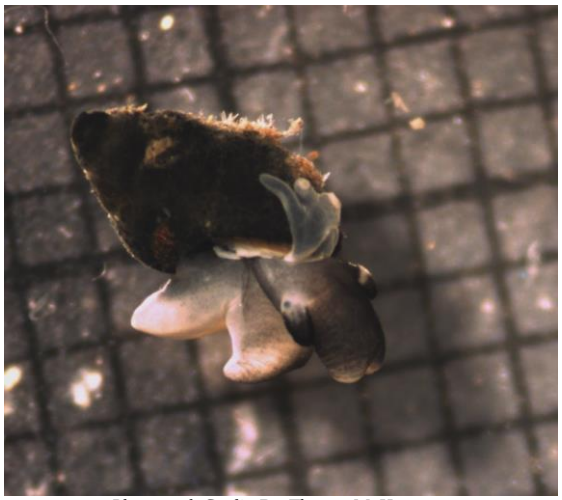
Armored Snail
Pyrgulopsis (=Marstonia) pachyta

5-Year Review:
Summary and Evaluation



Photograph Credit: Dr. Thomas M. Haggerty

U.S. Fish and Wildlife Service
South Atlantic-Gulf Region
Alabama Ecological Services Field Office
Daphne, Alabama

5-YEAR REVIEW

Armored Snail / *Pyrgulopsis* (*=Marstonia) pachyta*

I. GENERAL INFORMATION

A. Methods used to complete the review:

We announced initiation of this review in the *Federal Register* on May 7, 2018 (83 FR 20092) and opened a 60-day comment period. No public comments were received. The primary sources of information used in this analysis were the 2000 final listing rule (65 FR 10033), the 2010 five-year review (USFWS 2010), peer-reviewed reports, unpublished survey data and reports, and personal communication with recognized experts. This review was completed by the Alabama Ecological Services (ES) Field Office, Daphne, Alabama (lead recovery biologist Evan Collins with assistance from Erin Padgett). All literature and documents used for this review are on file at the Alabama ES Field Office. All recommendations resulting from this review are the result of thoroughly reviewing the best available information on the armored snail. The Appendix provides a brief summary of the peer-review method.

B. Reviewers

Lead Region:

Atlanta, Georgia: Aaron Valenta (404) 679-4144

Lead Field Office:

Alabama ES Field Office, Daphne, Alabama: Evan Collins (251) 441-5837
Erin Padgett (251) 441-5842

C. Background

a. Federal Register Notice citation announcing initiation of this review: 83 FR 20092. May 7, 2018

b. Species Status: The species continues to be found in the habitat it occupied at the time of listing. It has also been found in sites not known to be occupied at the time of listing. Furthermore, rapid urban growth, infrastructure development, and the presence of potential competitors expose the species to new stressors in addition to historical stressors.

c. Recovery achieved: 1 (1 = 0-25% species' recovery objectives achieved) A slight improvement has been observed due to the

expansion of the species known occupied range. However, this increase in the extent of occupied habitat improves population resiliency only slightly in the face of landscape level habitat alteration and interactions with novel competitors.

d. Listing history:

Original Listing
FR notice: 65 FR 10033
Date listed: February 25, 2000
Entity listed: Species
Classification: Endangered

e. Associated rulemakings: None

f. Review History:

Each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2006, we did a recovery data call that included population status recommendations such as "stable" for this snail. We continue to show that species status recommendation as part of our 5-year reviews.

Five-year Review: September 22, 2010
We did not recommend a change in the listing status of this snail in 2010 primarily due to the threats of habitat destruction and modification continuing throughout its limited range**.**

g. Species' Recovery Priority Number at start of 5-year review (48 FR 43098): 5.

The number indicates:
Degree of Threat: High
Recovery Potential: Low
Taxonomy: Species

h. Recovery Plan or outline

We are in the process of drafting a recovery plan this fiscal year and anticipate announcing it later this year.

II. REVIEW ANALYSIS

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

The Act defines species as including any subspecies of fish, wildlife, or plant, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPSs to only vertebrate species of fish and wildlife. Because the species under review is an invertebrate, the DPS policy is not applicable and will not be addressed further in this review.

B. Recovery Criteria

a. Does the species have a final, approved recovery plan containing objective, measurable criteria?

No. A technical draft recovery plan was prepared for the armored snail in 1994 (prior to the snail's listing in 2000) and is available at: https://ecos.fws.gov/docs/recovery_plan/940701.pdf. However this document is not a final, approved recovery plan.

C. Updated Information and Current Species Status

a. Biology and Habitat

a) Biology and Life History:

The armored snail is endemic to watersheds in northern Alabama (Figure 1). It appears to be most abundant in submerged root masses and bryophytes (non-vascular plants, e.g. mosses) along the creek edges, but also may occur on rocks and leafy or woody debris, and on other aquatic macrophytes (vascular aquatic plants) (Garner 2004a, Haggerty and Garner 2007, 2008).

It is a small species of snail, typically measuring less than 4 millimeters (mm) (0.15 inches (in)) in length (Thompson 1977 and Garner 2004a). The snail is typified by its shell's ovate-conical shape and complete peristome (lip around the aperture of the shell) (Thompson 1977). The pronounced thickness of the shell is another distinct characteristic for the species (Thompson 1977).

It has long been held that the armored snail has an annual life cycle like other similar species in its family (Haggerty and Garner, 2008). Starting in 2011 through 2012, Haggerty and Garner (2013) conducted research to test this hypothesis. A total of 3,245 armored snails were collected over the course of 15 months from Limestone Creek near the crossing at County Road 44 (Haggerty and Garner 2013). An apparent die-off of large individuals was observed during this study and supported the annual life cycle hypothesis (Haggerty and Garner, 2013). However, analysis of the shell lengths measured monthly showed two recruitment events one peaking in April and May and a secondary recruitment event in late August/September (Haggerty and Garner 2013). Haggerty and Garner (2013) gave three possible explanations for the evidence of the two, distinct reproductive events within the confines of an annual life cycle. The first explanation involves the

presence within Limestone Creek of two populations of morphologically similar snail species, each with unique reproductive cycles (Haggerty and Garner 2013). The second explanation assumes only one snail population inhabiting the site and that this single population has two reproductive events per year (Haggerty and Garner 2013). The third explanation again involves a single population but posits that they have two distinct age groups which annually reproduce but at different times during the year (Haggerty and Garner 2013). *Marstonia arga*, a snail species that is superficially identical to the armored snail (*Marstonia pachyta*), was present at the study site but previously unreported in Limestone Creek (Haggerty and Garner 2013). None of the three explanations could be entirely confirmed or rejected. However, it is reasonable to infer that the two observed recruitment events are due to the presence of two species of *Marstonia* present in the study area.

The presence of *M. arga* in conjunction with *M. pachyta* was of great concern to Haggerty and Garner (2013). The long-term interactions between these populations in Limestone Creek is unknown but potentially threatening to the armored snail and, as such, worthy of continued monitoring (Haggerty and Garner 2013).

b) Abundance/population trends, demographic features or trends:

Haggerty and Garner (2007) estimated catch per unit effort (CPUE) in Limestone and Piney Creeks and found the armored snail in relatively good numbers where suitable habitat was present. Of the 13 Limestone Creek sites surveyed during that study, nearly 70% (9 sites) had the snail present, while Piney Creek had armored snails present at 3 of the 10 (30%) sites surveyed. All sites where snails were present contained approximately 10 to 50 individuals and a mean CPUE of 34 individuals/hour/observer (Haggerty and Garner 2007). Their research built upon surveys previously conducted by Garner in 1992 and 1993, and subsequently expanded the range of the armored snail in both Limestone and Piney Creeks (Haggerty and Garner 2007).

In 2007, AST Environmental Group (AST) was contracted by Athens Utilities to perform a protected species / biological assessment consisting of ten survey reaches in Piney Creek and Piney Creek tributaries, including French Mill Creek (a second order tributary to Piney Creek) (AST 2007). In August and September of 2007, they collected armored snails within five of six

Piney Creek sites and two of four French Mill Creek locations. Numbers of armored snails collected were similar to those of Haggerty and Garner (2007) in 2007, with all sites containing approximately 10 to 50 individuals.

As a result of the biological assessment and the ensuing formal consultation conducted with the Service, AST continued to monitor two of the Piney Creek survey sites in addition to two downstream armored snail relocation sites. Data from these four sites were used to extrapolate densities per square meter and are listed in Table 1 (AST 2014a, 2015, 2016, 2017). The dramatic changes in densities between 2016 and 2017 were attributed to changes in habitat (AST 2017). At the Piney Creek 1.4 site and its relocation site, a noticeable increase in filamentous algae was observed (AST 2017). Decreases at both Piney Creek 3.2 and the 3.2 relocation site were attributed to the conversion of habitat from pool-like to a riffle/run. With the increased stream velocities, the faster currents reduced the amount of filamentous algae in the area (AST 2017). As of 2018, the presence of juvenile armored snails was commonly noted; and, to date, no major changes in the snail populations have occurred at these AST survey sites (J. Selby, senior biologist with AST, pers. comm. 2018).

In addition, AST surveys in 2012 found a sizeable population of armored snail in Little Piney Creek at the Huntsville Browns Ferry Road crossing (AST 2012).

Since 2011, further AST monitoring events have also been conducted in the Limestone Creek watershed which have documented persistence of populations of the armored snail (AST 2011a, 2011b, 2016). Where found, the armored snail was generally described as common or abundant (AST 2011b, 2014b, 2016).

The armored snail's range was also extended into Little Limestone Creek in 2014 where they were found to be common on the filamentous algae mats (AST 2014b). Armored snail populations were reconfirmed here in 2017 (AST 2017).

See Figure 2 for the current known range of the armored snail in northern Alabama.

c) Genetics, genetic variation, or trends in genetic variation:

Research to clarify the relationship among species within the genus *Marstonia* was conducted collaboratively between the Alabama

Department of Conservation and Natural Resources and the Smithsonian Institution and using methods that analyzed genetics between the years 2011 and 2012 (Strong et al., n.d.). This study collected 121 individuals from Alabama, Tennessee, Georgia, and one site in Indiana (Strong et al., n.d.).

Johnson et al. (2013) recognize fifteen *Marstonia* species occurring in North America. Eleven of which are recognized from the geographic extent reviewed by Strong and others, including the armored snail (*Marstonia pachyta*). However, the analysis conducted by Strong and others suggested that only five valid species of *Marstonia* occurred in the geography of study. The study concluded that future research is still needed to clarify the relationships of *Marstonia* snails (Strong et al., n.d.). Therefore, taxonomic and systematic uncertainty is present within the genus. The report also stressed caution with field identification due to morphologic similarities between species in the *Marstonia* genus (Strong et al., n.d.). Thus, it is recommended to use genetic tools to validate field identifications.

d) Taxonomic classification or changes in nomenclature:

Thompson (1977) first described the armored snail as *Marstonia pachyta*, within the family Hydrobiidae, and distinguished this species of *Marstonia* from others by the characteristics of both its internal anatomy and shell. The armored snail has two apical glands on the verge (male copulatory organ), where other closely related Marstonia (i.e., *Marstona arga*) have a single apical gland (Haggerty and Garner 2008). The shell is readily identified by its ovate-conical shape, its shell thickness, and complete peristome. Other conical *Marstonia* tend to have a thinner and almost transparent shell, usually with an incomplete peristome (Thompson 1977, Hershler 1994).

In 1987, Hershler and Thompson reassigned the armored snail to the genus *Pyrgulopsis*. However, a subsequent study showed that eastern and western *Pyrgulopsis* were consistently differentiable based on anatomical characters (Thompson and Hershler 2002). Therefore, the eastern species of *Pyrgulopis* were placed in the genus *Marstonia* and diagnosed by a suite of internal and external morphological characters (Thompson and Hershler 2002).

At the time of listing, the armored snail was assigned the genus *Pyrgulopsis* and this nomenclature was used in our original listing determination (65 FR 10033). Since the current accepted nomenclature places the species as a member of the genus

Marstonia we intend to update the species' name under regulations pursuant to 50 CFR 17.11, which requires the publication of a rule in the *Federal Register*.

The armored snail is also variously referred to as armored marstonia and thick-shelled marstonia in literature (Garner 2004a).

e) Spatial distribution, trends in spatial distribution, or historic range:

The armored snail was first documented, in 1969, by Thompson (1977) in Limestone Creek, Limestone County, Alabama. Later surveys extended its range to Little Limestone, Piney, Little Piney, and French Mill creeks but it is believed that the Limestone and Piney Creek watersheds are the extent of its range (Haggerty and Garner 2008).

The drainage area of Limestone Creek is 144 mi^2 (373 km^2) and the main stem of the creek measures approximately 44.7 miles (72 km) in length. The snail is only known to occur within the lower 13 miles (21 km) of Limestone Creek that are not influenced by Wheeler Reservoir (Figure 2). The drainage area of Piney Creek is approximately 96 mi^2 (249 km^2), measures 38.5 miles (99.7 km) in length. Only the lower 8 miles (20.7 km) of Piney Creek are known to be occupied by the armored snail (Garner 2004a, Haggerty and Garner 2007). While snail populations remain viable in both Limestone and Piney creeks, it is more widely dispersed in Limestone Creek (Haggerty and Garner 2008).

In August and September of 2007, biologists with AST Environmental, collected armored snails from Piney Creek as well as French Mill Creek, a second order tributary of Piney Creek (AST 2007). AST reported finding armored snails in Piney Creek and French Mill Creek, south of U.S. Highway 72, in Limestone County, Alabama (AST 2007). These surveys extended the armored snail range to the lower 1.5 miles (3.88 km) of French Mill Creek.

In addition, AST surveys in 2012 found a robust population of armored snail in Little Piney Creek at the Huntsville Browns Ferry Road crossing (AST 2012). This survey extended the snails range into the first mile of Little Piney Creek.

In 2014, the armored snail was found to occur into the first 2 miles (5.17 km) of Little Limestone Creek, north of its confluence with Limestone Creek (AST 2014b, 2017).

In total, the armored snail is considered to occupy approximately 15 miles (24 km) of streams in the Limestone Creek watershed and approximately 10.5 miles (17 km) of stream in the Piney Creek watershed.

f) Habitat:

The armored snail is found and appears to be most common on submerged roots, leaves, and bryophytes along stream edges, submerged bryophytes growing on rocks in moderate current, and in water willow. They are also found in areas of slow to moderate flow in the submerged detritus, leaves, and tree rootlets along pool edges (Thompson 1977, Haggerty and Garner 2007, 2008). The presence of armored snails is highly correlated with filamentous algae mats (AST 2017).

The Limestone and Piney Creek watersheds lie within the Tennessee Valley District of the Interior Low Plateau Physiographic Province. The underlying geology in the two watersheds is primarily dominated by Tuscumbia Limestone in the lower reaches, and Fort Payne Chert in the middle and upper reaches. Some of the upper reaches within Limestone Creek also have exposed sediments of the Ordovician System (Haggerty and Garner 2008).

Haggerty and Garner (2007) characterized the general habitat conditions used by the armored snail at a total of four sites in Limestone and Piney Creeks with the following eleven physical and chemical measurements: stream width, stream depth, stream velocity, temperature, dissolved oxygen, dissolved oxygen percent saturation, specific conductance, total hardness, calcium hardness, magnesium hardness, and pH. Water quality data was also obtained by AST biologists for several Piney Creek and Limestone Creek locations (AST 2014a, 2015, 2016, 2017). Table 2 combines the water quality data gathered by both groups for the two watersheds. Haggerty and Garner (2007) noted that a more detailed analysis of the physiochemical parameters of the streams throughout the year is needed to accurately characterize current conditions, as well as specific measurements of the microhabitat.

D. Five-Factor Analysis

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

Urban growth and development continues to pose a threat to the armored snail. Expansion from the City of Huntsville and its annexation of lands in Limestone County has led to an increase in residential and industrial development near Limestone Creek. For instance, in January 2018, Mazda Motor Corporation and Toyota Motor Corporation announced a joint venture (aka MTMUS) to manufacture automobiles at a shared facility to be located between Beaverdam Creek and Limestone Creek, north of Old Highway 20, in the Greenbrier area of Limestone County, Alabama. The proposed automotive manufacturing facility is estimated to encompass approximately 2,400 acres of land that was historically in agriculture. This facility includes portions of the 2,010 acre plot of land previously designated as a TVA Megasite. Such a large scale development has the potential to encroach upon and degrade habitat on which the armored snail depends. However, at the time of this writing, all parties involved in this project (MTMUS and the City of Huntsville) have been coordinating with the Service to develop site plans that would be compatible with conservation of imperiled and listed species adjacent to the manufacturing facility. There have also been productive conversations between several third party conservation entities in the watershed that are actively working on conservation-based agreements that could benefit the armored snail. Other examples of urban growth potentially threatening armored snail habitat include water/sewer pipeline crossings, oil/natural gas pipeline crossings, bridge replacements and other infrastructure updates, commercial and residential building activity, discharge of fill material, and other point and nonpoint pollution discharges.

Analysis of land use/land cover (LULC) data from 2001 to 2016, reinforces this trend in habitat modification from urban encroachment. Figure 3 provides a categorical representation of LULC, Landsat imagery from 2016. The two watersheds that contain the known armored snail range, cover approximately 143,706 acres and are dominated by agricultural activities, natural landscapes, and commercialized land. Since 2001, the amount of land classified as forest and agricultural have declined, whereas acreage classified as developed and/or barren have steadily increased (Table 3).

While the agricultural footprint in the watersheds has decreased since 2001, pastures and farmland still cover approximately 61 percent of the watersheds making agriculture the dominant land type in the area (Table 3). Agriculture poses a potential threat to armored snail through pesticide

and fertilizer runoff, excessive water withdrawal and irrigation, and introduction of fine sediments into streams (Garner 2004b, Haggerty and Garner 2007). Little toxicological research has been done on snails in general (Johnson, et al. 2013) so the total ramifications of pesticide and fertilizer exposure on armored snail is not fully understood. This combined with the limited knowledge of the armored snail's environmental and physiological tolerances, hinders our ability to develop comprehensive management and recovery plans for the species (Johnson, et al 2013).

b. Overutilization for commercial, recreational, scientific, or educational purposes:

The armored snail is not known to have any commercial value and overutilization has not been a problem. Therefore, based on the best available data, overutilization is not believed to be a threat at this time. However, because this snail is believed to have a short life span and generally occurs in specific habitat, collection could be a threat to the small populations and disturb natural reproduction.

c. Disease or predation:

Diseases of aquatic snails are for the most part unknown. No predators are currently reported or known for the armored snail, though some fish, like redear sunfish (*Lepomis microlophus*), that coexist with the armored snail are known to predate on snails, and as such, may also forage on the armored snail. At this time, we do not believe disease or predation to be a significant factor threatening this species.

d. Inadequacy of existing regulatory mechanisms:

The armored snail is afforded protections through Section 7 and Section 9 of the Endangered Species Act (ESA). It is also afforded protection by the State of Alabama under their Invertebrate Species Regulation (Alabama Administrative Code 220-2-.98), which prohibits taking, capturing, killing, or attempting to take, capture, or kill; possession, selling, trading for anything of monetary value, or offering to sell or trade for anything of monetary value the species without a permit. While the armored snail may have species protections from both state and federal governments, people may be unaware of its presence and protected status, and fail to take any additional precautionary measures to aid in the recovery of this species unless they specifically contact the Service for technical assistance.

The Clean Water Act (CWA) is the primary federal law in the United States governing water pollution. The CWA regulates the point source discharge of pollutants to surface waters through the National Pollutant Discharge Elimination System (NPDES) the permit process**.** The NPDES permit process in Alabama has been delegated by the Environmental Protection Agency to the Alabama Department of Environmental Management (ADEM). Currently ADEM requires that discharges not exceed state water quality standard (Alabama Administrative Code, Title 22, Section 22-22-1 et seq.)

Since there is no information on this species' sensitivity to common pollutants, federal (e.g., CWA) and state water quality laws may or may not be protective of the armored snail.

Section 303d of the CWA requires each state to list its polluted water bodies and to set priorities for their clean up with a watershed restoration action plan called a "Total Maximum Daily Load" (TMDL) for each impaired water body. Under CWA's Section 303d, water quality impairment from mercury has been identified for Limestone Creek (ADEM 2018). Siltation TMDLs have also been developed for Limestone Creek (ADEM 2002). French Mill Creek has a TMDL for pathogens (fecal coliform) originating primarily from nonpoint sources (ADEM 2006). Since land in the Limestone Creek watershed is dominated by agricultural and forested areas, these nonpoint sources are believed to include runoff from pasture and animal operations, animal (both livestock and wild animal) access to streams, and improper application of animal waste to agricultural fields (ADEM 2006).

Section 404 under the Clean Water Act regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Any activities in waters of the United States are regulated under this program, and often include fill related to development, such as water resource projects, infrastructure development, and mining projects.

Section 26a of the TVA Act requires TVA's approval be obtained prior to the construction, operation, or maintenance of any dam, appurtenant works, or other obstruction affecting navigation, flood control, or public lands or reservations along or in the Tennessee River or any of its tributaries. Within the Limestone Creek drainage, TVA's Section 26a permits are usually applied for concurrently with the Army Corps of Engineers Section 404 permits.

While a single project (e.g., Section 404 or Section 26a permit) may have no effect or discountable or insignificant effects on the species and therefore not require formal consultation, the collective effects of such projects may result in more substantial and measurable effects on the

armored snail's finite habitat. Because these individual projects would not be evaluated or recorded through a formal consultation process with the Service, they are not typically included in a cumulative effects analyses. Therefore, these activities may have a broader impact on the species than is currently known.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is intended to protect against "unreasonable human health or environmental effects." While pesticides are usually tested on standard biological test model organisms (e.g., honey bees, daphnia, bluegill sunfish, rainbow trout, mice) for toxicity testing, this toxic information may not relate well to the armored snail. Commercial applicators must also be tested and permitted on the proper application of pesticides, but applicators may not necessarily be aware of the presence of the armored snail.

Regardless of the federal or state regulatory mechanism, enforcement of these regulations is necessary to provide the intended protections.

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

Climate change is also considered a potential threat to the armored snail. The Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) concluded that the warming of the climate is unequivocal (IPCC 2014). Numerous long-term climate changes have been observed including changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns, and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones (IPCC 2014). There is uncertainty about the specific effects of climate change (and its magnitude) on the armored snail; however, climate change is almost certain to affect aquatic habitats in their watersheds. Climate change has the potential to increase the vulnerability of the snail to random catastrophic events, primarily through more intense or frequent droughts. Droughts can potentially have negative impacts on water quality (e.g. dissolved oxygen) and waste dissemination of point source discharges. Droughts may also reduce the amount of habitat available to the snail by dewatering habitat, and may also lead to direct mortality by stranding snails. Drought may also isolate sections of stream into stagnate pools. In Alabama, moderate to extreme drought conditions were recorded in 26% of months between the years 2010 and 2019 and approximately 8% of the months in this time period were considered severe droughts (NOAA 2020).

Human-induced random events such as toxic spills within the drainage could also jeopardize the armored snail if pollutants are spilled within the drainage. The range of the armored snail is already limited to two main

creeks. A die-off associated with a spill could potentially reduce the occupied range by half.

The observed sympatry of the ghost marstonia (*Marstonia arga*) and armored snail was of great concern to Haggerty and Garner (2013) and presents a new threat not assessed at the time of listing. The long-term interactions between these species in Limestone Creek is unknown. However, there is potential for the ghost marstonia to out-compete the armored snail and eliminate it from portions of its range.

E. Synthesis

The armored snail continues to be in danger of extinction due to stressors occurring in its limited range and its habitat. Its range is limited to the Limestone Creek and Piney Creek watersheds, occupying approximately 15 miles (24 km) of streams in the Limestone Creek watershed and approximately 10.5 miles (17 km) of stream in the Piney Creek watershed. Because the armored snail is geographically isolated to these watersheds, catastrophic events such as spills or natural events (e.g. drought) could greatly reduce the geographic or genetic viability of the snail. Additionally, the presence of an introduced competitor (ghost marstonia) has the potential to have substantial negative effects on armored snail populations.

Agriculture continues to affect the quality of the streams this species inhabits as evidenced by sections of the range being listed as impaired under Section 303d of the Clean Water Act. In addition, forested lands and agriculture fields are increasingly becoming converted to commercial or residential developments. Development and its associated point and non-point discharges increase within the basin as human populations continue to migrate from the surrounding cities such as Huntsville, Athens, and Decatur. Habitat destruction or modification continues to be a substantial threat to this species.

Based on the information in this review gathered since the 2010 five-year review, we believe the armored snail continues to meet the definition of endangered under the Endangered Species Act and we do not recommend a change in its listing status. This is based on our knowledge of the species' life history, its limited distribution, potential threats to its habitat, and the need to further evaluate the unanswered phylogenetic questions as summarized in this review.

III. RESULTS

A. Recommended Classification: No change is needed

IV. RECOMMENDATION FOR FUTURE ACTIONS

- More frequent monitoring of this species and habitat conditions should be performed. More surveys are needed to search for new populations or habitat. Surveys of tributaries of both Limestone and Piney Creeks may identify important source populations if a species kill should occur within either of the two creeks. Survey efforts should also monitor the population dynamics of both the ghost marstonia and the armored snail where they are sympatric.

- Further review of the entire *Marstonia* genus should be conducted to better understand the relationship between armored snail and its sister taxa.

- Create and implement an outreach program aimed at educating farmers, developers, and other landowners along Limestone and Piney creeks about good land use practices and water conservation (Garner 2004a).

- Specific life history and habitat needs for the armored snail have not been well documented. More research is needed to document life history and habitat needs, including toxicological information on similar species, as the creeks may face more pollution as humans encroach upon the habitat.

- Complete and finalize a recovery plan for this species.

- Update the armored snail's genus to align with currently accepted taxonomic nomenclature.

- Develop a contingency plan for response to a spill or natural disaster within occupied snail habitat.

- Develop partnerships and utilize conservation initiatives with landowners along the riparian habitats and within the recharge zone of the Limestone and/or Piney Creek watersheds.

- Pursue opportunities including land acquisition, conservation easements, etc. to secure creek habitat.

- Develop propagation techniques.

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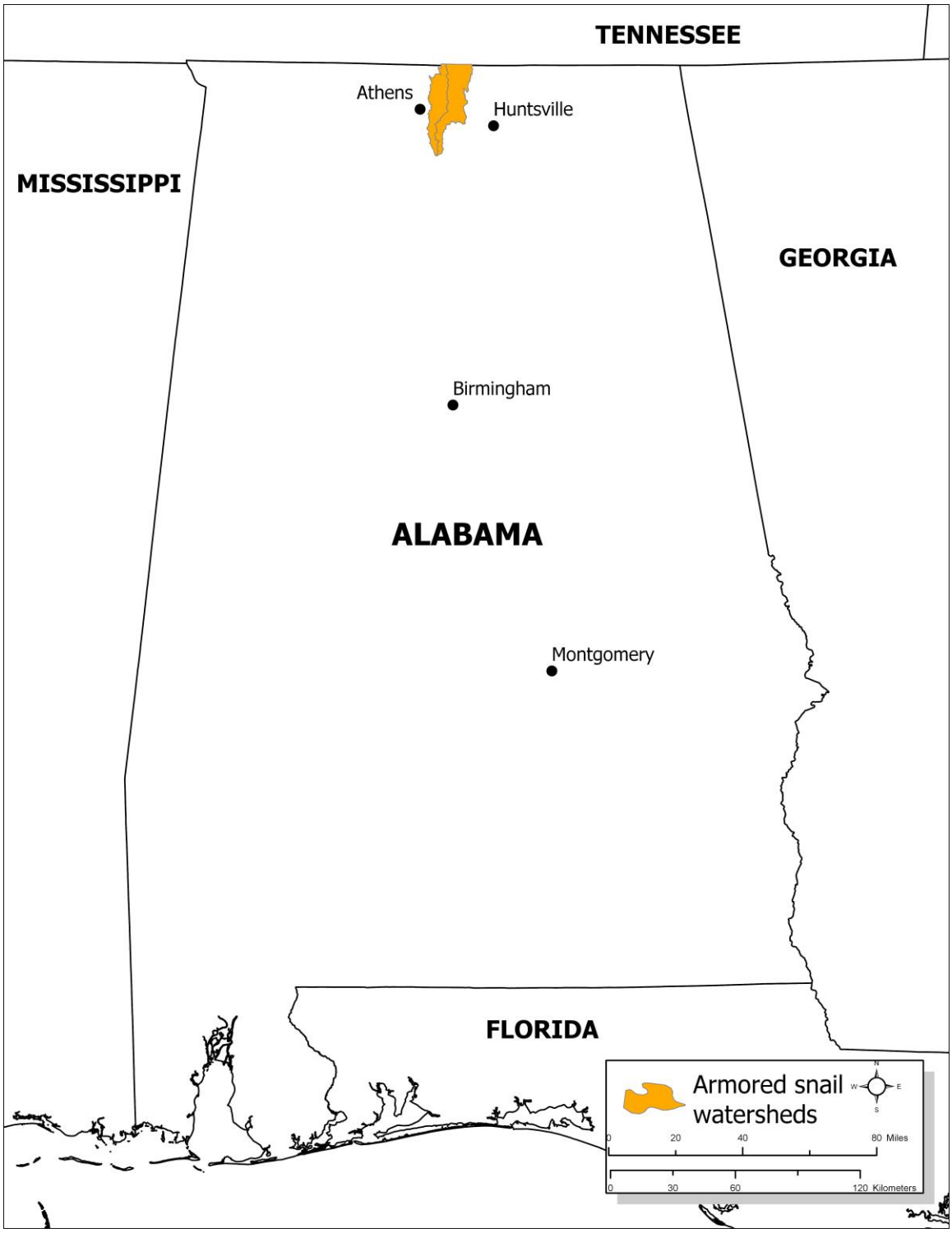

Figure 1. Location for armored snail watersheds. Map created by the U.S. Fish and Wildlife Service, Alabama ES Field Office, Daphne, AL.

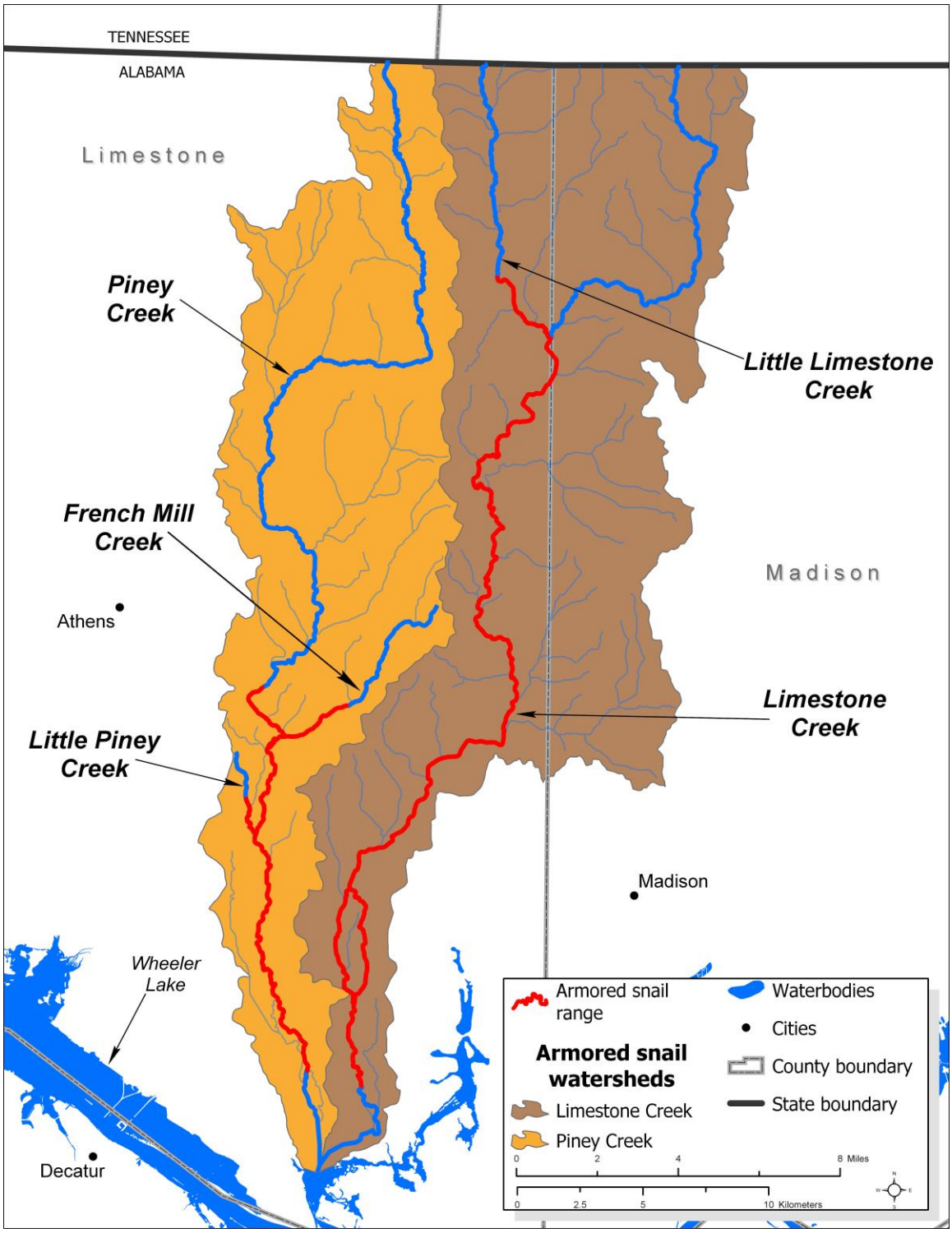

Figure 2. Range of the armored snail. Map created by U.S. Fish and Wildlife Service, Alabama ES Field Office, Daphne, AL.

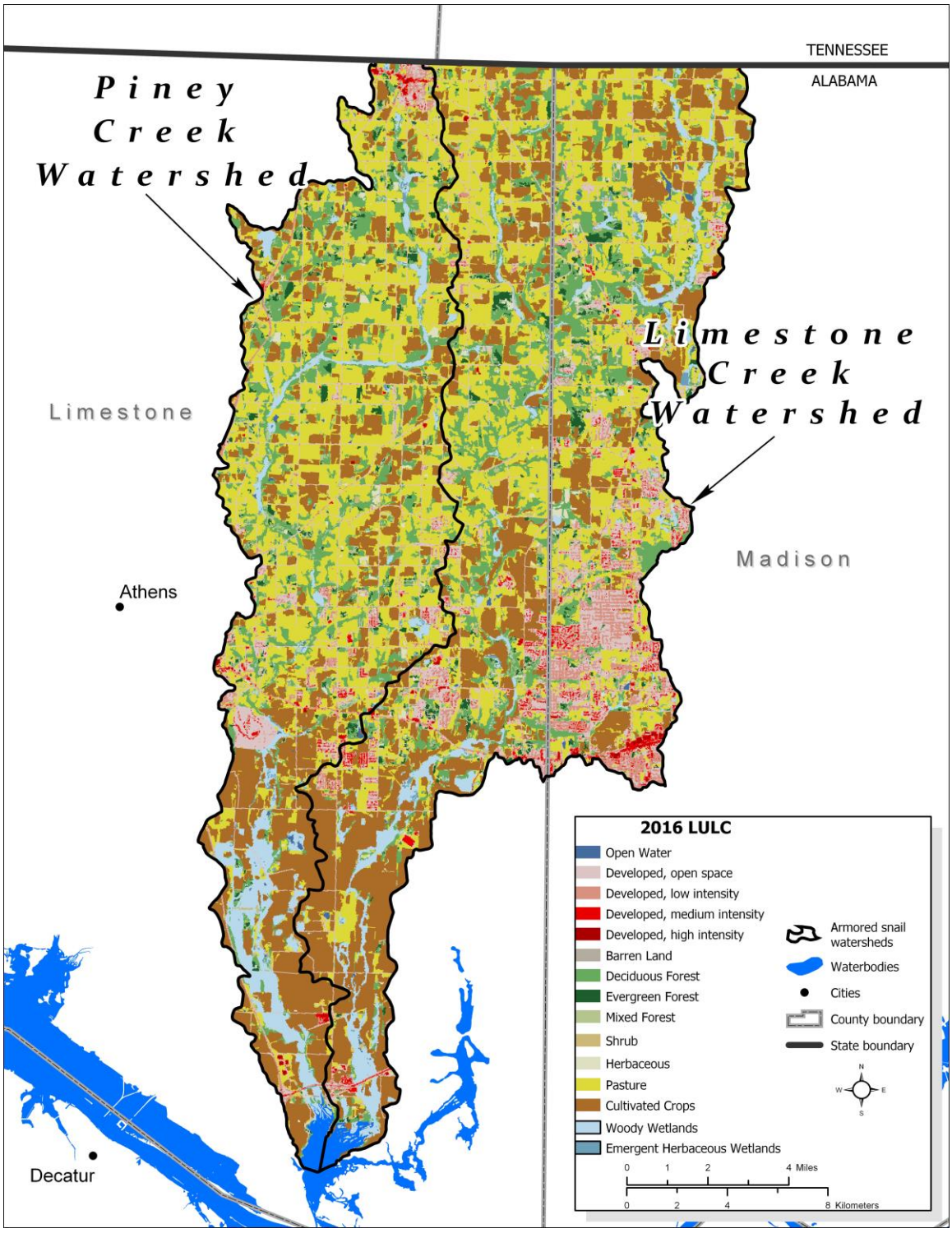

Figure 3. 2016 Land Use Land Cover (LULC) data within the armored snail watersheds (Yang et al. 2018). Map created by the U.S. Fish and Wildlife Service, Alabama ES Field Office, Daphne, Alabama.

Table 1. Snail densities (snail/meter^2) within Piney Creek at four, AST survey sites. Relocation sites are downstream of the original crossing areas. Five samples were collected at each site with a 240 cm^2 rectangular grid. An average density was calculated using these samples and extrapolated over a square meter (AST 2014a, 2015, 2016, 2017).

Snail Densities (snail/meter^2) within Piney Creek at AST survey sites

	1.4 Crossing	1.4 Relocation	3.2 Crossing	3.2 Relocation
July 2014	1,150	375	500	150
July 2015	208	2,267	758	392
July 2016	292	350	308	1,275
June 2017	833	650	125	167

Table 2. Water quality characteristics for four surveyed sites in Limestone Creek and six sites on Piney Creek. Haggerty and Garner collected data in June 2007; and width/depth/velocity data are averaged values at these sites. AST data from Piney Creek was collected either in June or July every year between 2014 and 2017; and values listed are an average of the four years. AST Limestone Creek slough data was collected in June 2016. Not all of Haggerty and Garner's water quality parameters where collected by the AST surveys, and a lack of data is denoted by "-".
[a]Haggerty and Garner 2007
[b]AST 2014a, 2014b, 2015, 2016, 2017

	Limestone Creek				Piney Creek					
Site	**LC1[a]**	**LC3[a] (slough near Old Hwy 20)**	**LC4[a]**	**Slough near Old Hwy 20[b]**	**PC2[a]**	**PC4[a]**	**1.4[b]**	**1.4 Relocation[b]**	**3.2[b]**	**3.2 Relocation[b]**
Width (m)	13.9 ± 6.6	13.9 ± 6.6	13.9 ± 6.6	18.29 ± 10.67	13.4 ± 4.7	13.4 ± 4.7	12.19	-	9.14	-
Depth (m)	0.77 ± 0.5	0.77 ± 0.5	0.77 ± 0.5	1.07	0.64 ± 0.4	0.64 ± 0.4	-	-	-	-
Velocity (m/s)	0.35 ± 0.39	0.35 ± 0.39	0.35 ± 0.39	-	0.18 ± 0.30	0.18 ± 0.30	-	-	-	-
Water Temperature (°C)	26.3	28.7	56.0	27.0	25.0	25.3	25.375	24.325	24.55	24.6
Oxygen Saturation (%)	76.0	100.0	5.0	-	69.2	24.0	104.375	95.125	104.975	98
Dissolved Oxygen (mg/l)	6.18	7.97	7.99	-	5.98	2.10	8.7275	8.0525	9.135	8.265
pH	7.70	8.00	135.00	7.86	7.70	7.29	7.495	7.575	7.69	7.5425
Conductivity (µ S/cm)	138	140	135	117.3	157	120	75.105	75.435	70.76	72.635
Total Hardness (ppm)	60	56	60	-	76	52	-	-	-	-
Calcium Hardness (ppm)	40	48	40	-	64	40	-	-	-	-
Magnesium Hardness (ppm)	20	8	20	-	12	12	-	-	-	-

Table 3. Analysis of land use land cover changes between 2001 and 2016 for the two watersheds associated with the armored snail. Geospatial analysis of land use land cover performed by US Fish and Wildlife Service, Alabama Field Office, Daphne, AL. Data was derived from 2001, 2006, 2011, and 2016 National Land Cover Database (NLCD) which was created by the Multi-Resolution Land Characteristics Consortium, a partnership of federal agencies led by the U.S. Geological Survey and uses 2001, 2006, 2011, and 2016 Landsat satellite data (Yang et al. 2018) .
***Land Use Land Cover groups have been consolidated from original data to form these six similar land cover classifications.**

	Land Use Land Cover*	2001		2006		2011		2016	
		Acres	%	Acres	%	Acres	%	Acres	%
Piney Creek	Agriculture	38991	64.49	38377	63.47	37874	62.64	37819	62.55
	Developed/ barren	5444	9.00	6051	10.01	6443	10.66	6492	10.74
	Forest	10586	17.51	10340	17.10	10266	16.98	10307	17.05
	Herbaceous	476	0.79	740	1.22	921	1.52	840	1.39
	Water	479	0.79	473	0.78	493	0.82	478	0.79
	Wetlands	4485	7.42	4480	7.41	4463	7.38	4524	7.48

	Land Use Land Cover	2001		2006		2011		2016	
		Acres	%	Acres	%	Acres	%	Acres	%
Limestone Creek	Agriculture	52539	63.11	50493	60.66	49676	59.67	49396	59.34
	Developed/ barren	10458	12.56	12763	15.33	13587	16.32	13925	16.73
	Forest	14919	17.92	14219	17.08	13736	16.50	13736	16.50
	Herbaceous	598	0.72	1033	1.24	1506	1.81	1388	1.67
	Water	506	0.61	562	0.68	567	0.68	570	0.69
	Wetlands	4226	5.08	4176	5.02	4174	5.01	4231	5.08

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Armored Snail *(Pyrgulopsis (=Marstonia) pachyta)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

__X__ No change needed

Review Conducted By: Erin Padgett and Evan Collins, Alabama ES Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve WILLIAM PEARSON Digitally signed by WILLIAM PEARSON Date: 2020.04.23 11:38:02 -05'00' Date _____

APPENDIX

Summary of peer review for the Armored Snail *(Pyrgulopsis (=Marstonia) pachyta):* 5 Year Review

Peer Review Method:

This document was peer-reviewed internally by Jeff Powell in the ES Field Office, Daphne, AL. No formal public comments were received. Since minimal new information was obtained that indicated changes in conditions since the last 5-year review in 2010, we did not seek external independent peer review of this document. As we continue to support exciting recovery actions with partners, we look forward to having additional data and surveys for our next 5-year review and its peer review.