, but presented a barrier at others. Fish passage upstream of Lock and Dam #1 was detected by USFWS (2012). Passage was determined through collection of fish above and below the dam, rather than by acoustically or radio tracking fish. Therefore it is unknown whether upstream passage was achieved by fish swimming over the dam or passing through the lock. However, since upstream passage is typically more difficult for fish due to swimming against the river current, it is likely that downstream passage is also possible since upstream passage was documented to occur. USFWS (2012) also noted that the 115-year-old dam was unstable and would need to be removed or repaired in the very near future.

While dams are believed to be the main cause of the initial decline of Alabama shad, and continue to block habitat and cause downstream effects today, few new dams are being built (Graf 1999). Some dams in the United States date back centuries. The greatest rate of increase in reservoir storage occurred from the late 1950s to the late 1970s, with more dams (and some of the largest) built in the 1960s than in any other decade (Graf 1999). In the ''golden age'' of U.S. dam building, thousands of large and small dams were built to supply power, reduce flood hazard, improve navigation, and impound water for irrigation and urban water supply with little thought to the environmental impacts, long-term fate, inevitable aging, and need for continued maintenance, renovation, or even removal of dams (Doyle *et al.* 2003, Pejchar and Warner 2001). There have been few new dams built since the mid-1980s and the nation's era of dam building is over (Graf 1999). Further, the aging of America's dams, coupled with increasing awareness of their environmental costs, has brought dam decommissioning and removal to the attention of the scientific community, management agencies, and the general public (Doyle *et al.* 2003). It is only since the late 1990s that the topic of dam removal has become common due to the convergence of economic, environmental, and regulatory concerns (Doyle *et al.* 2003). An understanding about how dams severely impair free-flowing rivers has become firmly established both in the United States and abroad and this knowledge has entered into the public debate on river conservation, both in terms of greater willingness of reservoir managers to minimize downstream ecological effects and of increased calls for outright dam removal (Poff and Hart 2002).

By 2020, an estimated 85 percent of the dams in the United States will be near the end of their operational lives (Doyle *et al.* 2003). The current intensification of economic and environmental concerns is coinciding with a policy window in which many private dams are coming up for regulatory re-licensing with FERC and operational guidelines for publicly-operated dams are being reviewed (Doyle *et al.* 2003). Stanley and Doyle (2003) predict that the aging of the U.S. dam infrastructure will make dam removal even more common in the future. American Rivers (2015) reports that 1,300 dams were removed between 1912 and 2015. Lovett (2014) notes that 1,150 of those dams were removed in the last 20 years, most of which were dams lower than 5 meters (16.4 feet) but also taller dams in recent years. In 2004, 2012, and 2013, 5 dams within the current range of Alabama shad in the ACF and Alabama River systems were removed (American Rivers 2015). Another 10 dams were removed since 1999 in the historical range of Alabama shad in the Mississippi, Tennessee, and Ohio Rivers (American Rivers 2015). The rapid aging of dams (especially small ones) and the costs of maintaining old dams suggests that dam removal will continue for the foreseeable future (Poff and Hart 2002). The benefits of dams have been routinely exaggerated and the costs have been frequently underestimated, prompting policy-makers to increasingly consider dam removal as a policy option (Pejchar and Warner 2001). The cost of repairing a small dam can be as much as three times greater than the cost of removing it (Born *et al.* 1998). In contrast, many cost-effective methods for water conservation in cities already exist, and new technologies are constantly evolving that will enable even greater efficiencies, reducing the amount of water that needs to be extracted from rivers through the use of dams and reservoirs (Richter and Thomas 2007). As dams in the U.S. age beyond their intended design lives (Doyle *et al.* 2008), some states are providing incentives to remove dams as means of river restoration (Ardon and Bernhardt 2009).

Besides dam removal, various designs of fishways or fish ladders have been developed to enable fish to pass upstream of barrier dams. The recognized need to pass fish upstream of dams and other obstacles inspired many seminal studies on fish swimming performance, energetics, and biomechanics (Castro-Santos *et al.* 2009). Within the last 50 years fishways and other passage operations have become increasingly sophisticated and efficient, their design a product of collaboration between hydraulic engineers and biologists (Roscoe and Hinch 2010). The presence of a fishway alone does not guarantee that the fish are able to pass upstream of the barrier to their movement and fishways do not always perform as intended (Roscoe and Hinch 2010). However, upstream passage technologies are considered to be well developed and well understood for the main anadromous species, including *Alosa* species (Larinier and Marmulla 2004). In the ACF and Alabama River systems, Federal, state, and non-governmental organizations are collaborating and utilizing existing facilities (*i.e.,* opening navigation locks) during spawning season to pass Alabama shad and other species upstream, with demonstrated success in the ACF River system, but with unknown results in the Alabama River.

River restoration will play an increasing role in environmental management and policy decisions, and has even become a highly profitable business (Bernhardt *et al.* 2005, Ardon and Bernhardt 2009). Bernhardt *et al.* (2005) synthesized information on 37,099 river restoration projects in the National River Restoration Science Synthesis (NRRSS) database. Fish passage is one of the four most commonly stated goals of river restoration, along with water quality management, instream habitat improvement, and riparian management. The NRRSS database shows that of the 58 percent of projects where cost information was available, $9.1 billion has been spent on river restoration projects since 1970. Bernhardt *et al.* (2005) notes that the majority of the money ($7.5 billion) spent on restoration was spent between 1990–2003, indicating that river restoration is a relatively recent and growing phenomenon. Specific river flow patterns cue anadromous species like Alabama shad to migrate and reproduce. To mitigate negative effects of flow patterns created by dams, dam operations are increasingly being adapted toward releasing ''environmental flows,'' the appropriate quantity, quality, and timing of water flows required to sustain freshwater and estuarine ecosystems (Lehner *et al.* 2011).

In summary, dams have impacted anadromous species populations and are believed to be the primary cause for the observed decline of Alabama shad. Existing dams continue to block access to upstream spawning habitat, although few new dams are being built today. The current diminished abundance of Alabama shad is a reflection of historical effects of the dams over decades, although the threat to Alabama shad from existing dams may be reduced with effective fish passage, conservation locking, dam removal, and other forms of river restoration. We believe that the presence of dams is contributing a moderate level of risk to the overall current extinction risk of Alabama shad, but could decrease in the foreseeable future with the increasing focus on restoring access to fish habitat blocked by dams.

Water Quality

Changes in water quality parameters (turbidity, flow, oxygen content, and pollutants) are a potential threat to Alabama shad. The presence of dams, dredging, and watershed activities can alter water quality in riverine and coastal habitat used by Alabama shad. In addition to blocking access to habitat, dams can degrade spawning, nursery, and foraging habitat downstream by altering flow, water temperature, and oxygen levels. Mettee *et al.* (2005) state that seasonal flow patterns in dammed rivers have been replaced by pulsed releases that alter water temperature and

DO levels, as well as nutrient and sediment transport.

Dredging can also affect water quality. Several decades ago, when vessel traffic on the Apalachicola River was much greater, the USACE frequently dredged the river to maintain depth of the navigation channel. The dredged material was placed along the river banks and eventually became re-suspended in the river. The dredged material (finer sands and clays) settled on the river bottom and filled in spaces between grains of the coarser sands and gravel that served as spawning habitat for Alabama shad (Mills 1972). McBride (2000) reports that dredging affected *Alosa* species, including Alabama shad, in Florida rivers through re-suspension of particulate matter in the water column, alteration of natural flow patterns, and removal of river-bottom habitat.

Alabama shad and their habitat are also exposed to sediment and pollutants introduced from land-based activities. Agriculture, silviculture, and industrial, commercial, and residential development in the watershed contribute to degraded water quality in rivers and coastal waters inhabited by Alabama shad. Wastewater treatment, municipal stormwater, industrial discharges, land clearing, and construction of impervious surfaces are examples of activities that increase runoff into the watershed, introduce sediment and pollutants, and lead to low DO. There are no specific data linking exposure to altered water quality parameters with responses in Alabama shad populations. However, McBride (2000) noted that the effects of declining water quality from low DO and industrial discharges were seen in other *Alosa* species on the Atlantic Coast throughout the nineteenth century.

States are required to report water quality conditions to the EPA under Sections 305(b) and 303(d) of the Clean Water Act. We reviewed the water quality assessment reports (available at *http://www.epa.gov/waters/ir/index.html*) for rivers occupied by Alabama shad spawning populations, as well as the Mobile/Alabama River system where Alabama shad conservation activities are occurring. Rivers were assessed by the states between 2008 and 2014, with most rivers assessed more recently (2012–2014). The water quality assessment reports provide information on river segments that have good water quality, as well as segments that are impaired. While the reports list what the impairment is based on (*e.g.,* the presence of heavy metals, sediment, or low DO), the reports rarely specify the source of the impairment (*e.g.,* dam releases, dredging, industrial discharge, or stormwater runoff). However, the water quality assessment reports provide some information on the water quality conditions Alabama shad are exposed to in the riverine areas they use.

We reviewed the water quality assessment reports for the following river systems: (1) ACF; (2) the Missouri/Gasconade/Osage; (3) Meramec; (4) White; (5) Ouachita/Little Missouri; (6) Pascagoula/Leaf/Chickasawhay; (7) Mobile/Alabama; (8) Escambia/Conecuh; (9) Choctawhatchee/Pea; and (10) the Suwanee. Of the approximately 4,500 combined river mi in these systems, water quality was deemed good for 2,150 or 48 percent of the assessed mi. Approximately 2,100 mi (47 percent) were designated as impaired based on one or more factors, and 275 mi were not assessed. Within each river system, between 6 percent and 100 percent of the river mi assessed were deemed to be impaired (too polluted or otherwise degraded to meet water quality standards) for one or more factors.

With the exception of the Meramec and White Rivers, all or portions of every other river system we looked at were impaired due to mercury levels. The EPA states that coal-burning power plants are the largest human-caused source of mercury emissions into the air within the United States, accounting for over 50 percent of all domestic human-caused mercury emissions (EPA 2014a). Mercury in the air may settle into rivers, lakes, or estuaries, where it can be transferred to methylmercury through microbial activity. Methylmercury can accumulate in fish at levels that may harm the fish and the other animals that eat them (EPA 2014b). Other heavy metals (copper, zinc, and lead) were found in impaired waters in the Meramec and Ouachita/Little Missouri River systems. There are no known studies on the effects to Alabama shad from exposure to, or accumulation of, mercury and other heavy metals.

All river systems we evaluated, with the exception of the Meramec and the Pascagoula/Leaf/Chicksawhay River systems, had some impaired river segments due to low DO. Low DO can cause lethal and sublethal (metabolic, growth, feeding) effects in fish. Different species have different oxygen requirements. For instance, sturgeon species, considered to be benthic species, are known to be more highly sensitive to low DO (less than 5 milligrams per liter (mg/L)) than other fish species (Niklitschek and Secor 2009a, 2009b). DO is often lowest at the benthos compared to the water column. Tagatz (1961) found that juvenile American shad (an *Alosa* species more closely related to Alabama shad than sturgeon) are able to acclimate to low oxygen concentrations (2–4 mg/L) when other environmental conditions are satisfactory. Howell and Simpson (1994) looked at the abundance of a variety of finfish captured across DO levels in Long Island Sound, New York, and found that American shad were captured in 79 percent of the tows in waters with DO greater than or equal to 3 mg/L. American shad were captured in 40 percent of the tows with DO levels of 2–2.9 mg/L, but no captures were made in waters where DO was less than 2 mg/L. The classification of Alabama shad as a pelagic species, meaning they inhabit the water column, indicates they are present above the benthos in areas where DO levels are usually higher. This suggests that Alabama shad could be less susceptible to the effects of low DO than other species, such as sturgeon.

Segments of several river systems inhabited by Alabama shad were designated as impaired due to biota. The water quality assessment reports define this category as ''the community of aquatic animals (fish, reptiles, amphibians, aquatic insects or others) normally expected in a healthy waterway is unhealthy, reduced, or absent, and the exact cause of the problem is unknown.'' The Chattahoochee River was designated impaired based on fish biota. Georgia DNR (2008) reported to the EPA that studies completed during 1998–2003 showed modification of the fish community in the Chattahoochee River. The general cause was determined to be the lack of fish habitat due to stream sedimentation. Even with access to the Chattahoochee River restored as a result of conservation locking at JWLD, Alabama shad preferentially spawn in the Flint River over the Chattahoochee River. Sammons (2014) conducted a study to determine habitat usage by Alabama shad in the Flint and Chattahoochee Rivers and did not find a single shad in the Chattahoochee during 4 years of tracking. The Flint and Osage Rivers are designated impaired due to benthic and aquatic macroinvertebrates, respectively. The Leaf River is also designated impaired due to biological impairment. It is unknown whether these conditions affect Alabama shad.

Sedimentation was listed as a potential threat to Alabama shad (Mettee and O'Neil 2003). Segments of the White, Leaf, and Conecuh Rivers were designated as impaired due to sedimentation. Other causes of impairments listed in the water quality assessment reports include the presence of PCBs (Chattahoochee River), organic material (Conecuh River), algal growth/chlorophyll-*a* (Suwannee River), and salinity/solids/chlorides/sulfites (Suwannee River). It is unknown how these conditions affect Alabama shad.

We also reviewed the National Coastal Condition Report (NCCR) published by the EPA to gauge the recent water quality conditions experienced by Alabama shad in coastal waters. The NCCR IV (EPA 2012) graded the overall conditions of the Gulf Coast region as ''fair,'' with an overall condition score of 2.4 out of a possible 5.0. Comparatively, the overall condition of the nation's coastal waters was also rated ''fair,'' with an overall condition score of 3.0. Using 2003–2006 data, the water quality index (based on parameters such as dissolved nitrogen, phosphorus, and oxygen, chlorophyll *a* concentrations, and water clarity) for the coastal waters of the Gulf Coast region overall was rated as ''fair.'' Only 10 percent of the region was rated as ''poor,'' although estuaries with ''poor'' water quality conditions were found in all five Gulf states. The Gulf Coast region is rated ''good'' for DO concentrations, with less than 5 percent of the coastal area rated ''poor'' for this factor. Although hypoxia is a relatively local occurrence in Gulf Coast estuaries, the occurrence of hypoxia in the Gulf Coast shelf waters is much more widespread. The Gulf of Mexico hypoxic zone is the second-largest area of oxygen-depleted waters in the world (Rabalais *et al.* 2002b). This zone, which occurs in waters on the Louisiana shelf to the west of the Mississippi River Delta, was not assessed for NCCR IV (EPA 2012) and the ''good'' rating for DO concentrations in the Gulf Coast region provided in the report is not indicative of offshore conditions. Because the life history of the Alabama shad in offshore Gulf of Mexico waters is unknown, it is not possible to determine if these conditions affect Alabama shad.

In summary, water quality has been cited by multiple studies as a threat to Alabama shad (*e.g.,* Mills 1972, Mettee *et al.* 1996, 2005, McBride 2000). Water quality assessments required by the Clean Water Act, as well as assessments of water quality along the Gulf Coast reported in NCCR IV (EPA 2012), indicate that water quality in some portions of the Alabama shad's range are good, while other areas are impaired by heavy metals, low DO, and other issues. Although it is likely that Alabama shad are exposed to water quality issues in their coastal and riverine environments, there are no clear data directly linking water quality problems with declines in Alabama shad, and the species may be less susceptible to some impairment factors (*e.g.,* low DO) than other species. The NCCR I–IV reports (EPA 2001, 2005, 2008, 2012) show that coastal water quality in the Gulf of Mexico has improved since 2001. As coastal populations grow and industrial, commercial, and residential development increases, water quality issues could also grow. At this time it is unknown what risk water quality presents to Alabama shad now or in the foreseeable future.

Water Allocation

Water allocation issues are a growing concern in the southeastern United States. Transferring water from one river basin to another can fundamentally and irreversibly alter natural water flows in both the originating and receiving basins, and exacerbate any existing water quality issues. Reallocation of water between river basins can affect DO levels, temperature, and the ability of the basin of origin to assimilate pollutants (Georgia Water Coalition 2006).

Water allocation issues have traditionally occurred primarily in the Western United States, but they are also occurring in the Southeast, with one of the biggest interstate allocation disputes occurring between Alabama, Florida, and Georgia (SELC 2015a, Ruhl 2003). These three states have fought over the future allocation of water in the ACF and Alabama/Coosa/Tallapoosa (ACT) River basins for decades (SELC 2015a) as population growth is driving competing water demands for urban, agricultural, and ecological uses. A 2006 study by the Congressional Budget Office (CBO 2006) reported that Georgia had the sixth highest population growth (26.4 percent) in the nation, followed by Florida (23.5 percent). The per capita water use in Georgia has been estimated to be 8 to 10 percent greater than the national average, and 17 percent higher than per capita use in neighboring states (UGA 2002). Georgia needs water to supply the large metro Atlanta area; Alabama needs its water supply for power generation, municipal uses, and fisheries; and Florida seeks to maintain its shellfish industry in Apalachicola Bay (SELC 2015a). Water shortages have already occurred and are expected to continue due to the rapid population growth anticipated over the next 50 years (Cummings *et al.* 2003). In an ongoing U.S. Supreme Court case, in 2014 Florida sued Georgia seeking to establish that it is entitled to equitable apportionment of the waters of the ACF River Basin and appropriate injunctive relief against Georgia to sustain an adequate flow of fresh water into the Apalachicola Region (*State of Florida* v. *State of Georgia,* No. 142, Original).

It is not known how much water is already being removed from rivers used by Alabama shad because there is little information concerning actual withdrawals and virtually no information concerning water discharges. This is particularly the case for municipal and industrial uses because water use permits are not required in Georgia for withdrawals less than 100,000 gallons per day (Cummings *et al.* 2003) and discharge permits are not required unless discharge contains selected toxic materials. Agricultural water use permits are not quantified in any meaningful way, thus neither water withdrawals nor return flows are measured (Fisher *et al.* 2003). The Metropolitan North Georgia Water Planning District, which was created through legislation in 2001 and includes 15 counties and 93 cities (Cole and Carver 2011), is the only major metropolitan area in the country with more than 100 jurisdictions implementing a long-term comprehensive water management program that is required and enforced. Since plan implementation, total water consumption in the region has dropped by 10 percent despite a one million person increase in population. The District's Water Supply and Water Conservation Management Plan (2009) recommends that the Georgia General Assembly consider requiring permits for withdrawals less than 100,000 gallons per day within the Metro Water District.

Large withdrawals of water (such as those for municipal and agricultural use) from rivers result in reduced water quantity and quality (altered flows, higher temperatures, and lowered DO). Florida and Georgia have developed water management plans in attempts to provide comprehensive basin-wide strategies for management of the water resources; Alabama is also developing a plan. Many cost-effective methods for water conservation in cities already exist, and new technologies are constantly evolving that will enable even greater efficiencies, reducing the amount of water that needs to be extracted from rivers (Richter and Thomas 2007).

It is unclear whether Alabama shad in the ACF system have been affected by these ongoing water allocation issues. The Georgia Ecological Services Office of the USFWS (2015) states that several species of snails and mussels have gone extinct in the ACT and ACF systems due to alterations in water quantity and quality. Currently, there are 65 ESA-listed species in the ACT and ACF systems. USFWS (2015) has provided instream flow guidelines to Georgia, Alabama, and Florida that describe flow regime features that would protect these listed species. It is unknown whether water allocation issues contribute to Alabama shad's extinction risk, either now or in the foreseeable future.

Climate Change

Changes in temperature, precipitation, drought, flooding, and sea level due to climate change could further exacerbate existing water quality and quantity issues in rivers and coastal areas used by Alabama shad. The Intergovernmental Panel on Climate Change (IPCC) in its fifth and most recent assessment report (IPCC AR5 2014) presented four Representative Concentration Pathways (RCPs) to assess future climate changes, risks, and impacts. The RCPs describe four possible 21st century pathways of greenhouse gas emissions and atmospheric concentrations, air pollutant emissions, and land use. The IPCC did not identify any scenario as being more likely to occur than any other. Because we cannot predict whether and how climate conditions may change, it is our policy to assume climate conditions will be similar to the status quo in making ESA listing determinations (memorandum from D. Wieting, Director of the Office of Protected Resources, to E. Sobeck, Assistant Administrator for Fisheries, regarding guidance for treatment of climate change in NMFS ESA decisions, January 4, 2016). In this listing determination, we use a baseline scenario, which is one without additional efforts to constrain emissions of greenhouse gases, leading to the RCP8.5 pathway, a scenario with very high greenhouse gas emissions (IPCC AR5 2014), in evaluating potential climate effects to Alabama shad.

The southern distributional limit for all *Alosa* species is believed to be determined by water temperature (McBride 2000). Although there have been no studies on the thermal tolerances of Alabama shad, other *Alosa* species cannot tolerate water temperatures greater than 32 °C; therefore, it is likely that Alabama shad cannot tolerate high water temperatures (Beitinger 1999). Under RCP8.5, the predicted increase in temperature from the 1850–1900 period to the end of the 21st century (2081–2100) is likely to exceed 2 °C (IPCC AR5 2014). However, current temperature trends indicate that warming has been less pronounced and less robust in the Southeast United States. Within North America, the Southeast is predicted to have the smallest changes in mean annual temperature, between 1.5–2.5 °C by the mid-21st century (IPCC AR5 2014). It is unknown what level of temperature increases could affect the current distribution and range of Alabama shad.

Precipitation can affect riverine habitat used by Alabama shad through increased runoff and introduction of sediment and pollutants. While precipitation is generally expected to increase for the northern portion of North America, little to no change in the annual average precipitation over the average recorded for 1986–2005 is predicted to occur in the Southeast by the mid-21st century (2046–2065) under RCP8.5 (IPCC AR5 2014). This is also the prediction for the late 21st century (2081–2100) for most of the Alabama shad's range. A small portion of the species' western range is in an area where greater than or equal to 66 percent of the prediction models for the late 21st century indicated changes in annual precipitation would occur, although the models could not predict whether precipitation would increase or decrease.

Similar to increased precipitation, increased flooding can also affect riverine habitat used by Alabama shad through increased runoff and introduction of sediment and pollutants. Conversely, increased periods of drought that result in lower than normal river flows can restrict access to habitat areas, expose previously submerged habitats, interrupt spawning cues, reduce thermal refugia, and exacerbate water quality issues, such as water temperature, reduced DO, nutrient levels, and contaminants. IPCC AR5 (2014) states that changes in the magnitude or frequency of flood events have not been attributed to climate change, as floods are generated by multiple mechanisms (*e.g.,* land use, seasonal changes, and urbanization). IPCC AR5 (2014) also states that it is not possible to attribute changes in drought frequency in North America to climate change.

Sea level rise resulting from climate change is projected to continue during the 21st century, at a rate faster than observed from 1971 to 2010. The projected increase in sea level for the period 2081–2100, relative to 1986–2005, is 0.45 to 0.82 meters with medium confidence under the scenario RCP8.5 (IPCC AR5 2014). Sea level rise is expected to occur in more than 95 percent of the ocean area by the end of the 21st century, although it will not be uniform across regions (IPCC AR5 2014). About 70 percent of the coastlines worldwide are projected to experience a sea level change within ±20 percent of the global mean (IPCC AR5 2014). A rise in sea level will likely create more estuarine areas and push the salt wedge farther upstream; this will likely impact any water intake structures located in the newly estuarine areas and may also increase the potential for salt water to enter aquifers (U.S. Global Research Group 2004). Saltwater intrusion will stress the availability of water in the southeast. The IPCC AR5 (2014) states that in the Southeast, ecosystems and irrigation are projected to be particularly stressed by decreases in water availability due to the combination of climate change, growing water demand, and water transfers to urban and industrial users. Existing water allocation issues could be exacerbated, potentially stressing water quality. However, it is unknown how Alabama shad may be affected by sea level rise in the future.

Most observations of climate change responses in species involve alterations in phenology (Parmesan 2006). Phenology is the study of how seasonal and interannual variations in the environment affect the timing of critical stages and events in a species' life cycle (Anderson *et al.* 2013). Phenological shifts attributed to climate change have been identified in both terrestrial and aquatic biota (Ellis and Vokoun 2009). In the marine ecosystem, the most important physical factors affecting phenology are water temperature and light, with the response to and importance of each factor being species dependent (Anderson *et al.* 2013). Importantly, climate change affects temperature but not photoperiod or light, which is key when considering the environmental cues that trigger species' migrations.

For marine species, climate-driven changes in temperature can modify the phenology of annual migrations to spawning grounds (Pörtner and Peck 2010). Seasonal temperature increases have been shown to correlate with changes in the timing of fish movement, with shifts towards earlier migrations of anadromous fish (Quinn and Adams 1996, Juanes *et al.* 2004) and earlier annual spawning events (Ahas and Aasa 2006). The importance of temperature in regulating the behavior and dynamics of *Alosa* species during spawning has been documented in several reviews (Aprahamian *et al.* 2010, Mettee and O'Neil 2003, Quinn and Adams 1996).

Ellis and Vokoun (2009) compared temperature records with fish surveys for anadromous alewives in several southern New England streams back to the 1970s. They determined that 13 °C was a consistent predictor of spawning run timing for alewives in one historical and three recent stream studies over several years. They found that stream temperatures in the spring warmed to 13 °C about 12 days earlier in recent years than they did in the 1970s. Ellis and Vokoun (2009) concluded alewife runs occur about 12 days earlier on average than they did in the 1970s.

Aprahamian *et al.* (2010) used a stock-recruitment model with a temperature component to estimate the effects on twaite shad (*A. fallax*) in the Severn Estuary in Great Britain from an increase in temperature resulting from climate change. They determined a 1 °C increase in water temperature would shift the spawning run into the River Severn 6–10 days earlier, and a 2 °C would shift the spawning run 16–17 days earlier. Aprahamian *et al.* (2010) also predicted that a 1–2 °C temperature increase would result in an increase in twaite shad abundance, likely through increased hatching success and growth rate.

Quinn and Adams (1996) identified shifts in spawning migrations in another *Alosa* species, American shad, in response to changes in temperature. Records show that annual spring warming has occurred progressively earlier in the Columbia River since 1950. Fish counts from Bonneville Dam indicate that the peak migration of American shad, introduced into the river in the late 1800s, occurs approximately 38 days earlier than it did in 1938 and correlates with the warming trend. Quinn and Adams (1996) also looked at the timing of sockeye salmon (*Oncorhynchus nerka*), and noted that while the species' upriver migration is 6 days earlier than it was in 1949, that period lags behind the rate of environmental change. Quinn and Adams (1996) state that salmon migration is primarily controlled by population-specific responses to cues such as photoperiod (a factor not affected by climate change) rather than species-specific responses to temperature (a factor that is affected by climate change), as may be the case in shad.

The differences in the environmental cues triggering spawning migration, as well as the life history differences, between shad and salmon highlight how species may be affected differently by climate change. A species with close links between the environments experienced by spawning adults and their offspring (*e.g.,* spawning within the migratory corridor and a brief larval period) should behaviorally adjust the timing of migration and spawning to optimize conditions for both the adult and the offspring in response to environmental variation. Shad spawn in the river mainstem and have a brief incubation period (Quinn and Adams 1996). Spawning adult shad experience conditions that will be closely correlated to those affecting survival of their offspring during incubation and hatching. In contrast, when greater spatial and temporal separation occur between the environmental conditions experienced by migrating adults and their offspring, as is the case with salmon, genetic control over the timing of their spawn is greater than the response to environmental cues. This can result in a decoupling of cues that initiate migration (*e.g.,* photoperiod, which is not affected by climate change) and the state of the target habitat that can be affected by climate-sensitive factors, such as temperature, flow, DO, etc. In some Pacific salmon species, such as sockeye, migration into freshwater may precede spawning by several months, fry emergence by many months, and the time of seawater entry by juveniles by a year or more (Groot and Margolis 1991). These salmon move through a mainstem migratory corridor that is separate from the spawning and incubation areas in tributaries that may be subjected to different thermal and hydrological regimes. The ability of *Alosa* species to shift the timing of their spawning migrations in response to temperature, and the close spatial and temporal proximity of habitats occupied by spawning adults and newly spawned offspring, likely buffer Alabama shad from some aspects of climate change.

Climate change may also disrupt the timing between the life cycles of predators and prey (Parmesan 2006). The presence of both the predators of Alabama shad and their prey sources may be shifted temporally or spatially due to climate change. Also, changes in water temperature could impact prey production, with greater production in warmer years (Aprahamian *et al.* 2010). Year-class strength in American shad has been shown to be positively correlated with zooplankton density, as shown by an increase in the percentage of larval fish with food in their guts (Aprahamian *et al.* 2010). However, ocean currents, fronts, and upwelling and downwelling zones play significant roles in the distribution and production of marine ecosystems, and it is not yet predictable how these features are likely to change in response to alterations in temperature, precipitation, runoff, salinity, and wind (Scavia *et al.* 2002). Little is known about predators of Alabama shad, in either the marine or riverine environment. It is unknown how phenological shifts brought on by climate change may affect interactions between Alabama shad, their predators, and their prey.

In summary, under the RCP8.5 scenario, there could be a 2.6–4.8 °C temperature increase by the end of the 21st century (2081–2100) relative to 1986–2005. However, current temperature trends indicate that warming has been less pronounced and less robust in the Southeast United States. Within North America, the Southeast United States is predicted to have the smallest changes in mean annual temperature (IPCC AR5 2014). Little to no changes in precipitation that could increase runoff are predicted within the range of Alabama shad. Sea level rise resulting from climate change is projected to continue during the 21st century, at a rate faster than observed from 1971 to 2010. However, it is unknown how Alabama shad may be affected by sea level rise in the future. The IPCC AR5 (2014) states that in the Southeast, ecosystems and irrigation are projected to be particularly stressed by decreases in water availability due to the combination of climate change, growing water demand, and water transfers to urban and industrial users. Existing water allocation issues could be further exacerbated, potentially stressing water quality. Most observations of climate change responses in species involve alterations in phenology, the study of how seasonal and interannual variations in the environment affect the timing of critical stages and events in a species' life cycle (Parmesan 2006, Anderson *et al.* 2013). For marine species, climate-driven changes in temperature can modify the timing of annual migrations to spawning grounds, which has been observed in other *Alosa* species. Studies on American shad (Quinn and Adams 1996), alewives (Ellis and Vokoun 2009), and twaite shad (Aprahamian *et al.* 2010) demonstrated that those species were able to shift their spawning migrations earlier to adapt to warmer temperatures occurring earlier in the year. A comparison of responses to climate change in American shad and salmon showed that the behavioral responses of adult shad to warming temperatures (*i.e.,* earlier spawning migrations) should optimize conditions for both the adults and the offspring, as there is less spatial and temporal separation between the environmental conditions experienced by migrating adults and their offspring in shad compared to salmon (Quinn and Adams 1996, Groot and Margolis 1991).

However, it is unknown how spatial and temporal changes in migration in Alabama shad may affect both their predator and prey relationships. Ultimately, it is unknown how climate change may contribute to the current and foreseeable risk of extinction of Alabama shad.

Deep Water Horizon Oil Spill

On April 20, 2010, while working on an exploratory well in the Gulf of Mexico (approximately 50 mi southeast of the Mississippi River Delta, Louisiana, and 87 mi south of Dauphin Island, Alabama), the semi-submersible DWH drilling rig experienced an explosion and fire. The rig subsequently sank, and oil and natural gas began leaking into the Gulf of Mexico. The well was temporarily capped on July 15, 2010, which significantly reduced the amount of leaking oil, but the well was not ultimately sealed and declared ''effectively dead'' until September 19, 2010. Estimates on the amount of released oil varied widely and over time, but final official estimates indicated 53,000–62,000 barrels were released per day as a result of the event; the total amount of oil released into the Gulf of Mexico was estimated at 4.9 million barrels (780,000 m^3) (McNutt *et al.* 2011). In addition, approximately 2.1 million gallons of chemical dispersant were applied to surface waters (1.4 million gallons) and directly at the wellhead (0.77 million gallons) between May 15 and July 12, 2010 (Kujawinski *et al.* 2011).

There have been no studies of the effects of the DWH spill on Alabama shad and no reports or collections of shad affected by the spill. Chakrabarty *et al.* (2012) estimated that the DWH spill zone overlapped with 1.26 percent of Alabama shad's nearshore habitat. This estimate is based on the percentage of the species' historical collection records that occur within the spill zone. Because few historical records for Alabama shad exist in some Gulf Coast systems, and almost no data exist for Alabama shad in the marine environment, the estimate by Chakrabarty *et al.* (2012) is likely an underestimate of the overlap of the DWH spill zone with habitat used by Alabama shad. However, it does confirm that Alabama shad may have been exposed to oil or chemical dispersants associated with the DWH spill.

Fish exposed to oil can be impacted directly through uptake by the gills, ingestion of oil or oiled prey, effects on egg and larval survival, or changes in the ecosystem that support the fish (USFWS 2010). Adult fish may experience reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproductive impairment when exposed to oil (USFWS 2010, Snyder *et al.* 2015). Oil has the potential to impact spawning success as the eggs and larvae of many fish species are highly sensitive to oil toxins (USFWS 2010).

There have been no studies on the effects of the DWH spill on Alabama shad. Based on their life history, it is likely that the earliest and most vulnerable life stages (eggs and larvae) were not exposed to oil and dispersants. The oil spill occurred in April when females are upriver, releasing their eggs at spawning sites. Over the summer, as oil recovery and cleanup was occurring, the newly spawned Alabama shad larvae were in their riverine habitats maturing. Alabama shad from northern rivers start the downstream migration toward marine waters in late summer. In comparison, shad from Gulf Coast river systems have been observed to stay upriver as late as December. Therefore, it is likely some juvenile and non-spawning adult Alabama shad were exposed to oil and dispersants associated with the DWH spill, but not the actively spawning adults and early life stages.

Polycyclic aromatic hydrocarbons (PAH) are considered the most toxic component of crude oil to marine life and are ubiquitous pollutants in the marine environment (Snyder *et al.* 2015). Exposure to PAHs has been linked with a variety of sublethal effects in fish, including DNA damage, internal and external lesions, gill and organ abnormalities, reduced adult fitness, altered and reduced growth, decreased fecundity, and reduced survival to maturity (Snyder *et al.* 2015). Red snapper (*Lutjanus campechanus*) sampled since 2013 show spatial variation in tissue concentrations of PAH metabolites (Snyder *et al.* 2015). Red snapper caught closer to the Mississippi River and the DWH spill area had higher PAH metabolite concentrations than snapper caught on the west Florida shelf. Additionally, the red snapper caught near the Mississippi River showed a decrease in PAH metabolite concentrations over time, indicating an exposure event to elevated PAHs that dissipated over time. Meanwhile, the snapper from the west Florida shelf showed no decrease in PAH metabolites over time, suggesting they were not exposed to elevated PAHs from the DWH spill. This indicates that the largest spawning population of Alabama shad, the population from the ACF River basin, and other populations in rivers that drain into the west Florida shelf may not have been exposed to oil and dispersants from the DWH spill, although this is uncertain.

Despite widespread contamination of offshore waters by the DWH spill and to a lesser extent, coastal waters, the results of a study by Moody *et al.* (2013) provided little evidence for large-scale acute or persistent oil-induced impacts on organisms that complete all or a portion of their life cycle within an estuary in Point-aux-Pins, Alabama. The abundance of resident estuarine species declined significantly following the DWH spill, but returned to pre-spill abundances by 2011. There was no significant decline in the abundance of transient species (those that only spent a portion of their life cycle in the estuary), even though transient species were more likely exposed to oiling in the marine environment. Moody *et al.* (2013) concluded that despite the presence of localized oiling in coastal habitats outside Louisiana, the most severe oil impacts were largely relegated to the deep sea. Fodrie and Heck (2011) reviewed pre- and post-DWH fish data collected by trawl surveys in nearshore seagrass habitats from Louisiana to Florida. They concluded that immediate, catastrophic losses of 2010 year classes of marine organisms were largely avoided, and that no shifts in species composition occurred following the DWH spill. Fodrie and Heck (2011) also noted that there is increasing evidence that the acute impacts of the DWH spill may be concentrated in the deep ocean rather than shallow-water, coastal ecosystems where Alabama shad are known to occur.

Little is known about Alabama shad in the marine environment, even though the species spends the majority of its life there. We considered the potential for effects to the species from the DWH spill by looking at studies of other offshore species. Rooker *et al.* (2013) looked at abundance and occurrence of the larvae of four deep-ocean species in relation to the DWH spill: Blackfin tuna (*Thunnus atlanticus*), blue marlin (*Makaira nigricans*), dolphinfish (*Coryphaena hippurus*), and sailfish (*Istiophorus platypterus*). They determined that both the abundance and percent occurrence declined in 2010 for all four species relative to the 3 years prior to the DWH oil spill, suggesting that changes in environmental conditions, possibly linked to the presence of oil and dispersants, may have contributed to observed inter-annual variability. The most conspicuous 2010 declines were seen in billfish (blue marlin and sailfish) larvae. Given these larvae are typically restricted to surface waters compared to the other taxa surveyed (blackfin tuna and dolphinfish), it is possible their exposure to DWH toxic compounds affected early life survival. However, Rooker *et al.* (2013) also note that inter-annual variability of larval abundance and distribution is relatively common for pelagic larvae in the Gulf of Mexico. Part of the apparent decline in billfish, dolphinfish, and tuna larvae therefore may be due to shifts in biological or oceanographic conditions and not entirely attributable to the DWH oil spill.

In summary, there are no data indicating Alabama shad were directly affected by the DWH spill. The spill occurred in April when the most vulnerable early life stages of Alabama shad were in riverine areas and it is unlikely they were directly exposed. The older juveniles and adults that entered coastal and nearshore waters in late summer through winter may have been exposed to toxins from the DWH spill, but studies of other coastal species indicate recovery occurred the following year. It is likely that the worst acute effects of DWH were experienced further offshore in the marine environment. Although we have almost no information on the marine portion of Alabama shad's life cycle, it is doubtful this smaller anadromous species spends a significant portion of its life cycle far offshore like the large oceanic species (*e.g.,* tuna and billfish). We ranked exposure to oil and other toxins from the DWH spill, on its own, as having a low risk of contributing to the extinction risk of Alabama shad. It is unknown whether the DWH spill will contribute to the extinction risk of Alabama shad in the foreseeable future.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Small commercial fisheries for Alabama shad once existed in Alabama, Arkansas, Kentucky, Indiana, Ohio, and Iowa (Adams *et al.* 2000, Daniels 1860). Based on existing records, Alabama shad populations have never supported an important or sizeable commercial or recreational fishery, at least since the 19th century (NMFS *et al.* 2012). Buchanan *et al.* (1999) reported that a ''limited'' commercial fishery existed in the Mississippi River system in the late 1800s. Only small catches of the species have been recorded for a few years in the statistical reports of the U.S. Fish Commission (Hildebrand 1963). The total reported commercial landings of Alabama shad were 3,165 kg (6,978 pounds) in 1889 (Hildebrand 1963). The U.S. Fish Commission Report for 1901 reported that a total of 3,154 kg (6,955 pounds) of the ''newly described species'' of ''Ohio'' shad (a species later determined to be the same species as Alabama shad) were caught in the Ohio River in West Virginia, Indiana, and Kentucky, valued at $355 (Townsend 1902). The report stated that the species had likely been caught in that river for a ''number of years.'' The 1901 report stated there was no catch of ''Ohio'' (Alabama) shad in Alabama, Arkansas, Illinois, Iowa, Kansas, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, Ohio, South Dakota, Tennessee, and Wisconsin. The following year (1902), Hildebrand (1963) reported Alabama shad landings of 68 kg (150 pounds) from Alabama, with no commercial landings reported since. Hildebrand (1963) noted that Alabama shad were still numerous enough in Kentucky and Ohio to be taken in considerable quantities, but were undesirable for human consumption, and no attempts were made to catch and sell them. Coker (1930) stated that there were enough ''Ohio'' (Alabama) shad at the Keokuk Dam in Iowa in 1915 to support a substantial fishery, but that none developed, and ''a few'' have been taken commercially from the Ohio River. Coker (1930) observed that ''Ohio'' (Alabama) shad in the Mississippi River had no economic value at that time. The FFWCC (McBride 2000) notes that even though there have been significant fisheries for other *Alosa* species like American shad, hickory shad (*A. mediocris*), and blueback herring, a fishery for Alabama shad never developed in Florida. McBride (2000) also states that recreational fishing for Alabama shad began around 1950 but has not developed significantly. There are currently no directed fisheries for Alabama shad in any U.S. waters (Smith *et al.* 2011). Mills (1972) noted that striped bass fishermen used Alabama shad as bait. NMFS *et al.* (2012) reported that fishermen occasionally catch Alabama shad in the Apalachicola River below JWLD for bait to use while fishing for striped bass or flathead catfish (*Pylodictis olivaris*). Some Alabama shad are also collected for scientific research and for educational purposes. However it is unlikely that past or present collection or harvest (utilization) of Alabama shad for commercial, recreational, scientific, or education purposes, alone or in combination with other factors, has contributed significantly to the species' extinction risk. Further, given the lack of the sizeable harvest in the past, we do not anticipate the development of new fisheries or that directed harvest levels will otherwise increase in the future. Therefore, collection or harvest of Alabama shad is unlikely to significantly contribute to the species' extinction risk in the foreseeable future.

C. Disease and Predation

Most of the Alabama shad collected during research and monitoring associated with JWLD conservation locking activities in 2013 had large, open sores or gash-like wounds, in some cases exposing organs and bone (Sammons 2013; S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014). These sores or wounds were not observed on other fish species collected (*e.g.,* gizzard shad [*Dorosoma cepedianum*] and mullet [*Mugil* spp.]), indicating Alabama shad are either more susceptible to the source of the wounds or they are distributed in areas that the other species are not (Sammons 2013). The wounds were only observed on adult Alabama shad and not on younger fish, indicating the source may have occurred in the Gulf of Mexico (Sammons 2013). A researcher attending the 2014 JWLD Fish Passage Year-End Summary Meeting suggested that the pictures of the Alabama shad sores or wounds looked similar to symptoms of a disease that occurred in blueback herring on the Atlantic Coast. The 12-month listing determination for alewife and blueback herring (78 FR 48944; August 12, 2013) states that mycobacteria, which can cause ulcers, emaciation, and sometimes death, have been found in many Chesapeake Bay fish, including blueback herring. Alabama shad with the wounds generally appeared to be in poor condition and suffered higher than normal mortality due to handling and tag insertion (Sammons 2013). Sammons (2013) also cited a news article reporting gash wounds on fish potentially associated with the Deepwater Horizon Oil Spill resembling the wounds found on Alabama shad. It is unknown what caused the sores or wounds in Alabama shad in the ACF River system and what percentage of the population may have been impacted. The sores have not been observed in any of the ~200 Alabama shad captured since 2013 (T. Ingram, Georgia DNR, pers. comm. to K. Shotts, NMFS, June 6, 2016). It is unknown whether disease is contributing to the species' extinction risk.

Little information is available regarding predation on Alabama shad in freshwater systems and no information regarding predation in marine environments (NMFS *et al.* 2012). Like other clupeids, Alabama shad are likely prey for piscivorous fishes, such as striped bass (Pattillo *et al.* 1997). NMFS *et al.* (2012) noted that birds of prey (bald eagles and osprey) have been observed eating Alabama shad from the Apalachicola River. There is no available information suggesting Alabama shad populations are significantly affected by predation. It is unlikely that predation, alone or in combination with other factors, is significantly contributing to Alabama shad's extinction risk.

D. Inadequacy of Existing Regulatory Mechanisms

Regulations on Harvest of Alabama Shad

The harvest or collection of Alabama shad is not regulated in Federal waters, although the legal authority exists, and regulations could be implemented as necessary through the Magnuson-Stevens Fishery conservation and Management Act. A variety of protective regulations exist in the states within the species' historical range (NMFS *et al.* 2012), although there are currently no directed fisheries for Alabama shad in any U.S. waters (Smith *et al.* 2011). Since January 1, 1997, hook-and-line has been the only allowable fishing gear for *Alosa* species in the State of Florida, with a limit of 10 shad (as an aggregate of Alabama, American, and hickory shad) for both recreational and commercial fishermen (Chapter 68B–52.001 of the Florida Administrative Code). In Louisiana, recreational regulations limit the taking of shad species (unspecified) to 50 pounds (22.7 kilograms) per day, with no size limit (NMFS *et al.* 2012). Alabama shad are not listed as a game fish in the Mississippi Department of Wildlife fishing regulations and may be taken as bait with dip/landing net, cast net, boat mounted scoop, or wire basket by resident anglers with the appropriate fresh or salt water recreational fishing license for personal use during sport fishing (NMFS *et al.* 2012). Alabama shad is a protected species in both Alabama and Georgia, and may only be collected with a state-issued scientific collector's permit that specifies Alabama shad. No recreational or commercial harvest is permitted in either state (NMFS *et al.* 2012). Alabama shad are classified as non-game fish in Missouri and Arkansas, and there are no catch or possession limits.

Although there are no restrictions on the harvest of Alabama shad in marine waters, virtually nothing is known about the life history of the species in the marine environment and only 5 specimens have ever been recorded from marine waters. It is highly unlikely that fishermen or researchers would be able to successfully target the species in the marine environment. Harvest and collection of Alabama shad is restricted to varying degrees in Louisiana, Alabama, Georgia, and Florida, while no restrictions are in place in Mississippi, Arkansas, or Missouri. Under ''Overutilization for Commercial, Recreational, Scientific, or Educational Purposes'' (Factor B), we determined that it is unlikely that past or present collection or harvest (utilization) of Alabama shad has contributed significantly to the species' extinction risk. We also determined under Factor B that, given the lack of the sizeable harvest in the past, we do not anticipate the development of new fisheries or that directed harvest levels will otherwise increase in the future. Therefore, although harvest and collection of Alabama shad is regulated in some areas where the species occurs, but not in others, we believe that the existing laws are adequate to regulate the low levels of harvest and collection and are unlikely contributing to the extinction risk of Alabama shad.

Regulations on Dams

The Federal Power Act (FPA) (16 U.S.C. 791–828), as amended, provides for protecting, mitigating damages to, and enhancing fish and wildlife resources (including anadromous fish) impacted by hydroelectric facilities regulated by FERC. FERC must consult with state and Federal resource agencies on proposed hydroelectric projects and implement recommendations concerning fish and wildlife and their habitat, *e.g.,* including spawning habitat, wetlands, instream flows (timing, quality, quantity), reservoir establishment and regulation, project construction and operation, fish entrainment and mortality, and recreational access. FERC must also consult with Federal and state resource agencies to renew the operating licenses for existing dams and must address impacts to natural resources. Both NMFS and USFWS, and in certain cases, U.S. Federal land management agencies, prescribe mandatory fish passage conditions for inclusion in hydropower licenses. These agencies and state resource agencies also may make nonbinding recommendations for additional mitigation to promote fish protection (OTA 1995). Specific regulations in section 10(j) of the FPA provide that licenses issued by FERC contain conditions to protect, mitigate damages to, and enhance fish and wildlife based on recommendations received from state and Federal agencies during the licensing or license renewal process. With regard to fish passage, Section 18 of the FPA requires a FERC licensee to construct, maintain, and operate fishways prescribed by the Secretary of the Interior or the Secretary of Commerce. Section 18 also allows that a fishway prescription can be reserved to address impacts that become apparent in the future.

The presence of dams that block Alabama shad from accessing upstream spawning habitat is believed to be the primary cause of their decline in some river systems (NMFS *et al.* 2012, USFWS 2009a). The era of big dam building began in the 1930s, but slowed over time with the advent of environmental laws and alternative power sources (USBR 2015). The greatest rate of increase in reservoir storage occurred from the late 1950s to the late 1970s, with more dams (and some of the largest) built in the 1960s than in any other decade (Graf 1999). In the ''golden age'' of U.S. dam building, thousands of large and small dams were built with little thought to the environmental impacts (Doyle *et al.* 2003). While very few new dams have been constructed since 1980 (Graf 1999), FERC continues to renew licenses under the FPA for existing dams due to expiring licenses, modifications to power generating capabilities, or no prior license because the dam was constructed pre-FPA. FERC's initial mandate under the FPA of 1920 was the regulation of energy production, distribution, and availability; and the promotion of hydropower (OTA 1995). Environmental concerns were largely addressed through a number of laws that were enacted (some much later than the original FPA) to protect natural resources and the environment, including: the Fish and Wildlife Coordination Act (1934), Wild and Scenic Rivers Act (1968), National Environmental Policy Act (1970), Federal Water Pollution Control Act/Clean Water Act (1972/1977), and the Endangered Species Act (1973; OTA 1995). In 1986, Congress passed the Electric Consumers Protection Act (ECPA), a series of amendments to the FPA, which was designed, in part, to place greater emphasis on environmental considerations in licensing decisions. The FPA, as amended by ECPA, directs FERC to give equal consideration to the full range of purposes related to the potential value of a stream or river, including energy conservation, fish and wildlife resources (including spawning grounds and habitat), and other aspects of environmental quality in addition to hydropower development. Although mandatory fish passage authority rested with the Federal resource agencies since the early part of this century, the ECPA was instrumental in elevating the importance of non-developmental values in and increasing FERC's accountability for licensing decisions (OTA 1995). Through the addition of section 10(j), Federal and state resource agencies may recommend conditions to protect, enhance, or mitigate for damages to fish and wildlife resources under the FPA.

FERC licenses have a term of 30 to 50 years, so NMFS' involvement in the licensing process to ensure the protection and accessibility of upstream habitat, and to improve habitat degraded by changes in water flow and quality from dam operations, may only occur 2–3 times a century for a particular project. However, an estimated 85 percent of the dams in the United States will be near the end of their operational lives by 2020 (Doyle *et al.* 2003). The current intensification of economic and environmental concerns is coinciding with a policy window in which many private dams are coming up for regulatory re-licensing with FERC (Doyle *et al.* 2003). Alabama shad may benefit from fishway requirements under section 18 of the FPA when prescriptions are made to address anadromous fish passage and during the re-licensing of existing hydroelectric dams when anadromous species are considered. Mitigation technologies to reduce the adverse effect of hydropower on the nation's fish resources have been employed, although not consistently, since the early 1900s; while their effectiveness is often poorly understood, in a review of 16 case studies, the majority demonstrated positive results for migratory fish stemming from technology implementation (OTA 1995). Decommissioning and/or removal of existing dam facilities as an alternative to relicensing has been raised more frequently since 1993 and as part of the movement toward greater scrutiny of the adverse impacts of hydropower plants on certain fish populations (OTA 1995). Lovett (2014) notes that 1,150 dams have been removed in the last 20 years. However, dam removal options are faced by a number of very real environmental, economic, and political constraints and, thus, are infrequently considered as alternatives to fish passage development.

The FPA does not apply to non-hydropower dams, such as those operated by USACE for navigation purposes. However, under Section 7(a)(2) of the ESA, Federal agencies are required to consult with NMFS or USFWS on activities that may affect listed species. Dam maintenance, repairs, and operational changes may require ESA Section 7 consultation and allow conservation measures benefitting listed species to be recommended or required. Alabama shad may also benefit from the conservation measures implemented for other species with similar needs or in similar habitats. USFWS (2007) completed a biological opinion under Section 7 of the ESA on USACE's drought operations for the Interim Operating Plan for JWLD in the ACF system. While that biological opinion did not evaluate Alabama shad it did analyze effects to Gulf sturgeon and three species of mussels (fat threeridge, purple bankclimber, and Chipola slabshell). USFWS (2007) determined that while there were likely to be some adverse effects to the mussels, the drought operations are not likely to jeopardize the continued existence of any of the species or destroy their critical habitat. Because Alabama shad have similar water quality and quantity requirements to Gulf sturgeon, the conservation efforts for the sturgeon likely benefit shad. Federal agencies may also choose to use their authorities and resources for the conservation of species.

In two river systems inhabited by Alabama shad, the ACF and Alabama River systems, USACE has voluntarily cooperated with state and Federal agencies to implement conservation locking for Alabama shad and other anadromous species. In 2012, the "cooperator" organizations (USACE, USFWS, NMFS, Georgia DNR, FFWCC, and TNC) signed a Memorandum of Understanding (MOU) clarifying their commitments and responsibilities in the continued implementation of fish passage at JWLD. In Part B. of the MOU, "Statement of Mutual Benefit and Interests", the cooperator organizations agree to: (1) Provide mutual assistance, share information and technology, and coordinate efforts for fish passage, (2) discuss a strategy for providing passage at JWLD for the conservation and restoration of migratory fishes in the ACF River Basin, consistent with authorized project purposes, (3) initiate and participate in a JWLD Fish Passage Partnership and discuss yearly fish passage operation for migratory fishes at JWLD. Collaborate, assist, and support research, monitoring, outreach, and related activities for determining the effects of fish passage on migratory fish populations and habitats at JWLD and the ACF River Basin, (4) foster partnerships that support the passage of migratory fishes in Georgia and Florida among state agencies, federal agencies, and the public within the ACF River Basin, and (5) designate a Partnership Coordinator from one of the cooperators in order to facilitate the partnership and fulfill the purpose of the MOU. The Partnership Coordinator shall provide a report of the annual fish passage operations, results, and related activities to all cooperators.

In fulfillment of the cooperation outlined in the MOU, an annual meeting to discuss the issues and outcomes from the previous spring conservation locking cycle is held, usually in the early part of the following year (*i.e.,* January or February). Powerpoints presented at the meeting, data summaries, reports to funding agencies, and journal articles or other publications resulting from research in the ACF are provided to cooperators and interested parties, satisfying the annual reporting noted in #5 of Part B. of the MOU. At the annual meeting, the cooperators and other interested parties (*e.g.,* universities that are not signatories to the MOU, but are heavily involved in research activities associated with the conservation locking in the ACF) discuss lessons learned from the previous year and participate in planning the next cycle of spring conservation locking, including whether the locking operation and schedule can be improved. For example, during the planned maintenance on the lock that occurred during the 2013–2014 season, the cooperators were able to upgrade the method of delivering the attractant flow (a stream of high velocity water used to attract spawning fish) from a manual system to an electric pump as a more efficient way to direct shad through the lock when conservation locking resumed (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014).

Although the MOU does not require implementation of conservation locking at JWLD, USACE had demonstrated a commitment to continuing conservation locking. The current operations considered in developing alternatives for the updated USACE Master Water Control Manual (FEIS; December 2016) includes standard operating procedures for conservation locking at the JWLD to benefit Alabama shad. All alternatives considered in the FEIS included conservation locking. The FEIS indicates that in most years since the spring of 2005, USACE has operated the lock at JWLD between March and May to facilitate downstream-to-upstream passage of Alabama shad in cooperation with pertinent state and federal agencies. In general two fish locking cycles are performed each day. While studies are ongoing to determine the most appropriate technique and timing for the locks, the number of lock cycles per day will not change (FEIS 2016).

The presence of dams that block Alabama shad from accessing upstream spawning habitat is believed to be the primary cause of their decline in some river systems. The purpose of the original FPA of 1920 was the regulation of energy production, distribution, and availability, and the promotion of hydropower, and dams were built with little or no regard for the environmental consequences. The adverse environmental effects, including effects to anadromous fish species, were largely unaddressed until the 1970s with the enactment of several major environmental laws. However, the FPA itself was amended by the ECPA in 1986, which directed FERC to give equal consideration to environmental issues. The FPA, through Section 18 and 10(j), provides opportunities to implement conservation measures at existing dams. Although some dams are not subject to the FPA, other mechanisms exist to achieve conservation measures in addition to fish passage at non-FPA dams (Section 7 consultation and voluntary efforts such as conservation locking). Therefore, we ranked the inadequacy of existing dam regulations as having a low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

Regulations Associated With Water Quality

The Federal Water Pollution Control Act, and amendments (FWPCA) (33 U.S.C. 1251–1376), also called the ‘‘Clean Water Act,’’ mandates Federal protection of water quality. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants. Section 404 of the FWPCA prohibits the discharge of dredged or fill material into navigable waters without a permit. The main responsibility for water quality management resides with the states in the implementation of water quality standards, the administration of the National Pollutant Discharge Elimination System (NPDES) program (where the state has received EPA approval to do so), and the management of non-point sources of pollution. Section 303(d) of the Clean Water Act requires states to identify waters that do not meet or are not expected to meet water quality standards. Each state develops Total Maximum Daily Loads (TMDLs) for its water quality-limited waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various point and non-point sources of that pollutant. Section 402 of the Clean Water Act created a system for permitting wastewater discharges. Collectively the NPDES sets specific limits on discharge of various types of pollutants from point-source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into streams. Efforts to reduce non-point pollution currently rely on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Water quality has been cited as a threat to Alabama shad (Mettee and O'Neil 2003, Mettee *et al.* 1996). We reviewed the water quality assessment reports for rivers occupied by Alabama shad submitted by individual states to the EPA under Sections 305(b) and 303(d) of the Clean Water Act. The assessment reports prepared by the states show that water quality in approximately half of the river mi within the species' current range is deemed to be good. The remaining areas are impaired for one or more reasons, including the presence of heavy metals, low DO, impaired biota, sedimentation, and the presence of other organic and inorganic contaminants. Further a comparison of NCCR I–IV, published by the EPA in 2001, 2005, 2008, and 2012, shows a pattern of overall improving water quality in the Gulf of Mexico, with the overall condition improving from NCCR I to IV. Contaminant loads in sediments and in fish tissue also improved from ‘‘poor'' to ‘‘fair.'' The DO content of coastal waters in the Gulf Coast has remained ‘‘good'' in all four reports. Based on this recent record of performance, regulatory mechanisms governing water quality are at a low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

Regulatory Mechanisms for Climate Change

Greenhouse gas emissions are regulated through multi-state and international agreements, and through statutes and regulations, at the national, state, or provincial level. One of the key international agreements relevant to attempts to control greenhouse gas emissions, the Copenhagen Accord, was developed in 2009 by the Conference of Parties to the United Nations Framework Convention on Climate Change. The Copenhagen Accord identifies specific information provided by Parties on quantified economy-wide emissions targets for 2020 and on nationally appropriate mitigation actions to help achieve the goal of capping increasing average global temperature at 2 °C above pre-industrial levels. The last conference of the Parties to the United National Framework Convention on Climate Change was held in Lima, Peru, in December 2014. The resulting decisions from the meeting were primarily to continue ongoing efforts to reach a new agreement for emissions reductions to be adopted at the 2015 meeting in Paris, France, and to have those implemented by 2020. The new agreement would maintain the same overall goal as the Copenhagen Accord, to cap additional warming at 2 °C.

Within the United States, President Barack Obama released the President's Climate Action Plan in June 2013. The plan is three-pronged, including proposed actions for mitigation, adaptation, and international leadership. The actions listed for mitigation include completing carbon pollution standards for new and existing power plants, accelerating clean energy permitting, increasing funding for clean energy innovation and technology, increasing fuel economy standards, increasing energy efficiency in homes, businesses, and factories, and reducing other greenhouse gas emissions including hydrofluorocarbons and methane. The plan states that the United States is still committed to reducing greenhouse gas emissions 17 percent below 2005 levels by 2020 if all other major economies agree to similar reductions. Additional efforts made domestically related to climate change are more focused on facilitating adaptation to the impending changes to the environment due to climate change in order to maintain the country's natural and economic resources, but do not directly address the emission of greenhouse gas.

National and international efforts to limit climate change are ambitious, but their success is uncertain since major agreements are still being formulated, and the outcomes of ongoing activities are not yet known. Likewise, the effects of climate change on Alabama shad and their habitat are also not yet known. However, climate change predictions by the IPCC (IPCC AR5 2014) suggest that temperature increases throughout the range of Alabama shad of 1.5–2.5 °C by the mid-21st century may be less than other areas in North America (2.5–4 °C by the mid-21st century), even with no additional efforts to constrain greenhouse gas emissions. Flooding and drought are not attributable to climate change, and the IPCC predicts little to no change in average annual precipitation within the range of Alabama shad through 2065, although the predictions are less certain for the remainder of the 21st century (IPCC AR5). Sea level rise associated with climate change may salinize groundwater and decrease freshwater availability, exacerbating existing water allocation issues. Regulatory mechanisms addressing water allocation issues (discussed in the following section) are likely to have as much immediate impact on this issue as regulatory mechanisms addressing the causes of sea level rise. It is unknown how regulations addressing climate change may contribute to Alabama shad's extinction risk, either now or in the foreseeable future.

Regulatory Mechanisms Associated With Water Allocation

It is unknown whether water allocation issues contribute to Alabama shad's extinction risk. Regulations associated with water allocation are both an intra- and inter-state issue. Within a state's borders, state laws determine rights to use water (CBO 2006). In the East, water rights are formed under riparian doctrine, meaning ownership of land adjacent to a body of water (riparian land) conveys the right to use the water in a way that is reasonable (Ruhl 2003, CBO 2006). Determining what is reasonable involves consideration of the purpose of the use, the suitability of the use to the body of water, economic and social values of the use, the extent of harm caused, the practicality of avoiding any harm by adjusting the methods or quantities of use, and the fairness of making the user who causes harm bear losses (CBO 2006). In practice today, owners of riparian land must obtain permits from a state agency to use water. Permits may also be available to others who do not own riparian land. The charters incorporating most cities give them power to procure water for public purposes and to supply the domestic needs of their residents, and states have modified the riparian doctrine by introducing exceptions that allow municipal uses (CBO 2006).

In Georgia, the 15-county Metropolitan North Georgia Water Planning District was created through legislation to manage the water supply and its consumption for economic, environmental, and social well-being. The Metropolitan North Georgia Water Planning District prohibits the inter-basin transfers of water from outside the district to meet water supply demands within the district (Cole and Carver 2011). The Metropolitan North Georgia Water Planning District encompasses the Atlanta metropolitan area, the most populous area in Georgia and the ninth largest metro area in the U.S. Therefore, regulations that limit inter-basin transfers would benefit Alabama shad by limiting the amount of water removed from rivers within their range. Georgia's Board of Natural Resources adopted an instream flow policy in 2001 that ensures the minimum flows required to protect aquatic habitat, such as that for Alabama shad, are maintained downstream of new water withdrawals (Cole and Carver 2011). In Florida, when determining whether the public interest is served by a transfer of groundwater from one water district to another, or surface water from one county to another, the governing board or department must consider an array of factors, including the potential environmental impacts (Cole and Carver 2011). The State of Florida statutes require local governments to consult with water suppliers to ensure that adequate water supplies will be in place and available to serve a new development by the time the local government issues the development's certificate of occupancy (Cole and Carver 2011). In addition to state laws governing water allocation, many states within the range of Alabama shad also have state water plans that are intended to be comprehensive strategies for the long-term management of water resources on a watershed basis. Georgia, Florida, Missouri, and Arkansas have state water plans in place, and Alabama and Louisiana have draft plans. The state plans vary in detail and goals, but generally attempt to balance economic, public health, and environmental needs. Water planning that considers environmental needs, such as downstream habitat for fish, are likely to benefit Alabama shad because it increases the likelihood that adequate water flows will be available.

When water allocation issues arise between states, there are generally three ways to resolve the issue. States can enter into a compact agreeing to a division of resources, which would then require congressional approval (Ruhl 2003). Second, the commerce clause of the Constitution gives Congress the authority to allocate interstate waters to serve the national interest, even if doing so means overriding state law (Ruhl 2003, CBO 2006). The third option is for states to take their dispute to the U.S. Supreme Court, which can exercise its jurisdiction to arrive at an equitable apportionment of the water (Ruhl 2003).

The major water allocation issues affecting Alabama shad are between Alabama, Georgia, and Florida over use of water in the ACT and ACF River basins. SELC (2015b) documented the following history of the dispute, which ensued in 1989 after USACE recommended reallocation of water from reservoirs in the ACT and ACF basins to supply the Atlanta, Georgia, metro area. Alabama sued USACE, stating they had ignored environmental impacts on the downstream states and breached their duty to benefit all downstream users. Florida intervened on the side of Alabama, and Georgia and metro Atlanta municipalities intervened or initiated their own lawsuits against USACE for not allowing the reservoirs to serve current and future water supply needs. The lawsuit was put on hold to allow the three states and USACE to negotiate a resolution, conduct comprehensive studies, and create a structure that would allow the states to work together. Each state passed a compact, and they were ratified by Congress in 1997. However, agreement could not be reached, the compacts expired without resolution in 2003 and 2004, and the states went back to court. The litigation continued for over a decade. In 2009, a judge ruled that Lake Lanier (part of the ACF basin) was not authorized to supply water to metro Atlanta. The ruling was reversed by the 11th Circuit Court of Appeals and after the U.S. Supreme Court subsequently declined to hear the case, the litigation was temporarily suspended. Currently at the U.S. Supreme Court is a case brought by Florida against Georgia alleging harm to Apalachicola Bay resulting from Georgia's disproportionate use of water from the ACF River system.

We evaluated water allocation issues under the ''Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range'' (Factor A). Transferring water from one river basin to another can alter natural water flows in both the originating and receiving basins, and exacerbate any existing water quality issues. It is not known how much water is already being removed and transferred from rivers used by Alabama shad. The biggest interstate allocation dispute is occurring in Alabama, Florida, and Georgia over the future allocation of water in the ACF and ACT River basins. While the outcomes of water allocation and the regulatory mechanisms governing it are unknown, the Alabama shad population in the ACF continues to be the largest known spawning population, and conservation locking is occurring in both the ACF and ACT basins to reduce the effects of dams, the primary threat to the species in both systems. Under Factor A, we determined that it is unknown whether water allocation issues contribute to Alabama shad's extinction risk, either now or in the foreseeable future. It is also unknown whether the regulatory mechanisms for managing water allocation in Alabama shad's riverine habitat are adequate or whether they are contributing to the species' extinction risk, either now or in the foreseeable future due to the complexity of the issue, the length of time (more than 25 years) the issue has persisted, and the inability of the major stakeholders to come to agreement or final decision. However, state and Federal agencies and an environmental organization (USACE, USFWS, NMFS, Georgia DNR, FFWCC, and TNC) did achieve agreement in the signed 2012 MOU for a cooperative fish passage strategy at JWLD that it was to their mutual interest and benefit to coordinate efforts for fish passage for the conservation and restoration of migratory fish, such as Alabama shad, in the ACF River Basin.

Other Regulatory Mechanisms Affecting Alabama Shad

Other ESA listings and critical habitat designations for species within the range of Alabama shad may also promote the conservation of Alabama shad. For instance, Gulf sturgeon, listed under the ESA as threatened in 1991 (56 FR 49653), inhabit many of the same rivers along the Gulf of Mexico as Alabama shad. Critical habitat for Gulf sturgeon was designated in 2003 (68 FR 13370). The primary constituent elements of Gulf sturgeon critical habitat include habitat elements that are also important for shad (*i.e.,* abundant food items, riverine spawning sites, riverine aggregation areas, flow regime, water quality, sediment quality, and safe and unobstructed migratory pathways). Measures to improve habitats and reduce impacts to Gulf sturgeon may directly or indirectly benefit Alabama shad. Both species are anadromous; adults spawn in freshwater in the spring and early summer then migrate back into estuarine and marine waters. Many of the habitats that Gulf sturgeon occupy are also habitats that Alabama shad use for spawning, migration, and juvenile rearing. Therefore, protection measures for Gulf sturgeon, such as improved fish passage and water quality, or reduction of water withdrawals, may also provide a benefit to Alabama shad. Passage for sturgeon species, although less studied, has become more of a priority in recent years (Kynard *et al.* 2008), while passage technologies are considered to be well developed and well understood for the main anadromous species, including *Alosa* species (Kynard *et al.* 2008, Larinier and Marmulla 2004). Sturgeon species are known to be more highly sensitive than most other species to water quality problems, such as low DO and contaminants (Niklitschek and Secor 2009a, 2009b, Dwyer *et al.* 2005). Because Alabama shad are likely easier to pass through fish passages and are less susceptible to water quality problems, it is reasonable that measures to improve fish passage and water quality for Gulf sturgeon will apply to Alabama shad, as well.

Alabama shad in the ACF River system have been found to be the host for the larvae of an ESA-listed freshwater mussel (S. Herrington, The Nature Conservancy, pers. comm. to K. Shotts, NMFS, JWLD Fish Passage Year-End Summary Meeting, January 2014). The purple bankclimber, a freshwater mussel listed as threatened under the ESA (63 FR 12664), is potentially one of the species using Alabama shad to transport larvae upstream. Critical habitat for the purple bankclimber and other listed freshwater mussels has been designated in the ACF River system (72 FR 64286), and the primary constituent elements include a geomorphically stable stream channel, stream substrate with low to moderate amounts of silt and clay, permanently flowing water, water quality, and fish hosts that support the larval life stages of the seven mussels. Conservation actions to benefit the purple bankclimber mussel could potentially protect both the Alabama shad and its habitat. For example when the USFWS consulted on the drought operations for the Interim Operating Plan for JWLD in 2007, they considered effects to the purple bankclimber. Reasonable and prudent measures required by USFWS (2007) during drought operations that may benefit Alabama shad include (1) adaptively managing operation of the system using information collected on species and their habitats, upstream water use, and climatic conditions, (2) increasing the lower threshold for reservoir storage from 8,000 to 10,000 cubic feet per second (*i.e.,* increasing flows in downstream areas by limiting reservoir storage during low flow times), (3) modifying the operation plan to provide higher minimum flow to the Apalachicola River when conditions permit, and (4) evaluating the sediment dynamics and channel morphology in the Apalachicola River to allow better prediction of the effects of operations on species in the riverine environment.

Thus, other ESA listings and critical habitat designations, are unlikely contributing to the extinction risk of Alabama shad. Overall, harvest and collection of Alabama shad are adequately controlled through the state regulations. Regulatory mechanisms governing water quality appear to be having success, although water quality is still impaired in some areas throughout the Alabama shad's range. The outcomes of state, Federal, and international laws governing dams, water allocation, and climate change, and their adequacy in protecting Alabama shad and their habitat, are unknown. Therefore, we ranked the inadequacy of regulatory mechanisms overall as having a low risk of contributing significantly to the current and foreseeable risk of extinction for Alabama shad.

E. Other Natural or Manmade Factors Affecting Its Continued Existence

Bycatch, the incidental catch of a species in fisheries targeting another species, is a potential threat to Alabama shad in the marine environment. Although there are no reports of Alabama shad being taken as bycatch in fisheries, many fisheries lack comprehensive bycatch monitoring (Harrington *et al.* 2005, Crowder and Murawski 1998). While bycatch in shrimp trawls is a significant source of mortality for many finfish in the Southeast, no *Alosa* species were recorded during mandatory observer reporting from the Gulf of Mexico shrimp trawl fishery in 2007–2010 (Scott-Denton *et al.* 2012). Guillory and Hutton (1982) surveyed incidental catch in the Louisiana Gulf menhaden (*Brevoortia patronus*) purse seine fishery in 1980 and 1981 by taking samples at processing plants. Total bycatch comprised 2.68 percent by number and 2.35 percent by weight of the menhaden catch. While no Alabama shad were found in the bycatch, another *Alosa* species, the skipjack herring, made up 0.1 percent both by number and weight of the overall bycatch. Hutchings and Reynolds (2004) stated that clupeids are more resilient than other fish in the marine environment, attributed in part to their reduced vulnerability to bycatch. There are no reports of Alabama shad being taken as bycatch in fisheries, although we have no information on life history or location of Alabama shad within the marine environment and much bycatch goes unreported. It is unknown whether incidental capture in other fisheries contributes to Alabama shad's extinction risk, either now or in the foreseeable future.

Conclusions on Extinction Risk of Alabama Shad Throughout Its Range

The presence of dams throughout the Alabama shad's range blocks access to upstream spawning sites in many rivers and is believed to be the primary cause of population decline in the species. While there are little historical or current data quantifying declines in Alabama shad, we believe that the species' abundance is reduced from historical levels. We believe both low abundance and the presence of dams are the greatest threats to Alabama shad and ranked both as posing moderate risks to the species. We noted these factors could, in combination with other factors, contribute significantly to their risk of extinction. In this section, we consider these factors in combination with other relevant demographic factors and threats to determine whether synergistic effects would result in a significantly greater extinction risk for Alabama shad to the extent that the species' persistence is at risk.

The abundance of Alabama shad in many river systems is considered to be low. However, we have estimates of current abundance from only one river system and we do not have any historical abundance estimates of Alabama shad, which can be indicative of abundance levels associated with low extinction risk. However, populations may also be at low risk of extinction at abundance levels below historical levels, and accurate estimates of historical abundance are not essential for evaluating extinction risk. Whether a species qualifies for listing under the ESA depends on whether the species is in danger of extinction or likely to become so within the foreseeable future as a result of one or more of the factors described in section 4(a)(1) of the ESA. If a species is viable at its current population levels into the foreseeable future, it is irrelevant whether that population level is or is not close to its historical levels. We believe the low abundance of Alabama shad is offset by the high productivity and spatial distribution of the species, which is believed to be stable. We ranked productivity and spatial distribution as having a low probability of posing an extinction risk to the species. Alabama shad are highly productive, reaching spawning age at 1–2 years, and spawning multiple times during a single spawning season, as well as potentially throughout their lifetime. The nine known Alabama shad spawning populations are widely distributed, ranging from Gulf Coast rivers and their tributaries, from the Suwannee River, Florida, to the Mississippi River, including Lower Mississippi tributaries in the Midwest.

Although some of these spawning populations are small, this wide geographic distribution of spawning populations increases the resiliency of the species, reducing its vulnerability to catastrophic events such as storms, disease, or manmade threats, which usually occur at smaller scales. The short generation time for the species also adds to its resiliency, allowing it to take advantage of suitable habitat conditions for reproduction. The spawning success of Alabama shad in the ACF River system illustrates this ability to take advantage of newly available spawning habitat made accessible through conservation locking at JWLD.

Alabama shad are anadromous and generally return to their natal rivers to spawn. While the genetic diversity of Alabama shad is low, likely due to natural bottleneck events that occurred during the Pleistocene, we ranked diversity as having a low probability of posing an extinction risk to the species. The bottleneck is believed to have reduced their genetic load (presence of harmful genes) and genetic analyses indicate the species strays into other river systems to spawn at a greater rate than most anadromous species. This higher rate of straying into other river systems, combined with the species' high productivity and ability to take advantage of suitable environmental conditions, along with the wide spatial distribution of the spawning populations increases the species resilience and could allow individuals to enhance smaller river populations and repopulate river systems that have experienced declines or extirpations.

Existing dams continue to block access by Alabama shad to upstream habitat, although few new dams are being built today. Under ''Inadequacy of Existing Regulatory Mechanisms'' (Factor D), we ranked the inadequacy of regulatory mechanisms regulating dams, primarily the FPA and ESA, as posing a low risk of extinction to the species. The FPA provides for protecting, mitigating damages to, and enhancing fish and wildlife resources, including anadromous fish, impacted by hydroelectric facilities regulated by the FERC. The FPA does not apply to non-hydropower dams, such as those operated by USACE for navigation purposes, but maintenance, repairs, and operational changes may require ESA section 7 consultation and allow conservation measures benefitting Alabama shad and other species to be recommended or required. In two river systems inhabited by Alabama shad (the ACF and Alabama River systems), USACE has voluntarily cooperated with state and Federal agencies to implement conservation locking for Alabama shad and other anadromous species. Conservation locking in the Alabama River, occurring since 2009, has only been coupled with stocking and monitoring since 2014, and any benefits to the species are not expected to be evident for a few years. Conservation locking in the ACF River system has had success. The abundance of Alabama Shad in the ACF has been variable, but higher in many of the years, since locking began. Also, a study by Schaffler *et al.* (2015) reported that 86 percent of Alabama shad were spawned above JWLD after conservation locking began. Even more compelling is a genetic study (Schaffler *et al.* 2015) that shows 86 percent of the spawning adult Alabama shad in the ACF were spawned in the Flint River, which has only become accessible with the recent conservation locking. In light of the inter-agency cooperation with other entities noted above in the discussion of the ACF system, we expect conservation locking to continue at JWLD. Although dams exist in other river systems, spawning populations of Alabama shad have persisted in a number of those systems notwithstanding the presence of obstacles to passage, as shown in range maps and discussed above.

We also evaluated water quality and the adequacy of regulations governing water quality in combination with the moderate threats of low abundance and the presence of dams, because water quality is often cited as a concern for Alabama shad and dams may affect water quality. Dredging and land-based activities (agriculture, silviculture, and industrial, commercial, and residential development) can also result in degraded water quality in rivers and coastal waters inhabited by Alabama shad. We looked at state water quality reports, required by Sections 305(b) and 303(d) of the Clean Water Act, for river systems inhabited by Alabama shad spawning populations. Of the assessed river mi, about half were deemed to have good water quality and half were impaired. Low DO, mercury, impaired biota, and sedimentation were listed as the primary impairments, although there are no known studies linking these impairments to effects in Alabama shad or indicating that the species is susceptible to effects from these impairments. We reviewed the EPA's NCCR I–IV reports, which show that the overall condition of the Gulf Coast region is fair and coastal water quality in the Gulf of Mexico has improved since 2001. We ranked water quality as having an unknown probability of posing an extinction risk to the species. We ranked the inadequacy of regulations governing water quality as having a low probability of posing an extinction risk to the species, as landmark laws such as the Clean Water Act have successfully worked to improve and maintain water quality in aquatic habitats supporting Alabama shad. We do not believe water quality or the inadequacy of regulations governing water quality, alone or in combination with other factors, are contributing significantly to the extinction risk of Alabama shad.

Other known threats ranked as posing an unknown, unlikely, or low risk of extinction to Alabama shad include climate change, direct harvest, bycatch, and the regulatory mechanisms governing these and other threats. National and international efforts to stem climate change are ambitious, but their success is uncertain since major agreements are still being formulated, and the outcomes of ongoing activities are not yet known. The effects of climate change on Alabama shad and their habitat are also uncertain, although based on the species' life history and evidence from responses by other *Alosa* species to temperature shifts, we believe there is a low probability of this factor contributing significantly to the extinction risk of Alabama shad. Data and literature suggest that harvest of Alabama shad, either directly for commercial, recreational, or scientific purposes or as incidental bycatch, is unlikely to contribute to the extinction risk of Alabama shad and existing regulatory mechanisms are adequate to control harvest. Additionally, environmental regulations, such as the FWCA and the ESA listing and critical habitat designations for other species are likely benefitting the species. We do not believe climate change, direct harvest, bycatch, and the regulatory mechanisms governing these and other threats, alone and in combination with other factors, are contributing significantly to the extinction risk of Alabama shad.

We were unable to rank the contribution of water allocation and the adequacy of regulatory mechanisms governing it, DWH, and disease and predation to the extinction risk of Alabama shad. Water allocation issues are a growing concern in the Southeast United States. One of the biggest interstate allocation disputes is ongoing between Alabama, Florida, and Georgia over the future allocation of water in the ACF and ACT River basins. The complexity of the issue, the length of time (more than 25 years) that the water allocation issue remains unresolved, and the inability of the major stakeholders to come to agreement or final decision, as well as the fact that we do not know whether or how Alabama shad may be affected by water allocation issues, leads to great uncertainty about the adequacy of regulatory mechanisms for managing water allocation in Alabama shad's riverine habitat. While the outcomes of water allocation and the adequacy of the regulatory mechanisms governing it are unknown, the Alabama shad population in the ACF continues to be the largest known spawning population, and conservation locking is occurring in both the ACF and ACT basins to alleviate the effects of dams, the primary threat to the species in both systems. There is no evidence that Alabama shad were affected immediately after the DWH oil spill. Given that the spill occurred in April when the most vulnerable early life stages were in riverine areas, it is unlikely they were directly exposed. The more mature Alabama shad that entered coastal and nearshore waters following the DWH spill in late summer through winter may have been exposed to toxins from the DWH spill, but studies of other coastal species affected by the spill show that most recovered by the following year. It is likely that the worst acute effects were experienced further offshore in the marine environment and more studies will be necessary to determine any long-term, chronic impacts from the DWH spill. There are few data on disease and predation in relation to Alabama shad and it is unknown whether either factor is contributing to the species' extinction risk.

In summary, we did not identify any demographic factors or threats that are likely or highly likely to contribute significantly to the Alabama shad's risk of extinction. We conclude that the greatest threats to Alabama shad, low abundance and the presence of dams, pose a moderate threat to the species. However, these threats, alone and in combination with other factors, do not pose a significant risk of extinction. Other demographic factors that pose a low likelihood of contributing to extinction risk, and potentially offset the threats of low abundance and dams, include the species' high productivity, wide spatial distribution, and genetic evidence that the presence of harmful genes has been reduced and genetic transfer between spawning populations is likely occurring at a greater rate than for most anadromous species. While dams originally led to declines in Alabama shad, the lack of new dam construction, the adequacy of regulations governing new and existing dams, and ongoing conservation efforts also reduce the effects of dams on Alabama shad. We believe water quality, climate change, direct harvest, bycatch, and the inadequacy of the regulatory mechanisms governing these and other threats are not contributing, alone or in combination, to the extinction risk of Alabama shad. We evaluated other threats (water allocation issues, DWH, disease, and predation), but found there was not enough information or too much uncertainty in pending outcomes, to determine their contribution to the extinction risk of Alabama shad. Based on these conclusions, we find that the Alabama shad is at low risk of extinction throughout all of its range, now and in the foreseeable future.

Significant Portion of the Range Evaluation

The ESA definitions of ''endangered'' and ''threatened'' species refer to two spatial scales: A species' entire range or a significant portion of its range. We initially evaluated the extinction risk of Alabama shad throughout its entire range and found it to be low. So we must consider if a ''significant portion of its range'' is at higher risk, such that it elevates the entire species' status to endangered or threatened. However, this evaluation can only be conducted if a ''significant portion of its range'' where the species' status is more imperiled can be identified.

The USFWS and NMFS have jointly finalized a policy interpreting the phrase ''significant portion of its range'' (SPOIR) (79 FR 37578; July 1, 2014). The SPOIR policy provides that: (1) If a species is found to be endangered or threatened in only a significant portion of its range, the entire species is listed as endangered or threatened, respectively, and the ESA's protections apply across the species' entire range; (2) a portion of the range of a species is ''significant'' if the species is not currently endangered or threatened throughout its range, and the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction or likely to become so in the foreseeable future, throughout all of its range; and (3) the range of a species is considered to be the general geographical area within which that species can be found at the time we make any particular status determination. We evaluated whether substantial information indicated that (i) the portions may be significant and (ii) the species occupying those portions may be in danger of extinction or likely to become so within the foreseeable future (79 FR 37578; July 1, 2014). Under the SPOIR policy, both considerations must apply to warrant listing a species as threatened or endangered throughout its range based upon its status within a portion of the range.

We reviewed the best available information on Alabama shad and considered several relevant factors in identifying whether portions of the species' range may be significant: (1) Population abundance, (2) contributions to other populations, and (3) concentration and acuteness of threats. Based on these criteria, we initially identified only one population, the Alabama shad that spawn in the ACF River system, as potentially constituting a SPOIR. First, we considered population abundance. The Alabama shad population spawning in the ACF is believed to be one to several orders of magnitude larger than other spawning populations. Next we considered the potential contribution of the ACF spawning population to other populations. Genetic analyses indicate that Alabama shad spawn in systems other than their natal system at a rate of about 10 migrants per year. Because the spawning population in the ACF River system is large relative to other systems, migrants from the ACF may make greater contributions as compared to shad from smaller populations. The loss of the largest spawning population of Alabama shad would leave only smaller populations of Alabama shad and could make the species as a whole less resilient to environmental perturbations, including catastrophic events. Finally, we looked at concentration and acuteness of threats. While the majority of threats to Alabama shad are neither concentrated nor acute in specific portions of the species' range, the ACF River system is one of two river systems within the range of Alabama shad that we identified as being threatened by water allocation issues.

We initially identified the spawning population of Alabama shad in the ACF River system as being potentially significant under the SPOIR policy because (1) it is believed to be the largest spawning population by one to several orders of magnitude, (2) it could contribute to the viability of the species as a whole because of its large relative size and potential role in enhancing other river populations through outmigration, and (3) the threat of water allocation issues is concentrated in the ACF River system. We did not identify any other SPOIRs since (1) we do not have abundance estimates for any other Alabama shad populations, although they are believed to be at least one order of magnitude smaller than the ACF population, (2) we do not have information that another population is making significant contributions to other populations, and (3) we did not identify any other populations that were differentially experiencing concentrated nor acute threats compared to other populations.

Following the SPOIR policy, we next evaluated whether the species occupying this portion of the range may be in danger of extinction or likely to become so within the foreseeable future. In our evaluation of the status of the species range-wide, we determined that none of the demographic risks or threats contribute, alone or in combination, to extinction risk for Alabama shad to the extent that the species' persistence is at risk. We believe this conclusion also applies to the Alabama shad in the ACF River system. We did identify the threat of water allocation as being concentrated in the ACF River system. As with the range-wide evaluation, we were unable to rank the contribution of water allocation, as we do not have information that water allocation is affecting Alabama shad, or the adequacy of regulatory mechanisms governing it to the extinction risk of Alabama shad in ACF, due to the complexity of the issue, the length of time (more than 25 years) that the water allocation issue remains unresolved, and the inability of the major stakeholders to come to agreement or final decision. While the outcomes of water allocation and the regulatory mechanisms governing it are unknown, upstream water withdrawals for public use have been occurring for over 25 years during which time the Alabama shad population in the ACF has persisted. The ACF population of Alabama shad continues to be the largest known spawning population. The abundance of Alabama shad in the ACF has been variable, but generally higher since conservation locking was undertaken, alleviating the effects of dams, the primary threat to the species in the system. The genetic study by Schaffler *et al.* (2015) shows that 86 percent of the spawning adult shad were spawned upstream of JWLD in newly available habitat in the Flint River, which was inaccessible prior to conservation locking.

We were able to model and quantify the resilience of Alabama shad from the ACF River system since it is the most studied population with the most available data, including the only population abundance estimate. Smith *et al.* (2011) conducted a population viability analysis (PVA) of Alabama shad in the ACF River system that estimated the future size and risk of extinction of Alabama shad. The results of any PVA are not an absolute predictor of what will happen to a population or a species; rather, a PVA is a tool to explore potential consequences of management actions in light of an uncertain future.

Using a sex-specific (females only), age-structured model, Smith *et al.* (2011) used data from the literature (*e.g.,* age at maturity, annual spawning period, natural mortality, carrying capacity, available habitat, frequency of drought, and anthropogenic mortality) and projected changes in population size over time under different scenarios (*e.g.,* varying mortality, survivorship, carrying capacity, and density dependence). Each modeled scenario was run 10,000 times to provide estimates of the range of possible values under the stochastic conditions specified. Smith *et al.* (2011) reported the estimated number of females returning to the ACF as the proportional increase or decrease in the population after 20 years from the initial population size (12,400 females). Quasi-extinction rates were measured as the probability of fewer than 420 females returning at least 1 year over 20 years. The number of females (420) used to initiate the model was taken from Ely *et al.* (2008; lower 95 percent confidence limit) as the approximate lowest population size, since historical population sizes of Alabama shad in the ACF River system are not available.

In most scenarios (15 out of 20), the PVA revealed positive proportional change in mean abundance from initial abundance and averaged about 250 percent for these positive scenarios (Smith *et al.* 2011). In 2 scenarios, the population abundance was relatively stable over the 20-year time period. In 3 scenarios, there was an overall decrease in population abundance after 20 years. The baseline model (*i.e.,* no anthropogenic mortality, density dependence affecting all vital rates, current carrying capacity of 75,687 females) predicted the population would increase to 23 percent of carrying capacity after 5 years and 37 percent after 10 years (Smith *et al.* 2011). When introducing potential mortality from downstream passage through dams under different scenarios, the number of females was still 16–37 percent of carrying capacity in 10 years. Only one scenario resulted in a 50-percent or higher probability of reaching quasi-extinction in 14 years (median time) during the 20-year projection (Smith *et al.* 2011). The remaining scenarios with population declines (scenarios m and s) did not drop below the quasi-extinction level more than 50 percent of the time.

While Smith *et al.'*s (2011) PVA cannot predict precisely the population size of the Alabama shad population in the ACF River system in the future, it demonstrates that Alabama shad populations are highly resilient and will likely increase, even when faced with anthropogenic induced mortality and drought, under all but the most dire conditions. While available information suggests the spawning population of Alabama shad in the ACF may be significant, we do not find that the species within this portion of its range is in danger of extinction nor do we believe it is likely to become so in the foreseeable future. Consequently, we are unable to identify a SPOIR for Alabama shad that would change the listing determination relative to the status of the species range-wide.

Listing Determination

Section 4(b)(1) of the ESA requires that NMFS make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account those efforts, if any, being made by any state or foreign nation, or political subdivision thereof, to protect and conserve the species. We have independently reviewed the best available scientific and commercial information on Alabama shad, including the petition, public comments submitted on our 90-day finding, and other published and unpublished information. We considered each of the section 4(a)(1) factors to determine whether it presented an extinction risk to the species. We found that the risk of extinction to Alabama shad throughout its entire range was low. We could not identify a SPOIR that was both significant and where the species' status is threatened or endangered. Therefore, our determination is based on a synthesis and integration of the foregoing information, factors, and considerations, and their effects on the status of the species throughout its entire range. We conclude that the Alabama shad is not presently in danger of extinction, nor is it likely to become so in the foreseeable future, throughout all or a significant portion of its range, and that listing as threatened or endangered is not warranted.

Peer Review

In December 2004, the Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review establishing minimum peer review standards, a transparent process for public disclosure of peer review planning, and opportunities for public participation. The OMB Bulletin, implemented under the Information Quality Act (Pub. L. 106–554) is intended to enhance the quality and credibility of the Federal government's scientific information, and applies to influential or highly influential scientific information disseminated on or after June 16, 2005. To satisfy our requirements under the OMB Bulletin, we obtained independent peer review of our review of the status of Alabama shad, including our extinction risk analysis. Three independent specialists were selected from the academic and scientific community, Federal and state agencies, and the private sector for this review. All peer reviewer comments were addressed prior to dissemination of the publication of this 12-month determination. The peer review comments can be found at: *http://www.cio.noaa.gov/services_programs/prplans/ID322.html*.

References

A complete list of all references cited herein is available at: *http://sero.nmfs.noaa.gov/protected_resources/listing_petitions/species_esa_consideration/index.html*.

Authority

The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Dated: January 5, 2017.

Samuel D. Rauch, III,

Assistant Administrator for Regulatory Programs, National Marine Fisheries Service.

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