Eastern Indigo Snake
Drymarchon corais couperi
5-Year Review:
Summary and Evaluation

Photo credit: Dirk Stevenson

U.S. Fish and Wildlife Service
Southeast Region
Georgia Ecological Services Field Office
Athens, Georgia

5-YEAR REVIEW
Eastern indigo snake (*Drymarchon corais couperi)*

I. GENERAL INFORMATION

A. Methodology used to complete the review: The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. 1531 *et seq*.). The Service announced initiation of this review and requested information in a published *Federal Register* notice with a 60-day comment period (83 FR 20092). In the notice, the Service requested new information regarding the eastern indigo snake that has become available since the last review of this species.

In conducting this 5-year review, the Service relied on available information pertaining to historic and current distributions, life history, and habitats of this species. Much of the information contained herein is taken from a Species Status Assessment (or SSA, Service 2019) that was developed to inform this 5-year review as well as other ESA documents. An SSA is a scientifically rigorous characterization of a species' status, and of the likelihood that the species will sustain populations in its natural systems over time. It provides a thorough assessment of the species' biology, and assesses the species' resource needs. The Service used a variety of information resources, including the SSA, information in our files, and solicited information from knowledgeable individuals including those associated with academia and state conservation programs. Other sources include the final rule listing for this species under the ESA, the Recovery Plan (1982), the 2008 5-year review for the species, peer-reviewed scientific publications, State and other experienced biologists, unpublished survey reports, and notes and communications from other qualified biologists or experts. The completed draft was sent to other affected Service offices in the species' range and peer reviewers (see Appendix A) for review and comment. Comments received were evaluated and incorporated into this final document as appropriate. During the 60-day open public comment period following the initiation of this review, the Service received and addressed three public comments (see Appendix B). In addition, the SSA went through a review process with responses from three peer reviewers and the state wildlife agencies in Georgia and Florida. The final SSA, on which this 5-year review is based, was revised in response to comments received during its review process.

B. Reviewers

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

Lead Field Office – Georgia Ecological Services, Michele Elmore, 912-403-1873

Cooperating Ecological Services Field Offices – Alabama; Mississippi; North Florida; Panama City (Florida); South Florida; South Carolina.

C. Background

1. **Federal Register Notice citation announcing initiation of this review:** May 7, 2018 (83 FR 20092).

2. **Species status:** Declining. The species was listed as Threatened on January 31, 1978 under the ESA due to threats from habitat modification, collections for the pet trade and gassing while in gopher tortoise (*Gopherus polyphemus)* burrows (Service 1978). At the time of listing, commercial pet trade was probably the main cause for the species' decline. Since listing under the ESA, wild collection of eastern indigo snakes for the pet trade and gassing of gopher tortoise burrows are no longer considered to be significant threats; however, habitat decline (both quantity and quality) remains a significant threat across the range of the eastern indigo snake.

3. **Recovery achieved:** 2= 25-50% recovery objectives achieved.
Recovery achieved assessment is based on significant progress to maintain and protect existing populations, to reestablish populations and to educate the public about the species. Land conservation has increased in some areas (particularly in Georgia), especially where there are on-going efforts to conserve gopher tortoise populations. Furthermore, significant research on the life history of eastern indigo snakes has been conducted to help estimate viability of extant populations and inform population viability models and conservation efforts. Reestablishment of populations into areas of extirpation (South Alabama and the Florida Panhandle) is also on-going. Public outreach and education regarding the conservation status of the eastern indigo snake has also increased. However, additional land protection is needed in Southeast Georgia and North Florida (*e.g.*, along the Suwannee River, see SSA (Service 2019) for description of regions), and critical habitat corridors need to be secured throughout the range. Range-wide population viability models need further development (including necessary research and monitoring to inform models) and the success of reestablishment efforts should be guided by these models.

4. **Listing history**

   Original Listing
   FR notice: 43 FR 4026
   Date listed: January 31, 1978
   Entity listed: Subspecies (*Drymarchon corais couperi*)
   Classification: Threatened

5. **Review History:**
   Recovery Plan: 1982

   Each year, the Service reviews and updates listed species information to benefit the required Recovery Report to Congress. Through 2013, the Service performed a recovery data call that included status recommendations for this species. The

Service continues to report this species' status recommendation in 5-year reviews. The last review for this species to inform the Recovery Report to Congress was conducted in 2018.

Five-year reviews:

December 8, 1983 (48 FR 55100)
In the 1983 review, the Service determined that the species should remain listed as "threatened" due to primary threats of habitat loss and inadequate protection.

November 6, 1991 (56 FR 56882)
In the 1991 review, multiple species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors or threats as they pertained to each species' recovery. In particular, no changes were proposed for the status of the eastern indigo snake in the review.

September 8, 2006 (71 FR 53127)
In this review (signed in April 2008), the Service determined that the eastern indigo snake's classification of "threatened" remained valid and appropriate due, primarily, to habitat impacts.

6. **Species' Recovery Priority Number at start of review (48 FR 43098): 11C**
   Degree of Threat: Moderate with some degree of conflict between the species' recovery efforts and economic development.
   Recovery Potential: Low
   Taxonomy: Species
   At the time of listing in 1978, the eastern indigo snake was considered a subspecies of indigo snake, *Drymarchon corais couperi* (Service 1978). Post-listing, Collins (1991) elevated this lineage to species status based on geographic isolation and morphology. Subsequent work supported this designation, and the eastern indigo snake was accepted by the scientific community as its own species, *Drymarchon couperi* (Wüster *et al*. 2001, Crother 2012). The Service recommended adopting this change in nomenclature in the 2008 Five-year review (Service 2008), however a final rule to formally change the List of Endangered and Threatened Wildlife (50 CFR 17.11) is required and has not been completed. Therefore, the recovery priority number should not have been changed in 2008. Since both "12" and "11" as recovery priority numbers reflect moderate degree of threat and low recovery potential, the Service recognizes this error and plans to formally modify 50 CFR 17.11 via a final rule for the eastern indigo snake.

7. **Recovery Plan:**
   Name of plan: Eastern Indigo Snake Recovery Plan
   Date issued: April 22, 1982

II. REVIEW ANALYSIS

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

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

2. Is there relevant new information that would lead you to re-consider the classification of this species with regard to designation of DPSs? No.

B. Recovery Criteria

1. Does the species have a final, approved recovery plan containing objective, measurable criteria? No. There is a final approved recovery plan that provides a recovery objective and related recovery tasks; however, there are no objective or measurable recovery criteria.

2. Adequacy of recovery criteria

a. Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? No. The Eastern Indigo Snake SSA (Service 2019) provides the best available data and biological information. New information from the SSA is summarized in Section II.C. For example, new information from research and monitoring programs regarding the species' distribution, response to habitat conditions, movements, home range and overall spatial ecology in Georgia and Florida has been published. In addition, new information on the species' genetic diversity is available. Based on new species information, the SSA described populations distributed across 4 representative regions (Southeast Georgia, the Panhandle (includes portions of Alabama, Florida and Georgia), North Florida and Peninsular Florida). This and other new information from the SSA regarding current and future conditions of resilience, representation, and redundancy are summarized in Section II.C below.

b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria? No. There are no recovery criteria.

The recovery plan states that the ultimate recovery plan objective should be to ensure that numerous eastern indigo snake populations exist, are reproducing, and protected where suitable habitat still exists in the historical range of the species. It also states that once this is accomplished, and all states in the range of the snake provide legal protection, delisting might then be considered since the snake would be protected from interstate commerce by the Lacey Act.

An addendum to the Eastern Indigo Snake Recovery Plan was written for eastern indigo snakes that occur in South Florida that included general criteria for the species in that region (Service 1999). The objective within this plan was to stabilize and increase the populations in South Florida. The plan included a measure of demographic data that could be used in determining whether the South

Florida populations are increasing. This was a rate of increase greater than 0 as a 3-year running average over at least 10 years. Furthermore, the plan stated that the development of delisting criteria would require the analysis of demographic data to demonstrate that there are adequate, contiguous tracts of upland habitat in South Florida to ensure at least a 95 percent probability of persistence for the eastern indigo snake in this area for 100 years.

The original Eastern Indigo Snake Recovery Plan (Service 1982) requires revision to reflect the best available information on the species and its habitat, and to provide objective and measurable recovery criteria. This process is underway. At the time of listing, removal of snakes from the wild for the pet trade and gassing of gopher tortoise burrows were significant threats. Due to listing the eastern indigo snake under the ESA and Alabama, Florida, and Georgia providing legal protection to this snake (see details under Factor D of the Five-Factor analysis), these threats have been considerably reduced. However, the threat of habitat destruction and degradation has become a more significant threat and continues at a similar level since our last 5-year review in 2008. Thus, the protection of the Lacey Act does not provide sufficient protection to justify removal of this snake from the Federal List of Endangered and Threatened Wildlife and Plants.

Even though there are no measurable recovery criteria in the Recovery Plan (Service 1982), progress has been made towards the overall recovery objective. Numerous populations occur on and around protected lands, two extirpated populations are being reestablished and public attitude is improving in some areas from an increase in public outreach and education. Additional details on related recovery tasks are provided in the following section and in Section II.C.2.

3. **List the recovery criteria and discuss how each criterion has or has not been achieved.** Since the recovery plan does not have objective/measurable criteria, the principal recovery tasks identified in the Eastern Indigo Snake Recovery Plan (1982) are listed below with a summary of progress made towards those recovery tasks.

   (1) Maintain and protect existing populations of eastern indigo snakes.
   Status: It is difficult to delineate and monitor biological populations of eastern indigo snakes across its range due to the snake's large home ranges, secretive behavior, low densities, and other challenges associated with identifying population boundaries. However, in the recent SSA (Service 2019), eastern indigo snake populations and their resiliency were estimated using new scientific information from research efforts, since the last 5-year review (2008), that expand our knowledge of eastern indigo snake distribution, resource needs, home range size, movements and relationships to landscape condition. In addition to compiling and verifying eastern indigo snake records range-wide (Enge *et al.* 2013), populations from two areas have been studied extensively using radio-telemetry to track individual snakes. These two areas include populations around Fort Stewart Military Reservation in Southeast Georgia (Hyslop 2007, Hyslop *et al.* 2009a, 2009b, 2009c, 2012, and 2014, Bauder *et al.* 2017) and populations in

Peninsular Florida (Bauder 2018, Bauder *et al.* 2018, 2016a, 2016b, Breininger *et al.* 2004, 2011, 2012) including Avon Park Air Force Range and Archbold Biological Station.

While the eastern indigo snake remains widely distributed in Southeast Georgia and Peninsular Florida, its current distribution has contracted from its historical distribution. Fifty-three (53) populations, including two populations undergoing reestablishment, were estimated in the SSA (Service 2019). The current populations represent a decrease in the overall distribution and extent of historical populations due to fragmentation of the larger historical populations into multiple smaller populations, and the extirpation of 30 of the historical populations. Some of the range contraction has occurred since listing under the ESA, particularly in the Florida Panhandle due to the decline of gopher tortoise populations (Enge *et al.* 2013); however, conservation efforts are underway to repatriate gopher tortoise and eastern indigo snake populations in this region.

The resiliency of the 53 populations was assessed in the SSA (Service 2019) based primarily on habitat conditions such as habitat fragmentation, road density, gopher tortoise populations and habitat type. Due to the species' large home ranges, resilient populations need good-quality habitat of sufficient size with connectivity among populations. Therefore, conservation lands having multiple patches of habitat at least 2,500 acres (ac) (1,000 hectares (ha)) in size are needed to support eastern indigo snakes (Moler 1992), but a more recent study suggests that 12,000 to 22,000 ac (5,000 to 9,000 ha) of unfragmented habitat may have the best chance for long-term population viability (Bauder 2018). In the SSA, the overall current population resiliency was estimated to be medium to low and was predicted to be low to very low in the future without increased conservation to maintain and protect populations. More details of this analysis can be found in Section II.C.2 below, and in the SSA (Service 2019).

In Georgia, the eastern indigo snake remains widespread in the lower and middle Coastal Plain of southeastern Georgia, with strongholds in the Alapaha, Altamaha, and Ogeechee River basins (Enge *et al.* 2013). There are recent records (post year 2000) for 29 Georgia counties (Enge *et al.* 2013, Service 2019). The eastern indigo snake has been recently documented from 19 public lands and preserves in Georgia that are greater than 2,500 ac (1,000 ha) in size (6 sites are greater than 12,000 ac (5,000 ha)) (Enge *et al.* 2013). Land protection, via a multi-partnership effort (The Nature Conservancy, The Orianne Society (Orianne), The Conservation Fund, Georgia, and others), to protect the gopher tortoise has been accelerated as part of Georgia's gopher tortoise conservation initiative which has a goal to permanently protect 65 gopher tortoise populations. Since 2008, over 78,000 ac of additional public and private land has been protected that has significant conservation value for the eastern indigo snake (*e.g.*, Alapaha River Wildlife Management Area (WMA), Alligator Creek WMA, Canoochee Sandhills WMA, Orianne's Indigo Snake Preserve, Sansavilla WMA).

In Florida, the eastern indigo snake has been documented throughout the state but observations are rare in the Florida Panhandle and the northeastern portion of the North Florida region (Enge *et al.* 2013, Service 2019). There are recent eastern indigo snake records (post 2000) for 46 Florida counties. The eastern indigo snake has been recently (post 2000) documented from 93 public lands and preserves in Florida that are greater than 2,500 ac (1,000 ha) in size (48 sites are greater than 12,000 ac (5,000 ha)). In 2012, Florida updated their Gopher Tortoise Management Plan (FWC 2012). The overarching conservation goal of this management plan is no net loss of gopher tortoises from the time of plan approval in 2012 through 2022. Objectives of the plan include: minimizing the loss of gopher tortoises; increasing and improving gopher tortoise habitat; enhancing and restoring gopher tortoise populations where the species no longer occurs or has been severely depleted on protected, suitable lands; and maintaining the gopher tortoise's function as a keystone species. Eastern indigo snakes in Florida should benefit from these actions taken on behalf of the gopher tortoise. In addition, Florida has revised an Eastern Indigo Snake Maxent Habitat Model (North and South) (FWC, Unpublished) to aid in identifying potential habitat for the species in Florida.

Currently, specific efforts to maintain and protect populations of eastern indigo snakes focus primarily on populations on public lands or sites where federally funded activities occur in Florida and Georgia. Conservation success for the eastern indigo snake is highest on protected lands, where various restrictions are assumed to be in place to prevent or limit development; however, intervening private properties play an important role for habitat connectivity. Protection from development alone may not be enough to adequately conserve eastern indigo snake populations because the primary habitat most desired (and required in the northern range) by eastern indigo snakes requires habitat management, specifically fire management. However, conservation lands are the most likely lands to receive appropriate habitat management.

Surveying and monitoring the eastern indigo snake is very difficult due to its cryptic nature. However, long-term population monitoring is needed to better understand the effects of our protection and management efforts. In Georgia, conservation partners (*e.g.*, Orianne, Georgia Department of Natural Resources, The Nature Conservancy) have conducted capture-mark-recapture (CMR) monitoring, and since 2008, about 400 snakes have been marked with over 200 recaptures (includes multiple recaptures of individuals) (unpublished data). As part of these efforts, 96 individuals were captured a total of 128 times in 2018 to 2019 (46% were recaptured snakes). These data provide important insight of population persistence and distribution, but it is difficult to determine population trends because survey sites and sample effort are not consistent through time. Orianne is a non-profit wildlife conservation organization, founded in 2008, that focuses on conserving the eastern indigo snake through monitoring, research, land acquisition, habitat management and environmental education. In 2010, Orianne developed and implemented a standardized long-term eastern indigo

snake monitoring program in Georgia to augment the CMR monitoring efforts. The program aims to evaluate site occupancy of eastern indigo snakes and how they respond to continued longleaf pine habitat improvement efforts across southeast Georgia. Occupancy monitoring measures the percentage of suitable sites that are occupied by a species over time while accounting for imperfect detection (*i.e.*, the species' cryptic nature). Occupancy probabilities are generally easier to measure than abundance, especially for rare, secretive species. The program includes about 60 sites sampled over a 3-year period in three river drainages in Georgia. The monitoring program is focused on upland habitat with sites that have gopher tortoise populations because eastern indigo snakes rely on tortoise burrows for overwintering habitat.

In Peninsular Florida, monitoring of populations is difficult because snakes are not reliant on gopher tortoise burrows for winter shelters, can use a variety of habitats throughout the year and remain dispersed across the landscape. Therefore, few sites have long-term monitoring. Monitoring data is often from opportunistic surveys and most are associated with research or other projects. However, they do provide indication of persistence within an area. For example, Orianne collaborates with Sanibel-Captiva Conservation Foundation to monitor eastern indigo snakes in Lee County, Florida on North Captiva, Cayo Costa and Pine Island via visual encounter surveys. According to their data, Pine Island may still have a breeding population of eastern indigo snakes but is believed to be decreasing due to increase of impacts from humans (*i.e.* road mortality) (unpublished data). Surveys at Avon Park Air Force Range and Archbold Biological Station, using different techniques such as gopher tortoise burrow scoping, burrow cams, and opportunistic visual encounters, confirmed presence at these sites in recent years. A concerted range-wide monitoring program is needed to better assess viability of populations in Florida over time.

A range-wide potential habitat model was generated, for the SSA (Service 2019), to assess the current range-wide status of habitat availability and quality for the eastern indigo snake. Identified habitat was considered potential habitat based on expert opinion of the species' use of land cover types, however habitat was not assumed to be occupied. Protected habitat was assessed using the U.S. Geological Survey Protected Areas Database of the United States (PAD-US) (USGS 2016) and other sources acquired from the States. An estimated 34% of the eastern indigo snake potential habitat is on some type of conserved land (federal, state and private). Broken down by region, 42% of the habitat in Peninsular Florida is protected, 38% in the Panhandle (includes Florida and extreme southern Alabama and southwestern Georgia), 20% in Southeast Georgia and 19% in North Florida (See SSA for details (Service 2019)). However, connectivity among these conserved lands will be critical for species viability, especially in the face of predicted development, and needs to be further assessed. Habitat condition was also assessed and used in the population resiliency assessment (Service 2019) and is summarized in Section II.C.2 below.

In recent years, many public and private partners have joined together in an effort to better understand the status of the gopher tortoise in the eastern portion of its range where it is considered a candidate for federal protection under the ESA. In 2008, a Candidate Conservation Agreement (CCA 2012) for the gopher tortoise was developed as a cooperative effort among state, federal, non-governmental and private organizations to proactively implement conservation measures for the species. Partners are implementing critical conservation to protect the species from declining to a level where federal protection under the ESA is warranted. This public-private partnership is focused on land protection and management strategies that will permanently protect gopher tortoise populations across the eastern portion of its range. Gopher tortoise populations are also being restored and augmented (*e.g.*, Eglin Air Force Base in the Florida Panhandle) through translocation and captive propagation programs. On-going efforts to conserve the gopher tortoise will help conserve the longleaf pine (*Pinus palustris*) ecosystem and have lasting conservation benefits to hundreds of species, including the eastern indigo snake across much of its range.

Other landscape-scale conservation projects such as America's Longleaf Restoration Initiative also have added benefits to the eastern indigo snake. This collaborative effort among many public and private sector partners actively supports range-wide efforts to restore and conserve longleaf pine ecosystems, with a goal to increase longleaf pine from 3.4 to 8.0 million ac (ALRI 2018). These efforts are focused within 16 "significant landscapes." Within these significant landscapes, Local Implementation Teams (LITs) are leading conservation efforts by coordinating partners, developing priorities, and fundraising to implement on-the-ground conservation. Five LITs are working within the range of the eastern indigo snake: the Gulf Coastal Plain Ecosystem Partnership, Apalachicola Regional Stewardship Alliance, Fort Stewart/Altamaha Longleaf Pine Restoration Partnership, Okefenokee-Osceola Partnership and the Ocala Local Implementation Team. Each of these LITs has components of their conservation plans that support eastern indigo snake recovery. For example, both the Gulf Coastal Plain Ecosystem Partnership and Apalachicola Regional Stewardship Alliance help restore longleaf habitat and support the ongoing eastern indigo snake reestablishment efforts at Conecuh National Forest and the Apalachicola Bluffs and Ravines Preserve, respectively. The other LITs play important roles in habitat restoration, management, and monitoring.

(2) Reestablish populations where feasible.

Status: Beginning in 1976 and continuing through 1987, 537 eastern indigo snakes were released at about 20 sites across Alabama, Mississippi, Georgia, Florida and South Carolina (Speake 1990) in an attempt to reestablish eastern indigo snakes in portions of its historical range. A captive breeding colony at Auburn University was used to produce snakes for the repatriation efforts (Speake 1990). A preliminary survival assessment of released snakes was conducted from 1986 through 1989; captures or sightings of eastern indigo snakes occurred at 5 of the 16 release sites evaluated (Speak 1990). However, no recent records of

eastern indigo snakes are known from these areas and the repatriation effort is considered unsuccessful (Hart 2002, Irwin *et al.* 2003, Smith *et al.* 2006, Stevenson *et al.* 2008). Possible explanations for the failure of the original release effort include releasing low densities of animals at each site, selecting too many reintroduction sites, and releasing snakes into inappropriate habitat (Godwin *et al*. 2007).

In 2007, a feasibility study was launched to assess captive propagation and repatriation as a conservation tool for recovery in Alabama. The objectives were to establish a breeding colony, develop husbandry methods for eastern indigo snakes and prepare an appropriate release site (Conecuh National Forest) where the snakes could be monitored (Godwin *et al.* 2007). The first snakes were released in 2010, and the project is on-going showing several measures of success (*e.g.*, site fidelity, reproduction). Building on the feasibility study, a Captive Propagation and Repatriation Plan (CPRP) for the eastern indigo snake is under development (Service, unpublished data) that further describes the following primary objectives to facilitate the goal of reestablishing extirpated populations of the eastern indigo snake: (1) establish protocols for the husbandry, maintenance and propagation of eastern indigo snakes at the Orianne Center for Indigo Conservation (OCIC), (2) develop a strategy for identifying appropriate source populations from which to obtain founders for the OCIC colony, (3) draft a list of geographic areas and potential sites for repatriation that support eastern indigo snake recovery goals, (4) identify existing federal and state policies and requirements for permitting reintroductions and (5) ensure communication and coordination among partners. An Eastern Indigo Snake Reintroduction Committee (EISRC) meets regularly to guide program actions.

In order to meet the objectives of the Eastern Indigo Snake CPRP, the OCIC was established by Orianne. This facility was expanded upon to become the premier captive propagation center for the eastern indigo snake repatriation project. In 2014, Orianne partnered with the Central Florida Zoo to operate and manage the OCIC. The Central Florida Zoo coordinates the Association of Zoos and Aquariums' (AZA) eastern indigo snake Species Survival Plan (SSP). The SSP partners work cooperatively to maximize genetic diversity and appropriately manage the demographic distribution and long-term sustainability of select species in captivity (AZA 2018). The eastern indigo snake became an AZA SSP species in 2008 when the first studbook (pedigree and demographic history of each snake within the SSP) was published (Antonio and Odum 2008). The current studbook (Hoffman 2016) is expected to be updated in late 2019. The eastern indigo snake SSP Population Analysis and Breeding and Transfer Plan (Hoffman and Andrews 2017) is designed to maintain a healthy, genetically diverse stable population over the long-term and additional research is underway to examine the genetic diversity of the captive population and how it compares to wild populations. In 2018, the eastern indigo snake was accepted as part of the AZA's SAFE (Saving Animals From Extinction, AZA 2017) program to help bring together AZA members and field-based partners to enhance the probability

of conservation success. Partners include Alabama, Florida, Georgia, federal agencies (U.S. Forest Service, Department of Defense, Welaka National Fish Hatchery), universities (Auburn University, University of Florida), non-profits (Orianne, The Nature Conservancy), AZA zoos (Central Florida Zoo, Zoo Atlanta, Zoo Tampa, Birmingham Zoo, etc.) and private consultants.

There are 2 active repatriation sites; the Conecuh National Forest in southern Alabama, initiated in 2010 with 169 snakes released as of 2019, and the Apalachicola Bluffs and Ravines Preserve in the central Florida Panhandle with 47 snakes released during 2017 to 2019. At each site, the first two years of released snakes (38 and 32, respectively) were intensively monitored via radio telemetry to study their movements and survival. Although mortality (due to a combination of vehicular strikes, predators and unknown factors (Godwin *et al*. 2011)) was reported at the Conecuh National Forest, the study showed snakes had site fidelity and were persisting at the conclusion of the radio-telemetry study (Godwin *et al.* 2011). The first indication that the repatriation at Conecuh National Forest may prove to be a success is evidence of successful breeding at the site; two females tracked via radio telemetry were captured in 2012 and laid eggs that produced nine offspring (Stiles *et al.* 2013). Then in 2019, a previously released snake was captured, brought to OCIC for a health check, and laid 2 viable eggs in captivity that had not hatched at the time of this review. Post radio-telemetry monitoring, at least 10 confirmed observations of eastern indigo snakes near the release sites have been reported between 2012 and 2018 (Godwin 2018). No unmarked eastern indigo snakes have been captured, which would be an indicator of survival of offspring from repatriated snakes (Stiles *et al.* 2013). At the Apalachicola Bluffs and Ravines Preserve in Florida, radio-tracking of the first two cohorts of released snakes will conclude in December 2019. Similar to the results at the Conecuh National Forest, mortality has been reported, but there is evidence of site fidelity and persistence (Piccolomini, unpublished data). Future monitoring is being discussed by the EISRC.

Future releases are planned for both sites, with a goal to release approximately 300 snakes at each site over the next 5 to10 years (about 30 snakes each year at each site). In order to reach this goal and determine if repatriating additional sites is feasible, the EISRC continues to develop strategies to assess population viability at each site, and to implement long-term monitoring at repatriation sites to evaluate success (Godwin and Steen 2017, Service, unpublished data). While the outlook for reestablishing populations is positive, the long-term success of reestablishing populations is currently unknown.

(3) Improve the public attitude and behavior towards the eastern indigo snake. **Status**: Improving public attitudes and behaviors towards the eastern indigo snake is a priority recovery action. Direct mortality by humans, especially by vehicular strikes, is a significant factor affecting eastern indigo snakes. Many partners across the species' range are working to educate the public and improve public attitudes by hosting events, giving presentations and inviting the public to

learn about the species and its habitat. For example, Orianne routinely provides programs using captive animals to educate the public about eastern indigo snakes and other herpetofauna. The state wildlife agencies in Alabama, Florida and Georgia also provide programs and educational materials to the public. The state wildlife agencies, federal agencies, non-profits (*e.g.*, Orianne and OCIC), zoos and other partnerships (*e.g.*, Gopher Tortoise Council Upland Snake Conservation Initiative) all play important roles in public education and outreach. Informational materials including signage, brochures, and posters have been produced to inform and engage the public about conservation of the species. In recent years, the eastern indigo snake has gained additional attention in education and outreach programs aimed to conserve the gopher tortoise, due to the snake's dependence on the tortoise in the northern portion of its range. Various community talks and wildlife festivals across the range provide an opportunity for the public to learn more about the species and its habitat. One example is the Annual Rattlesnake and Wildlife Festival in Claxton, Georgia that historically was called a "rattlesnake roundup" and promoted negative attitudes toward eastern diamondback rattlesnakes (and consequently eastern indigo snakes). In 2012, the roundup transitioned to a festival where many species of snakes, including eastern indigo snakes are displayed and information related to snake ecology and conservation is disseminated. Another example is the Eastern Indigo Snake Festival at the Conecuh National Forest in Alabama, which aims to educate the community about the ecosystem and the repatriation program on the forest.

In summary, although the current Recovery Plan (1982) only describes recovery tasks and does not have measurable recovery criteria, substantial progress has been made on the recovery of this snake since the last 5-year review (Service 2008). The Service is in the process of issuing a revised draft recovery plan with measurable recovery criteria.

C. Updated Information and Current Species Status

The Eastern Indigo Snake SSA (Service 2019) provides updated data on the species' biology and ecology, and new information on resilience, representation, and redundancy. The SSA was prepared using the Service's SSA framework and process (Smith *et al*. 2018). Resilience is related to population size and growth and is the ability of a population to persist in response to stochastic demographic, environmental and other disturbances. Redundancy spreads risk among populations and reduces the likelihood of impacts from large-scale or catastrophic events. Representation is future adaptive capacity in response to natural or man-made events, measured as the breadth of patterns of ecological, geographic, and genetic diversity. The SSA was prepared by a team of Service personnel, with technical and scientific input and reviewed by biologists, scientists, and managers of state and non-governmental organizations. A summary of the SSA is provided here. Refer to the SSA (Service 2019) for more detailed information on eastern indigo snake biology and ecology, as well as how current and future population conditions were evaluated with regard to resilience, redundancy, and representation.

1. Biology and Life History

The eastern indigo snake is a large, non-venomous snake with populations occurring in portions of Florida and southeastern Georgia (Figure 1). Mature adult eastern indigo snakes weigh from 2 pounds to over 10 pounds. The eastern indigo snake is the longest species of snake native to the U.S. and reaches up to 8.6 feet (2.6 meters) (Service 2019). Historically, the eastern indigo snake occurred throughout Florida and in the Coastal Plain of Georgia, Alabama, and Mississippi (Figure 1). Although the eastern indigo snake is difficult to consistently locate in the field, important life history characteristics and species needs have been learned from numerous studies. The eastern indigo snake is a diurnal species and prefers upland habitat types (*e.g.*, longleaf pine sandhills, scrub, pine flatwoods, tropical hardwood hammocks, and coastal dunes), but it also uses a variety of lowland and human-altered habitats. They may move seasonally between upland and lowland habitats, especially in northern portions of their range. Throughout their range, eastern indigo snakes use below-ground shelter sites for refuge, breeding, feeding and nesting. They depend on gopher tortoise burrows in xeric sandhill habitats throughout the northern portion of the species' range for overwintering shelter sites. Adult eastern indigo snakes move long distances and have very large home ranges from about a hundred to several thousand acres (tens to over a thousand hectares). On average, home range sizes are larger for males and also vary by season and latitude. Home ranges in the northern portion of the range tend to be larger than in the southern portion. Eastern indigo snakes may live for 8 to 12 years in the wild, become sexually mature around 3.5 years of age and breed October through January. They consume a wide variety of animals, including other snakes**.**

2. Distribution and Abundance Trends

Current Resilience

The broad distribution, large home range size and cryptic behavior of the eastern indigo snake complicate evaluation of its population status and trends. Thus, population trend data for the eastern indigo snake are virtually absent. Like most snake species, this species is very difficult to locate in the field, even in areas where it is known to occur. It is not amenable to standard population survey and monitoring studies. Therefore, population attributes such as abundance, sex ratio, age structure, reproductive variables, and mortality in the wild are generally unknown. However, loss and fragmentation of habitat that supports eastern indigo snakes is continuing and documented due to the pressures of human population growth and development within the species' range; therefore, the number of eastern indigo snakes is likely decreasing.

Since the last 5-year review, progress has been made via research and monitoring efforts to better understand the needs of eastern indigo snakes. In addition to compiling and verifying eastern indigo snake records range-wide, there is an expanding body of research describing eastern indigo snake home range size,

movements and relationships to landscape condition. The Service is required to gather and evaluate the best available information, including all records for the species, many of which are opportunistic sightings. While the knowledge about the eastern indigo snake and documented occurrence records have increased since the last 5-year review, limitations on exactly where these snakes are and how they are using the extent of their home ranges remain. In addition, some occurrence records may represent the same snake. Therefore, distribution and abundance may be overestimated to some degree, but the best available data was used based on records and movement patterns, to model in a scientific and structured way the location of potential populations. Based on this available information 83 (53 extant and 30 extirpated) potential populations for the eastern indigo snake were estimated by using occurrence records buffered by the snake's estimated maximum home range width (*i.e.*, maximum annual linear distance movement). Population estimates will be refined as more information becomes available. See the SSA (Service 2019) for more detailed explanation on how populations were estimated.

The primary negative factors influencing the viability of the species are habitat fragmentation and loss due to land use changes, especially urbanization. Urbanization includes a variety of impacts that remove or alter available habitat or impact snakes directly including: residential and commercial development, road construction and expansion, direct mortality (*e.g.*, road mortality, human persecution, domestic pets), invasive species, predation and inadequate fire management. Habitat loss for coastal populations is also an increasing risk due to sea level rise (Service 2019).

The cooperation of many partners to implement conservation efforts can help mitigate the negative factors and positively influence long-term viability of the species. To accelerate recovery, repatriation of eastern indigo snake populations in areas of extirpation is underway. Since listing under the ESA, wild collection of eastern indigo snakes for the pet trade is not believed to be a substantial threat. Land conservation has increased in some areas, especially where there are on-going efforts to conserve gopher tortoise populations. These conservation efforts will have lasting conservation benefits for the eastern indigo snake across much of its range.

To summarize the overall current resiliency condition of eastern indigo snake populations, population factors and habitat factors for each population were assessed. The current resiliency is an estimated score from high (good) to very low (poor) condition based on the analysis of two population factors (population extent and population connectivity) and six habitat factors reflecting habitat quantity and quality (habitat amount, habitat type, habitat fragmentation, shelter site availability, tertiary road density and percent urbanized). Of the 83 populations (53 current and 30 extirpated) assessed for current resiliency conditions, 30 (36%) are extirpated and 8 (9%) are in very low condition. Twenty-eight (28) (34%) are in low to medium-low condition, 13 (16%) are in

medium to medium-high condition, and 4 (5%) are in high condition (Service 2019).

The highly resilient populations are found in the central portion of the Peninsular Florida region (Lake Wales Ridge area) and the Southeast Georgia region (Fort Stewart area) (Figure 2). Populations considered in medium condition are largely found in the North Florida region, the northern portion of the Peninsular Florida region and scattered smaller populations in Southeast Georgia and southern Peninsular Florida. The majority of the extirpated populations are in the western portion of the range in the Panhandle region and the western part of the Southeast Georgia region. Other extirpated populations occur along the eastern side of the North Florida region and in the southern extreme of Peninsular Florida. Low and very low resilience populations are found along the coasts and near extirpated populations (Figure 2).

Current Representation and Redundancy

The populations are distributed across four (4) representative regions (Southeast Georgia, the Panhandle (includes portions of Alabama, Florida and Georgia), North Florida and the Peninsular Florida). Representation of the eastern indigo snake can be described in terms of its ecological (latitudinal or regional) variability, which incorporates the genetic variability for the species across its range. Ecologically, eastern indigo snakes are known to differ markedly between northern and southern populations in seasonal activity. The southern populations (in Peninsular Florida) do not depend upon gopher tortoise burrows for winter shelter sites, likely because of milder winter temperatures, but are closely associated with gopher tortoises where they co-occur. The northern populations (in North Florida, Southeast Georgia, and the Panhandle) are dependent on gopher tortoise burrows for overwintering shelter (Enge *et al.* 2013). Genetic variability has been documented within a north-south gradient (Folt *et al*. 2019) as well as an east-west (Atlantic-Gulf) gradient (Krysko *et al.* 2016b). The north-south genetic gradient is generally the same as the ecological gradient.

From an ecological and genetic variably perspective, the contemporary distribution of the eastern indigo snake provides species' representation but has considerably decreased from its historical representation. Most notable is the loss of populations in the Panhandle region and a contraction of the distribution in the southern extent of the Peninsular Florida region, including the Florida Keys. In addition, losses from the North Florida region may be particularly important for maintaining species diversity because this is where both the ecological and genetic gradients come together.

In the SSA, eastern indigo snake redundancy was assessed by evaluating the number of populations and the extent for both the historical and current distribution of populations. The total number of current populations is 53. Although there were 51 historical populations, the current abundance of populations represents fragmentation of the historically larger populations into

multiple, smaller populations, especially in Peninsular Florida (Figure 3). Thirty (30) of the historical 51 populations are extirpated (59%). Population extent has declined in all regions, with a 48% decline across the species' historical range. Southeast Georgia has one (1) and Peninsular Florida has three (3) highly resilient populations, as well as multiple medium resilient populations (Figure 2). The Panhandle and North Florida regions have zero (0) highly resilient populations, thus limiting overall redundancy. This is important for the species, especially for the North Florida region, because loss of redundancy in these areas limits connectivity to the other regions. As stated earlier, there is uncertainty regarding the extent of these snakes' movements and what constitutes a population. In summary, redundant populations still largely exist throughout Peninsular Florida and Southeast Georgia (Figure 2). The snake is extirpated from Mississippi and Alabama but is now being reintroduced back to Conecuh National Forest in Alabama. Scientists have documented that they no longer have sightings in several areas like the Florida Panhandle and northeastern Florida (Jacksonville area) (Enge *et al.* 2013). It is believed that the eastern indigo snake did not ever occur in South Carolina.

Future Resilience

The SSA considered not just the factors that influence viability (*i.e.* 5-factor analysis) but assessed the degree that they influence risk (Smith *et al.* 2018). The SSA analysis of the past, current, and future influences on eastern indigo snake needs for long-term viability revealed that several influences pose risks to future viability of the species. These risks are related to habitat changes from urbanization and climate change. Urbanization affects habitat from residential and commercial development, road construction and expansion, energy development such as solar arrays and introduction of invasive species. Increased urbanization can also increase occurrence of direct mortality from vehicular strikes and persecution from humans. While indirect effects on eastern indigo snakes will likely be due to shifting changes in temperature and precipitation from climate change, rising sea levels are expected to directly impact coastal populations of eastern indigo snakes. Other important influencing factors are related to non-urban land use and land management such as fire management, forestry, mining, and agriculture. In the SSA, potential future condition for the eastern indigo snake was assessed using projections (at years 2050 and 2070) of urban development and sea level rise to assess potential habitat loss and fragmentation. Scenarios A, B and C represent low, moderate and high rates of urbanization, respectively, with sea level rise at years 2050 and 2070. In addition, a targeted conservation scenario (Scenario D) was considered that included land use and management.

The SSA assessment showed future overall eastern indigo snake population resiliency to be low to very low. In the future (at years 2050 and 2070) without targeted conservation, the majority (66 to 77%) of currently extant populations (53) are expected to be in low to very low resiliency condition, and 13% (7) are likely to be extirpated. High to medium resiliency are predicted for 9 to 22% of

the extant populations. In contrast, for the conservation-focused scenario, low to very low condition populations make up 45% of the extant populations and high and medium resilient populations make up 11 and 30% of the total, respectively. Seven (or 13%) of the populations are expected to be extirpated due to sea level rise in all scenarios. One Southeast Georgia population (Fort Stewart) is the only population that remains highly resilient in all future scenarios without targeted conservation. The most significant shifts in resiliency occur first between current condition and year 2050 when the number of extant populations that are highly resilient (Figure 4) and their population extent (Table 1) decline considerably. Also, while the overall number of populations that have low to very low resiliency is about the same across scenarios and time (Figure 4), the extent of those populations increases (Table 1) thus decreasing future resilience. The next considerable drop in resiliency is apparent in Scenario B by year 2070, when the number of populations in medium resiliency (Figure 4) and their population extent (Table 1) decline by about half from the current condition.

Future Representation and Redundancy

In the future, ecological and genetic representation (north-south and east-west gradients) decrease in Scenarios B and C, with no high or medium resilient populations in the Panhandle and North Florida regions. Furthermore, the redundancy of high to medium resilient populations is considerably decreased from the current condition (Figure 5). Most notable for Scenarios A, B and C, no highly resilient populations remain in Peninsular Florida, medium resilient populations are lost by 2070 (Scenario A) in the North Florida region, and high to medium resilient populations remain absent from the Panhandle (Figure 5). Redundancy of resilient (high to medium) populations is lost in the North Florida region. Furthermore, all island populations of eastern indigo snakes are likely lost (with the possible exception of the population on Merritt Island, see Martin *et al.* 2018) by 2050 due to both sea level rise and urbanization. Although the ecological and genetic uniqueness of island populations of eastern indigo snakes has not been explicitly studied, Folt *et al.* (2019) found the population of indigos snakes on Sanibel Island to be very unique. Therefore, island population losses exemplify further declines in representation and redundancy for the species. The decline of populations in North Florida and the northern portion of Peninsular Florida are important losses in representation and redundancy and may have significant implications for long-term genetic connectivity across the range. Therefore, increases in land protection, management and population monitoring will be essential in this area to recover the species.

3. Taxonomy

When it was listed in 1978, the eastern indigo snake was considered a subspecies of indigo snake, *Drymarchon corais couperi* (Service 1978). Post-listing, Collins (1991) elevated this lineage to species status based on geographic isolation and morphology. Subsequent work supported this designation, and the eastern indigo snake was accepted by the scientific community as its own species, *Drymarchon*

couperi (Wüster *et al*. 2001, Crother 2012). The Service recommended adopting this change in nomenclature in 2008 (Service 2008; refer to Section I.C.7 from earlier). In addition to the eastern indigo snake, other common names include blue indigo snake and blue gopher snake.

4. Genetics

Recent genetic studies have provided additional taxonomic insights. Shamblin *et al*. (2010) used 22 nuclear microsatellite markers to successfully differentiate individual snakes from Fort Stewart, Georgia, and suggested the technique used in their genetic analysis could also prove valuable in conducting population level studies. Krysko *et al*. (2016b) evaluated the genetic diversity of 20 eastern indigo snakes across Florida and southern Georgia using mitochondrial DNA (mtDNA) derived from tissue samples. Krysko *et al*. (2016b) described a divergence of the species into two genetic lineages, an Atlantic lineage occupying southeastern Georgia and northeastern Florida and a Gulf lineage occupying southern Florida, the central Lake Wales Ridge of Florida, the Gulf Coast drainage of Florida, and the Florida Panhandle. The authors hypothesized that these two lineages represent two different species of indigo snakes (Krysko *et al*. 2016a, b), and described differences in scalation that they assert provide a method to morphologically distinguish between the two species. These two lineages illustrate a similar biogeographic pattern previously identified for other plants and animals that have come in and out of contact with each other many times during historical sea level changes. Nevertheless, in certain areas of Florida, this potential classification would place the two eastern indigo snake lineages in close enough proximity that no barrier to gene flow would exist between them. This region was described by Krysko *et al.* (2016b) as a hybrid zone between the two lineages.

More recent data bring into question the validity of splitting the eastern indigo snake into two species. Genetic diversity was further evaluated by Folt *et al.* (2019) using microsatellite (nuclear) DNA (nDNA) from 428 tissue samples of eastern indigo snakes from across the species' range, including the 20 samples used by Krysko *et al.* (2016a). These genetic analyses found evidence of genetic structure among populations of eastern indigo snakes; however, the geographic pattern suggested a north-south orientation rather than a Gulf-Atlantic orientation, and the contemporary gene flow was widespread across this geographic pattern (Folt *et al.* 2019). Folt *et al.* (2019) concluded that genetic structure among populations is best described as continuous isolation by distance rather than discrete evolutionary lineages, and there are no strong barriers to gene flow across the range (Folt *et al.* 2019).

In addition, Folt *et al*. (2019) suggest that this high level of contemporary gene flow between eastern indigo snakes and the inconsistent patterns between mtDNA and nDNA may be driven by high dispersal of males relative to females. Since female eastern indigo snakes move over much shorter distances than males, it

follows logically that results from a study of mtDNA (Krysko *et al.* 2016b), which passes maternally, would show population sub-structuring among females that may not be reflected in contemporary patterns of nDNA. The differences in movement and home ranges between male and female eastern indigo snakes are well documented, with males on average having larger home ranges, moving more frequently and over longer distances. This type of life history limits the utility of mtDNA alone to reveal novel species (Folt *et al.* 2019).

Because of the differences in inheritance and mutation rates, mtDNA is often used to determine species phylogeny and systematics, whereas patterns in nDNA illustrates more contemporary gene flow and population subdivision (Sunnucks 2000). Folt *et al*. (2019) recognize that a historical climatic event may have separated *D. couperi* into the two populations described by Krysko *et al.* (2016a,b,) using mtDNA, but they suggest that the observed levels of gene admixture (nDNA) indicate that contemporary genetic populations of *D. couperi* have resulted in a single species.

This research (Folt *et al.* 2019) provides strong evidence for a single species of eastern indigo snake and this taxonomy remains widely accepted by the scientific community. Therefore, at this time, the Service considers the eastern indigo snake, *Drymarchon couperi* (Collins 1991), to be one species.

5. Five Factor Analysis (threats, conservation measures and regulatory mechanisms)

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

Continued destruction, modification and curtailment of habitat is the primary threat to species viability for the eastern indigo snake. Fragmentation, destruction, and degradation of habitat are forms of habitat loss that are related but also have discrete effects on habitat suitability. Fragmentation reduces habitat into patches that become too small and unconnected (isolated) to support snakes and increases the risk of direct mortality (*i.e.*, exposure to roads and other edge effects). Outright destruction of habitat reduces the overall amount of habitat available, and degradation reduces resource availability (*e.g.*, burrows) within habitat patches. Each of these forms of habitat loss are further explained below.

<u>Habitat Fragmentation</u>
Eastern indigo snakes have large home ranges, move long distances (especially males) and generally have little home range overlap. Thus, habitat connectivity needs to be maintained to support viable populations and reduce exposure to threats associated with habitat edges. Development, particularly urbanization, creates habitat fragmentation by reducing habitat patch sizes and connectivity as well as increasing edge effects. Another example is primary and secondary roads (such as interstates and highways) that are prominent features of urbanizing areas and can

contribute to isolation and fragmentation of eastern indigo snake populations because they often avoid these type of roads (Bauder *et al.* 2018). However, eastern indigo snakes may eventually cross these road types in search of food and mates when habitat patch sizes decrease (Breininger *et al*. 2004, 2011, 2012). Habitat fragmentation also increases the threat of direct mortality from roads, predators (such as domestic pets) and human persecution. The threat of direct mortality is discussed in more detail in Section 5.e. below.

As urbanization of natural areas progresses, the size of fragmented habitat patches becomes smaller, sustaining fewer snakes and creating islands of fragmented habitat with little or no connectivity within a landscape of unsuitable habitat. However, eastern indigo snakes will likely persist in localities where large, contiguous patches of natural habitat remain. It has been suggested that eastern indigo snake populations that occur on federal, state, or other privately managed conservation lands with multiple patches of at least 2,500 ac (1,000 ha) (*i.e.*, multiple patches is >5,000 ac (>2,023 ha)) may have long-term viability (Moler 1992). However, high edge-area habitat patches (*e.g.*, edges created by roads or human-altered habitats) have greater extinction risk due to direct mortality (Breininger *et al*. 2004, 2011, 2012). A recent study suggested that 2,500 ac is too small to support even a single pair of eastern indigo snakes and suggested about 12,000 to 22,000 ac (5,000 to 9,000 ha) of unfragmented habitat is needed to sustain eastern indigo populations in central Florida (Bauder 2018). Sytsma *et al.* (2012) estimated a reserve size of 10,000 ac (4,047 ha) could support a small population of eastern indigo snakes. However, Hyslop *et al.* (2014) reported that the collective extent of eastern indigo snakes studied (n=31) near Fort Stewart in Southeast Georgia, where the snakes are believed to travel the farthest distance, was about 20,000 to 35,000 ac (8,000 to 14,000 ha). Habitat fragmentation is increasing across the species' range due to urbanization and is projected to continue into the future (Terando *et al*. 2014). However, it is encouraging that nine (9) tracts of conserved land in Georgia and 48 tracts of conserved land in Florida currently supporting eastern indigo snake populations are greater than 12,000 ac (5,000 ha) in size. Securing critical habitat corridors among these large protected habitat patches is needed to reduce negative impacts from fragmentation and sustain populations of eastern indigo snakes across its range.

Habitat Destruction

Throughout the eastern indigo snake's current range, development (*e.g.*, urbanization, agriculture, mining, energy) of natural habitat continues to destroy and degrade eastern indigo snake habitat. Because of its relatively large home range and low degree of home range overlap (Hyslop *et al.* 2014, Bauder *et al*. 2016a), the eastern indigo snake is especially vulnerable to habitat loss (Lawler 1977, Moler 1985, Breininger *et al*. 2004, 2011, 2012; Hyslop *et al*. 2012, Bauder *et al.* 2018).

Habitat impacts due to urbanization are increasing across the species range, particularly in Florida. Lawler (1977) reported that the loss of natural habitat in Florida was increasing and eastern indigo snake habitat was being lost at a rate of 5

percent per year. Zwick and Carr (2006) predicted that by 2060 nearly 3 million acres of natural habitat in Florida would be lost to urbanization. In a more recent study, Carr and Zwick (2016) projected that Florida's population will grow from about 18.8 million to approximately 33.7 million by 2070. This projected population growth is not evenly distributed and may be accommodated by more compact pattern of development and increased protected lands (Carr and Zwick 2016). Generally, central Florida is projected to experience much greater growth and therefore have the greatest increase in developed lands while the Panhandle region is predicted to have the lowest rate of development with significant open space remaining (Zwick and Carr 2006, Carr and Zwick 2016). Although eastern indigo snakes may occupy areas of low density residential housing in the southern portions of its range in Florida, this also represents a potential negative influence to the species because of the increased likelihood of snakes being killed by humans and domestic pets (Breininger *et al.* 2012). The effects of habitat destruction on the eastern indigo snake are likely most substantial along the Florida coasts, in the Keys, and along the high ridges of central Florida, where human population growth is expected to continue to accelerate. In Southeast Georgia, urbanization also is increasing but not as rapidly as Florida. Georgia is mostly forested (>57% in 2012), followed by agricultural land (>18% in 2012) and developed land (>12% in 2012); however developed land continues to increase (USDA 2016).

Solar developments on sand ridges are increasing substantially in Georgia and Florida in recent years (EIA 2018a). In 2010, Florida produced approximately 80,000 Megawatts (MW) increasing to 870,000 MW in 2017. In Georgia, solar development has increased almost 2.5 times more than in Florida, from only 3,000 MW in 2012 and increasing to 2,137,000 MW in 2017. By the end of 2016, Georgia ranked 8th in the nation in solar energy output (EIA 2018b). A number of solar sites are known to have impacted gopher tortoise habitat and the Service has been contacted regarding potential impacts to eastern indigo snakes from solar developments. Some solar utility developers and companies recognize the potential impact that this type of development may have on rare species and their habitat and have begun working with conservation organizations to avoid and minimize impacts via strategic siting assessments (NASA Develop 2018).

Conversion of eastern indigo snake habitat to agricultural land uses (including crop, pasture and timber land) also contributes to habitat destruction and degradation throughout much of Georgia and Florida but to a lesser extent than urbanization (Enge *et al.*2013, USDA 2016, Carr and Zwick 2016). These anthropogenic land uses have variable influences on eastern indigo snakes, but may provide important habitat for them (*e.g.*, Jackson 2013, Ceilley *et al.* 2014, GDNR 2017). However, these land uses are subject to relatively frequent alteration (*e.g.*, herbicides, plowing) and heavy equipment as a result of various production needs (harvesting, planting, ditching, etc.) that may negatively affect eastern indigo snakes (*e.g.*, Godley and Moler 2013, Enge *et al.* 2013). Nevertheless, eastern indigo snakes are known to inhabit extensive canal systems in central and southern Florida. Efforts to restore natural wetlands at these agricultural sites may adversely impact eastern indigo

snakes (Ceilley *et al.* 2014). Agricultural land use practices (*e.g.*, heavy herbicide use, bedding, planting dense stands of *Pinus* spp.) can reduce herbaceous ground cover and negatively influence gopher tortoise populations (CCA 2012, Enge *et al.* 2013) and reduce the availability of gopher tortoise burrows as shelter sites for eastern indigo snakes (Smith *et al.* 2015). Loss of thermally stable, below-ground shelter sites can negativity impact eastern indigo snakes. For example, the decline of the eastern indigo snake in the Florida Panhandle has been attributed to the loss of gopher tortoises and their burrows (Enge *et al*. 2013). While agricultural lands present some risk to eastern indigo snake populations, negative impacts may be offset by conservation of agricultural lands. For example, conserved agricultural land (*e.g.*, conservation easements, Sustainable Forestry Initiative) may reduce impacts from urbanization, improve wildlife habitat, and maintain connectivity among eastern indigo snake populations.

Mining for resources such as sand, limestone, phosphate and heavy minerals continues to increase in Georgia and Florida (GEPD 2017, FDEP 2018), and it adversely impacts eastern indigo snake habitat. Generally, resource mining causes intensive land disturbance over relatively large areas over time. In an effort to reduce overall environmental impacts from mining, mitigation and reclamation of mined lands are often implemented. Land protection (mitigation) in strategic areas may help offset impacts to habitat loss; however, the effectiveness of reclaiming retired mines and restoring habitat suitability for eastern indigo snakes is not known. In Georgia, multiple sand and heavy mineral mines within the range of the eastern indigo snake have been permitted since 2008 (GEPD 2017). In Florida, mining is widespread across eastern indigo snake habitats; for example, phosphate mines disturb between 3,000 and 6,000 acres (1,200 and 2,400 ha) annually in Florida (FDEP 2003).

Habitat modification from any of the above activities can also lead to direct mortality from impacts due to equipment and/or hazardous materials. Heavy equipment can kill or injure snakes. Construction materials and debris can also cause harm to individuals. For example, snakes are particularly vulnerable to entanglement in plastic netting that is often used in matting for erosion control on construction projects (Stuart and Watson 2001), and eastern indigo snake entanglement has been documented (Enge *et al.* 2018). In some cases alternative materials, such as biodegradable matting, may be used to minimize impacts to snakes.

<u>Habitat Degradation (inadequate fire management)</u>

Eastern indigo snakes use a variety of habitats, and patterns of habitat use may shift seasonally. Throughout its range, however, eastern indigo snakes show a strong affinity for upland habitat types, especially longleaf pine habitats. Most of these upland habitat types depend on recurring periodic fires to maintain good quality, especially for maintaining gopher tortoise populations (and their burrows). Natural fires are now often suppressed, and many habitats are degraded from inadequate fire management (Wear and Greis 2002); however, the number of states offering

education and training to certify prescribed fire managers has increased over time increasing the capacity for prescribed fire (Melvin 2018).

The ability to meet prescribed fire goals will likely be reduced with expanding urbanization and climate change. Climate change is predicted to increase wildfire risk and limit the number of suitable burn days due to warming temperatures and regional drying via evapotranspiration regardless of changes in precipitation (Ingram *et al*. 2013). Additional air quality restrictions (*e.g*., PM 2.5) may further limit prescribed fire to reduce "non-essential" carbon emissions. In 2017, state forestry agencies in the southeastern United States ranked weather, capacity, and air quality and smoke management as the top three challenges limiting prescribed burning, with liability/insurance ranking much higher than the national average (Melvin 2018). Nevertheless, it is positive that prescribed burning remains a top priority for land managers in the southeast and this region leads the nation in total acres burned annually, with Georgia and Florida having burned over 1 million acres in 2017 (Melvin 2018).

Gopher Tortoise Populations

Eastern indigo snakes use gopher tortoise burrows for breeding, feeding, sheltering and nesting. In the northern part of their range, eastern indigo snakes depend on gopher tortoise burrows for winter shelter sites. Past declines in gopher tortoise populations are suspected to have negatively affected eastern indigo snake populations, especially in the northern portions of the snake's range (Enge *et al*. 2013). The practice of gassing, introducing gasoline into animal burrows (*e.g.*, gopher tortoise burrows), to expel rattlesnakes, is usually fatal to tortoises, eastern indigo snakes and other commensal species (Speake *et al.*1978, Speake and McGlincy 1981). Gassing of gopher tortoise burrows, one of the factors for listing the eastern indigo snake as threatened under the ESA (Service 1978), is now illegal in Florida and Georgia, but still occurs to some extent (*e.g.*, Dozier 2010). Although still a factor, it is unlikely that gassing is currently having a large negative impact on most eastern indigo snake populations (Enge *et al*. 2013). In the Panhandle Florida, it is suspected that eastern indigo snakes populations declined due to the impact of past human harvest of gopher tortoises for food (Enge *et al.* 2013). Gopher tortoise populations have declined throughout much of their range due to human impacts from gassing and harvest, and habitat conversion and degradation. However, conservation efforts are on-going to protect, manage and restore tortoise populations, which will support conservation and recovery of the eastern indigo snake.

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

Collection of eastern indigo snakes from the wild for the pet trade was a primary reason for listing the species. Furthermore, concerns existed at the time of listing, that publicity from listing of the eastern indigo snake would increase demand for this species in the pet trade, resulting in more collection from the wild. Although some unauthorized wild collection of eastern indigo snakes may still occasionally occur

(*e.g.*, Roebuck 2014), it is thought to have negligible impacts on wild populations (Enge *et al*. 2013). However, the high price of adult eastern indigo snakes in pet trade may incentivize unauthorized activities associated with take and sale. Some eastern indigo snakes from South Florida have extensive, bright red-orange pigment on their heads and necks (a condition found on some adult male snakes and termed "high-red" by herpetoculturists); snakes with this type of coloration are coveted by some breeders and hobbyists, making wild eastern indigo snakes from South Florida potentially attractive for some unauthorized collection. Wild collection remains a concern for the species (FWC 2017) but, State and Federal law enforcement agencies have not reported an increase in cases of illegal take. In addition, activities that will contribute to the species' recovery by enhancing their survival, such as propagation and educational animals, interstate commerce of captive eastern indigo snakes and other recovery actions may be permitted under Section 10 of the ESA. Because cases of illegal take are rare and take for scientific (recovery) purposes are carefully reviewed prior to permitting, overutilization for commercial, recreational, scientific, or educational purposes is not considered to be a substantial threat to the species, at this time.

c. Disease or Predation:

Disease

Since our 2008 5-year review, more investigations have been conducted on potential disease concerns for the eastern indigo snake. A health assessment of 61 wild eastern indigo snakes captured in southeastern Georgia was completed by Knafo *et al.* (2016). Similar to a south-central Florida study (Layne and Steiner 1996), they found that a high percentage of snakes examined during the winter months had scabrous boils and skin lesions varying from superficial wounds to ones extending down to muscle tissue. Based on mark-recapture and health assessment studies, snakes tend to recover from the boil-lesion condition which generally disappears in the summer months (Stevenson *et al*. 2009, Knafo *et al*. 2016). Healthy eastern indigo snakes commonly harbor a wide variety of endoparasites; however, these organisms are generally common in wild snakes and may not be a threat to the species (Foster *et al*. 2000, Knafo *et al*. 2016). However, Metcalf *et al.* (2018) determined that parasite load from *Kiricephalus coarctatus* was a contributing factor in the death of one eastern indigo snake in Collier County, Florida.

Snake fungal disease (SFD) (*Ophidiomyces ophiodiicola*) is an emerging disease that has infected snakes throughout the eastern United States, including eastern indigo snakes in Georgia, and has been implicated in population declines of several snake species (Lorch *et al.* 2015, Chandler *et al*. 2019). Snake fungal disease is a fungal pathogen of endemic and captive snakes in North America and can persist in soil as well as colonize living hosts (Allender *et al.* 2015). In Georgia, an on-going study by Orianne documented 117 SFD infections (positive DNA qPCR test) of 786 snakes sampled with positive results for 22 species, water snakes (genus *Nerodia*) and the eastern indigo snake exhibited the highest rates of infection (43.9%) (Chandler *et al.* 2018, 2019). Scabbing and lesions may indicate SFD infection, but

snakes with scabbing or lesions do not always test positive for SFD (Chandler *et al*. 2018). There is some evidence that SFD may not be a recent development for eastern indigo snakes, at least one snake tested positive in 2004 (Chandler *et al.* 2019), but the extent and prevalence has only recently been investigated. No reports of SFD in eastern indigo snakes have been documented from Florida (Rothermel 2017, Enge 2018), but few individuals from Florida have been examined for SFD. Eastern indigo snakes may exhibit a higher prevalence of SFD during winter months when the snakes are often underground (*e.g.*, in tortoise burrows) in humid environments that may make them more susceptible to developing SFD than at other times of the year. It is possible that eastern indigo snakes may be able to rid themselves of SFD, since recapture data has shown some snakes apparently cleared SFD infection from one year to the next (Chandler *et al.* 2019). The prevalence of SFD is apparently widespread in Georgia, where there is a stronghold for the species, which could negatively impact conservation of the species. However, long-term impacts to the species remain unclear. Additional surveys (especially in Florida), monitoring and research are needed to better understand the extent of SFD and its effects on the eastern indigo snake.

Cryptoporidium serpentis is a protozoa that can cause parasitic disease in snakes. Symptomatic snakes infected with *C. serpentis* often have poor growth, weight loss, regurgitation, and gastric hypertrophy leading to a visible mid-body swelling. It has been proposed that reptiles that are immunosuppressed by stress or concurrent illness are more likely to develop clinical signs. However, some snakes infected with *C. serpentis* can enter a chronic carrier state where they do not show clinical signs, and intermittent shedding of *C. serpentis* does occur. Reported prevalence and fate of snakes with *C. serpentis* in captive and wild populations is not well studied. An extensive survey of over 500 wild and captive reptiles over three continents found a 3% prevalence of infection with *Cryptosporidium* (Upton *et al*. 1989, entire). However, it seems there is a higher prevalence rate in captive populations (Sevá *et al.* 2011, entire) and infection may be more common in the zoological collections than traditionally thought. Partners in Georgia and Florida are currently expanding surveys to research the occurrence of *C. serpentis* in wild snake populations to better understand the distribution and prevalence of this disease in the wild.

Burmese pythons (*Python bivittatus*) are native to Southeast Asia and have been introduced into South Florida where they have rapidly expanded their range and have become a serious concern for the greater South Florida ecosystem including areas such as Everglades National Park (Harvey *et al*. 2010, NPS 2016). They are known to carry novel pathogens and parasites that have been documented to spillover to native snakes in Florida. For example, a pentastome lung parasite (*Raillietiella orientalis*) introduced to North America by Burmese pythons, has been documented in 13 native snakes including two eastern indigo snakes (Miller *et al.* 2018). Dozens of wild-caught Burmese pythons have also recently tested positive for Nidovirus. While no native snakes have tested positive so far, research is underway to better assess the prevalence of Nidovirus in the wild (Miller 2019). Burmese pythons also represent a competitive threat in these areas due to their broad

dietary preferences (Reed 2005). The American alligator (*Alligator mississippiensis*) is the only reptile species documented as Burmese python prey (Harvey *et al*. 2010), and it is unlikely that pythons prey upon eastern indigo snakes. Conversely, an eastern indigo snake was recently documented preying upon a hatchling python in Collier County, Florida (Andreadis *et al.* 2018). The threat of Burmese pythons to eastern indigo snakes is most likely from the risk of spreading exotic pathogens and competition for prey.

Predation

In captive populations, hatchlings do not all emerge at the same time (Alessandrini 2005), with a single clutch taking up to 2 weeks for all eggs to hatch. During this time, the odors present at the initiation of the hatching process could attract predators such as fire ants (*Solenopsis*), skunks (*Mephitis*), coyotes (*Canis*), foxes (*Vulpes*), opossums (*Didelphis*), raccoons (*Procyon*), crows (*Corvus*), and other snakes. Newberry *et al.* (2009) reported depredation of eastern indigo snake eggs by a raccoon in a xeric sandhill near an active gopher tortoise burrow in southeastern Georgia. Laboratory studies demonstrated that red imported fire ants (*Solenopsis invicta*) can penetrate the eggs of another colubrid snake, the yellow rat snake [sic] (eastern ratsnake: *Pantherophis alleghaniensis*) (Diffie *et al.* 2010) and likely caused the mortality of eggs of the rough green-snake (*Opheodrys aestivus)* in the wild (Conners 1998). It is likely that eggs of the eastern indigo snakes can be penetrated, damaged and/or the embryos killed by fire ants. As a result, the red imported fire ant may potentially contribute to the decline of eastern indigo snake populations; however, at present, we have no documented reports of fire ants impacting eastern indigo snakes.

d. Inadequacy of existing regulatory mechanisms:

The eastern indigo snake was listed due to population decline caused by habitat loss, over-collecting for the pet trade, and mortality from gassing gopher tortoise burrows to collect rattlesnakes (Service 1978). As a result of effective law enforcement and the Lacey Act, exploitation for the pet trade has declined but still remains a concern (Moler 1992, FWC 2018). Gassing of gopher tortoise burrows is illegal in both Florida and Georgia, but likely still occurs to some extent. Although still a threat, it is unlikely that gassing currently has a large negative impact on most eastern indigo snake populations (Enge *et al*. 2013). However, habitat destruction and degradation have become much more serious threats and continues at a similar level since our last 5-year review in 2008. Although the Lacey Act provides protection against removal from the wild for the pet trade it does not provide sufficient protection to justify removal of this snake from the Federal List of Endangered and Threatened Species.

Each state within the historical range of the eastern indigo snake provides some protection for the species. In Alabama, the eastern indigo snake is listed as endangered and is a nongame species protected by State regulation (Alabama Department of Conservation and Natural Resources (ADCNR 2018 (AL Code §

220-2-.92)). In Florida and Georgia it is listed as threatened (FWC 2017, GDNR 2018 (FL Code § 68A-27.003, GA Code § 391-4-10)). In Mississippi it is listed as endangered (MNHP 2015, (MS Code § 49-5-107)). The South Carolina Department of Natural Resources has removed the eastern indigo snake from its list of protected species because the lack of any specimens from the state made it impossible to verify the species' historic or current presence (Bennett 2008). Alabama, Florida, Georgia, and Mississippi include the eastern indigo snake as a priority species for conservation action in their State Wildlife Action Plans. The protections provided by each state vary. However, most state laws focus on prohibitions against direct take of eastern indigo snakes, such as removing snakes from the wild and possessing, killing, exporting, or selling them, although Georgia regulations also protect the habitat of listed species on public land (GDNR 2018). State regulatory mechanisms are not adequate because they do not prohibit take of eastern indigo snakes as an incidental consequence of incompatible land use. However, in Florida, permits must be obtained before any land clearing or development takes place where gopher tortoises occur. This requirement may offer some indirect protection for eastern indigo snakes as a commensal species.

Since the listing of the eastern indigo snake, the Lacey Act has provided protection against the removal of snakes from the wild for the pet trade. However, it is not adequate to protect against the threats of habitat destruction and degradation that continue to threaten the eastern indigo snake.

Protection is afforded to this species under Sections 7, 9, and 10 of the ESA. Projects that may cause impacts to eastern indigo snake populations are assessed to ensure actions are not likely to jeopardize the continued existence of the species. If this threshold is not reached, but lesser impacts will occur, incidental take of the species may be permitted. The result of this standard of protection has been the continued incremental loss of habitat for the eastern indigo snake. In addition, Section 7(a)(1) of the ESA requires that Federal agencies use their authorities to further the conservation of listed species. However, to date, no known Section 7(a)(1) conservation management plans have been written for the eastern indigo snake.

While the ESA prohibitions include those for incidental take, state and federal regulatory prohibitions alone are likely inadequate to conserve and recover this species. This is because eastern indigo snakes require active conservation programs to effectively restore, sustain, and increase habitat and populations. Across much of its range, eastern indigo snakes depend on fire-maintained ecosystems, particularly those that support gopher tortoise populations. In addition, natural recolonization of eastern indigo snakes into portions of their former range would be difficult despite their ability to move relatively long distances. Exposure to threats inherent in fragmented habitats, including road mortality, predation, and intentional human persecution, combine to challenge natural modes of population expansion. Therefore, active repatriation programs are necessary.

Other existing laws and regulations like the National Forest Management Act for National Forests, Sikes Act for Department of Defense Installations, and National Wildlife Refuge System Improvement Act include provisions authorizing these agencies to identify, fund, and conserve wildlife. In addition Section 404 of the Clean Water Act is the primary Federal law that has the potential to provide some protection for wetland sites on private land that are occupied seasonally by eastern indigo snakes, but the success of protecting eastern indigo habitat by implementing this regulation is unknown. Several of the laws and regulatory mechanisms identified above have supporting allocations that can be used to help restore and sustain eastern indigo snake populations and their habitat. State and other regulatory mechanisms described above are inadequate to recover and protect the eastern indigo snake. The ESA, with successful implementation of the recovery plan and conservation programs, remains vital to eastern indigo snake recovery.

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

Direct Mortality

Continued human population growth will increase the potential of eastern indigo snake mortality from both intentional and unintentional killing. This will likely occur from direct mortality by people and domestic animals, use of chemicals to control disease and pests, and road mortality. Deliberate killing of snakes is common (Andrews *et al.* 2008) and studies have shown that 3% of motorists intentionally hit reptiles (Ashley *et al.* 2007, Crawford and Andrews 2016). Life history traits such as the snake's diurnal nature, large body size and large home range size (that often results in the necessity of crossing roads), make them more susceptible to being observed and deliberately killed.

An increase in the number of mortalities from vehicles on roads may result in declines or extirpation of populations. At a study site in Florida, researchers compared the catch-per-unit-effort during 1981to1983, and 2005 to 2009, and they found that the eastern indigo snake population had declined by greater than 95 percent (Godley and Moler 2013). Potential eastern indigo snake habitat did not appear to substantially decline or change in quality over the three decades of this study. The researchers suggested evidence supported cumulative, unsustainable mortality from vehicular traffic as a primary factor in the population decline (Godley and Moler 2013).

Because of the cryptic nature of eastern indigo snakes and the difficulty surveying for them, many records are from sightings on roads, either dead on road (DOR) or alive on road (AOR). A preliminary summary of DOR/AOR data by Enge, Stevenson, Chandler and Elliott (unpublished data), noted in Georgia and Florida that over 200 snakes were observed on roads since the year 2000 with most of these sightings being DORs. These 200 snakes are likely only a very small fraction of the actual DOR/AORs because many go unreported and DORs are often scavenged by other animals.

While eastern indigo snakes will cross roads, telemetry data indicate that they prefer areas away from roads (Breininger *et al.* 2012, Hyslop *et al.* 2014, Bauder *et al.* 2018). Breininger *et al.* (2012) found that eastern indigo snakes had relatively high survival in conservation core areas, but their survival was greatly reduced along roads and in suburbs. They found study animals dead along roads, including individuals intentionally killed by humans (Hyslop *et al.* 2009c, Breininger *et al.* 2012). Hyslop *et al.* (2014) did not record any radio-tracked study snakes outside boundaries created by paved roads, but found two eastern indigo snakes not included in the telemetry study dead on these roads. The radio-tracked snakes were found to regularly cross unpaved roads. In central Florida, 13 radio-tracked snakes did not cross paved roads, but five DOR eastern indigo snakes were found during the study (Smith 2006). Bauder *et al.* (2018) suggested that eastern indigo snakes avoid larger paved roads (primary and secondary roads such as interstates and highways), but readily cross smaller paved roads (tertiary roads such as two-lane rural county roads). In populations with low numbers of individuals, any additional negative factors impacting populations could cause local extirpations. This is especially true in long-lived snakes, such as the eastern indigo snake, that make long-distance movements, have low reproductive rates, and have low natural densities. Models have demonstrated that protection of adult eastern indigo snakes, which are the age class most likely to be killed on roads, is the most important factor in survival of a population (Hyslop *et al*. 2012).

Climate Conditions

Changing climate conditions are likely to affect eastern indigo snakes. Sea level rise from climate change will impact coastal populations due to inundation of habitat and increased saline environments. Florida has undergone drastic changes in size and shape over long geologic periods due to sea level changes that influenced the distribution and genetic diversity of the eastern indigo snake (Kyrsko *et al*. 2016b). Some eastern indigo snakes have been observed in saline habitats (mangrove swamp) (Metcalf 2017) suggesting the species has some tolerance to salinity. Habitat loss and degradation of today's landscape reduces connectivity and creates movement barriers. For example, Metcalf (2017) suggests that a heavily trafficked road (SR 951) at Rookery Bay Reserve may block snakes in this coastal population from escaping inland to avoid rising sea levels.

Impacts of shifting temperatures and rainfall due to climate change are variable but may cause indirect effects, such as changes in dependence on gopher tortoise burrows for winter shelter sites and shifts in prey base. However, since the eastern indigo snake has a diverse diet, dietary needs for the snake will likely be met with changing climate conditions. Shifting temperature and rainfall can negatively affect the ability to conduct prescribed fire (Melvin 2018) which is an important management tool for maintaining good quality habitat. In the SSA, 22 eastern indigo snake populations were predicted to be impacted by sea level rise in the future with nine (9) populations losing more than 10% of their habitat and seven (7) predicted to become extirpated (Service 2019). To minimize risk of habitat loss from sea level rise and variable effects from changing weather, maintaining

connectivity among habitat patches so that snakes can move in response to changing climate conditions will be essential for long-term viability.

Pesticides

Because the eastern indigo snake is an apex predator, pesticides that bioaccumulate (become more concentrated) through the food chain may present a potential hazard (Lawler 1977). For example, secondary exposure to rodenticides used to control black rats may result in mortality to eastern indigo snakes in developed areas (Speake 1993). Although Knafo e*t al.* (2016) found that organochlorine (OC) pesticides and their by-products were all below detection limits in their eastern indigo snake blood samples, Lawler (1977) examined body fat where high accumulation of these compounds were detected. Both blood and fat samples may be needed to accurately document variable levels of OC exposure (Rainwater 2005). Herbicides used on crops or for silviculture may have negative effects on eastern indigo snake populations (Speake 1993). There are no documented cases of eastern indigo snake mortality from pesticide use. While there may be some indirect effects to individuals, negative impacts from pesticide use is not considered a threat to the species at this time.

D. Synthesis

The eastern indigo snake has been extirpated in Alabama and Mississippi and, since listing under the ESA its distribution has further contracted in other areas, particularly in the Florida Panhandle due to the decline of gopher tortoise populations (Enge *et al.* 2013). Wild collection of eastern indigo snakes for the pet trade and gassing of gopher tortoise burrows are no longer considered to be substantial threats although they still occur to some extent. Habitat destruction, modification, and curtailment, however, remain significant threats to the species' recovery and long-term viability. Since the last review (Service 2008), significant progress has been made in our understanding of the species' distribution, life history and habitat requirements which has supported development and implementation of conservation strategies for the species. This new information was summarized and assessed in the eastern indigo snake's recent SSA (Service 2019).

Fifty-three (53) potential populations were estimated in the SSA (Service 2019). Of these populations, resilience was classified based primarily on habitat conditions as follows: 8 very low, 28 low to medium-low, 13 medium to medium-high, and 4 high. The overall current population resiliency is medium to low. Population growth rates are unknown due to the lack of data on this cryptic species. The contemporary distribution of the eastern indigo snake represents the species' known ecological and genetic diversity, but the redundancy of populations has decreased. Most notable are the loss of populations in the Panhandle region (includes parts of Alabama, Florida, Georgia, and Mississippi) and a contraction of the distribution in the southern extent of the Peninsular Florida region, including the Florida Keys. The Panhandle and North Florida regions have zero (0) highly resilient populations, thus limiting overall redundancy.

Today, the primary threats to the long-term viability of the species are from habitat fragmentation and loss due to land use changes, especially urbanization. Urbanization includes a variety of negative impacts that remove or alter available habitat or impact snakes directly including: residential and commercial development, road construction and expansion, direct mortality (*e.g.*, road mortality, human persecution, domestic pets), invasive species, predation and inadequate fire management. Habitat loss for coastal populations due to sea level rise is also an increasing risk. Snake fungal disease has emerged as an additional negative factor, but, impacts to long-term viability remains uncertain, and research is on-going.

The cooperation of many partners to implement conservation efforts (*e.g.*, implementing State Wildlife Action Plans) can help mitigate the threats and positively influence long-term viability of the species. Land conservation has increased in some areas, especially where there are on-going efforts to conserve gopher tortoise populations. These conservation efforts have diminished the threat of gassing gopher tortoise burrows and will have lasting conservation benefits for the eastern indigo snake across much of its range. Land management, particularly use of prescribed fire, to maintain gopher tortoise habitat, remains a challenge. Maintaining habitat connectivity so that snakes can move in response to changing habitat conditions will be essential for long-term viability.

To accelerate recovery, repatriation of eastern indigo snake populations in areas of extirpation in the Panhandle region (Florida and southern Alabama) is underway to increase redundancy of populations in this region. The two active repatriation sites show some signs of success but additional releases of snakes over the next 5-10 years is needed. Long-term monitoring will be needed to determine the success of re-establishing populations.

Based on future urbanization and sea level rise models, eastern indigo snake population resiliency is predicted to be low to very low in the future. Future ecological and genetic representation decreases due to loss of resilient populations in the North Florida region, lowering the species' potential to adapt to changing environmental conditions. Low (in Southeast Georgia and Peninsular Florida) to no (in Panhandle and North Florida) redundancy in representative areas increases the species' risk to catastrophic events. One population is predicted to remain highly resilient without targeted conservation efforts aimed to protect and repatriate populations. Therefore, based on our review of the best available scientific and commercial information, which indicates a decline in resilient populations; and the five-factor analysis that demonstrates increasing risk from potential threats in the foreseeable future, the Service concludes that the eastern indigo snake continues to meet the definition of a threatened species.

Additional habitat protection to create conservation areas large enough to support viable populations and to ensure connectivity among populations is essential. Commitments to manage and implement long-term monitoring of select eastern

indigo snake populations across the species' range are needed to better understand how populations are responding to landscape conditions. Monitoring programs and additional research will aid our understanding of which demographic and habitat factors influence viability as well as track the significance of other key factors such as disease and predation. If protected populations are distributed across the species range and are well-managed and monitored to reduce threats of habitat loss, degradation and fragmentation such that sufficient habitat quantity and quality exist for the species to remain viable into the foreseeable future, it is possible to recommend that the eastern indigo snake be considered recovered and suitable for delisting.

III. RESULTS

A. Recommended Classification:

No change is needed.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Protect existing eastern indigo snake populations through appropriate habitat management and conservation techniques identified in site-specific management plans.
2. Protect habitat via land acquisition along corridors of known occupied habitats, such as the river corridors of southeastern Georgia and the central ridge systems of Florida.
3. Work to obtain protection and develop appropriate management plans for sites on privately-owned lands.
4. Study and implement long-term monitoring of eastern indigo snake populations on selected sites across the range of the species.
5. Continue efforts to develop reliable and efficient survey methods.
6. Expand on the initial efforts by Breininger *et al*. (2004) and Bauder *et al*. (2018) to determine the appropriate size, acceptable fragmentation level, habitat types, and geographic location for eastern indigo snake reserves across the species' range.
7. Establish a centralized range-wide Geographic Information System (GIS) database for data storage, analyses, and recovery review.
8. Continue reestablishment efforts of the eastern indigo snake in areas where the species has been extirpated.
9. Further develop a range-wide eastern indigo snake habitat model that incorporates the variety of habitats used by the species throughout its range.
10. Use GIS data to examine landscape level connectivity and habitat quality within the range of the eastern indigo snake. Use these data to prioritize sites for acquisition and habitat management to support recovery of the species.
11. Develop a range-wide conservation action plan that provides appropriate avoidance, minimization and compensation recommendations to reduce impacts to eastern indigo snakes.

12. Continue to survey and monitor for Snake Fungal Disease (*Ophidiomyces ophiodiicola*), and other pathogens across the range of the eastern indigo snake and research the effects of the disease on populations.
13. Continue to provide public education on the values, attributes, and protected status of the eastern indigo snake.
14. Revise recovery plan and establish measurable recovery criteria.
15. Officially adopt the change in nomenclature of eastern indigo snake to the species *Drymarchon couperi*.

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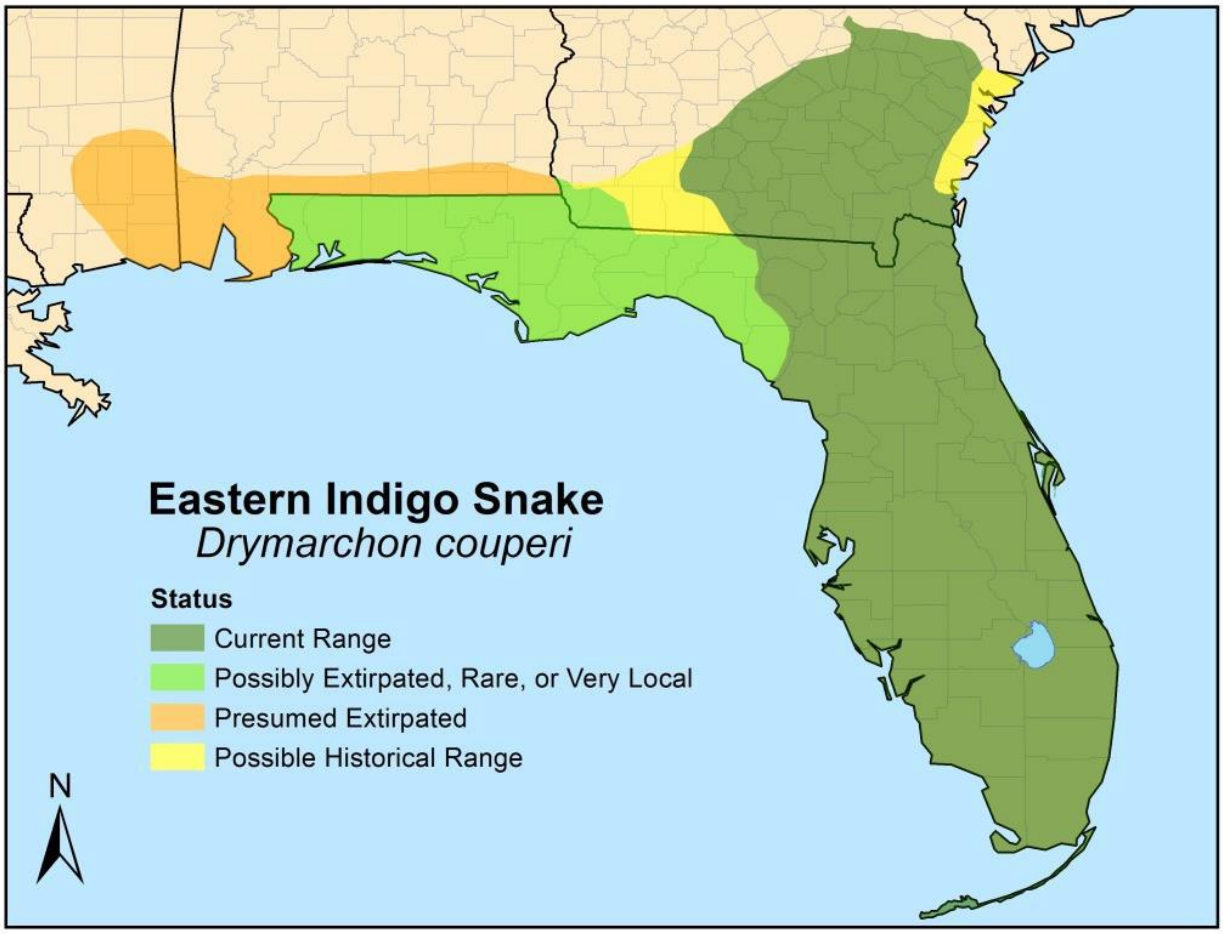

Figure 1. Historical and current range of the eastern indigo snake. Map by Javan Bauder.

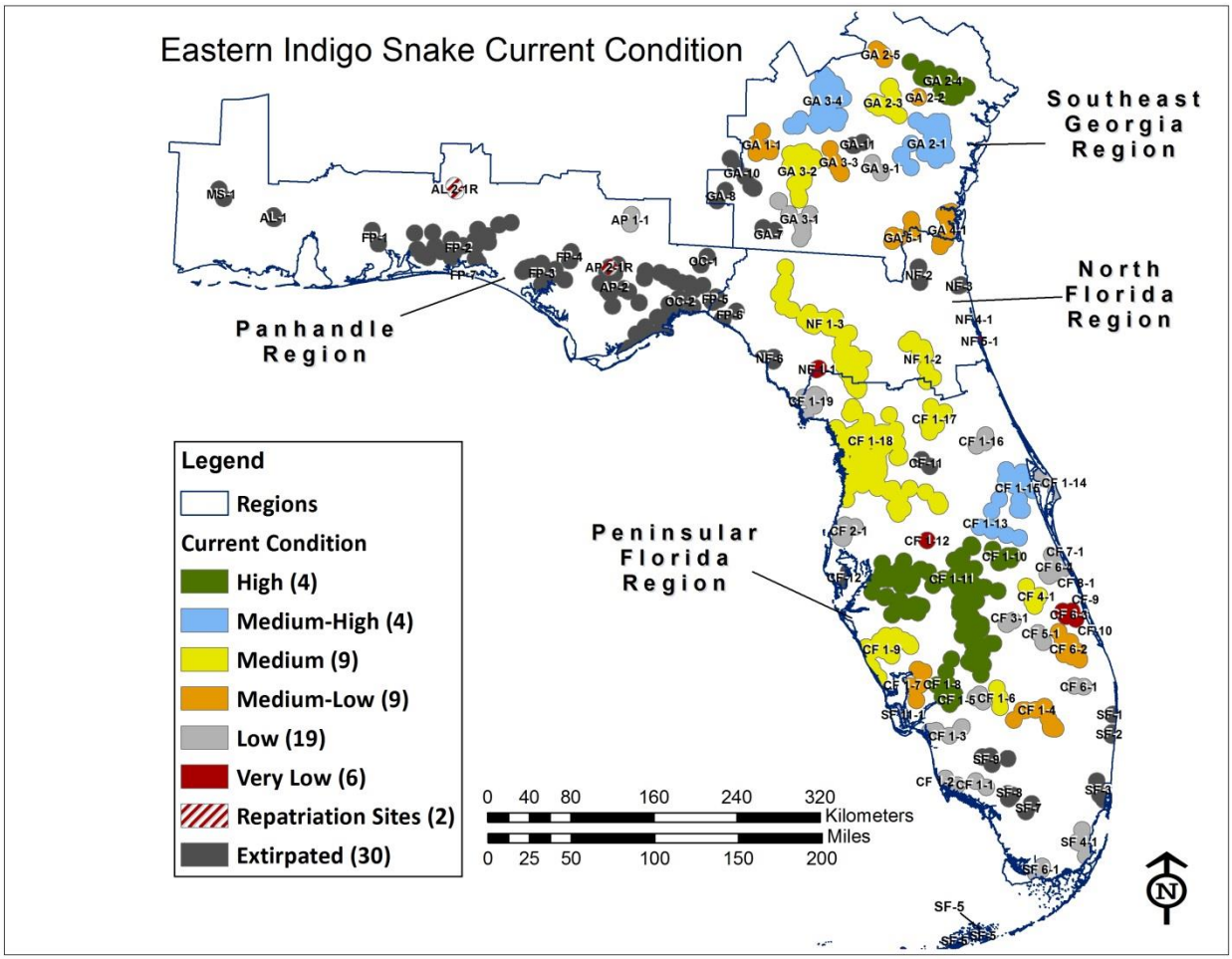

Figure 2. Distribution of eastern indigo snake populations and current resiliency condition classes.

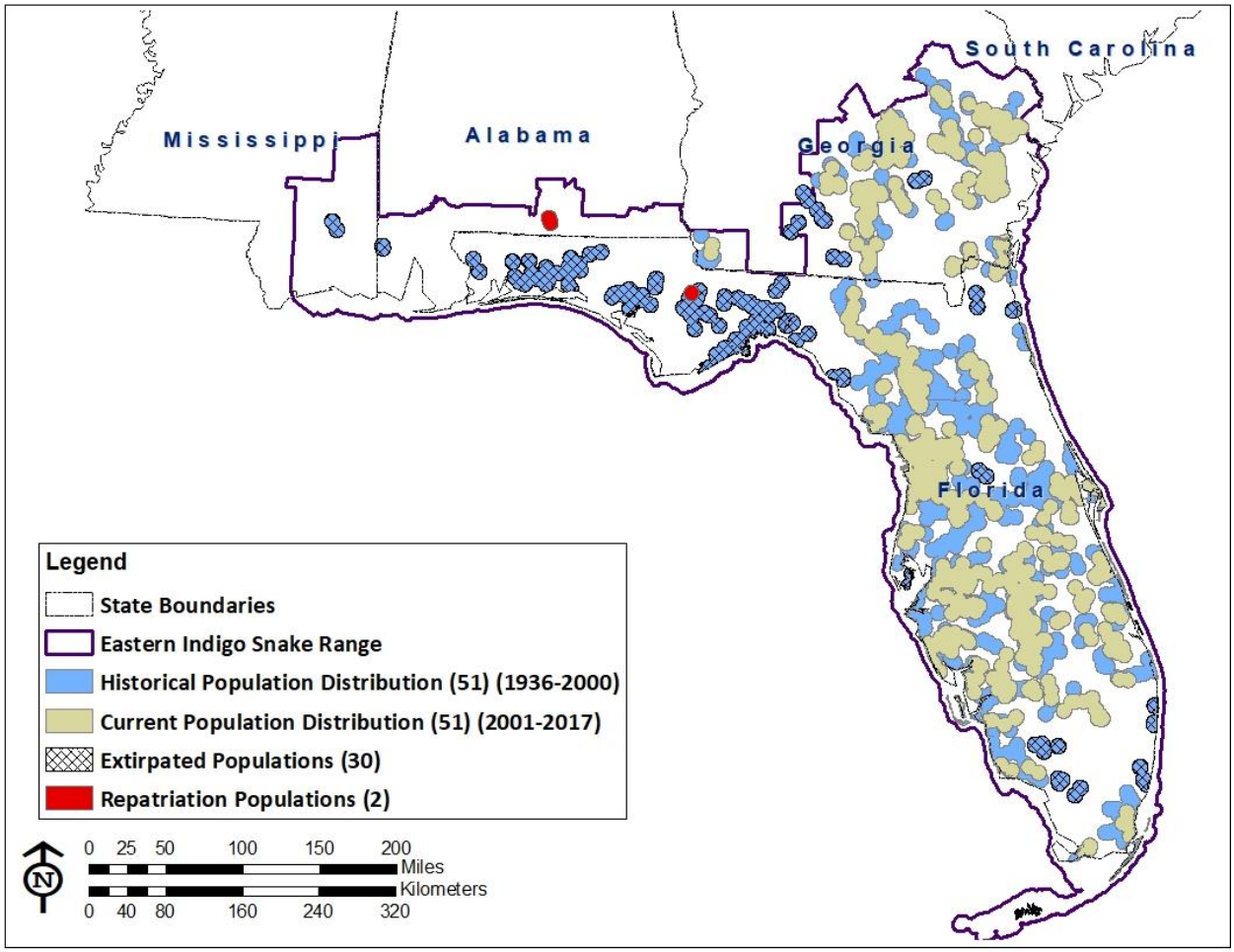

Figure 3. Historical and current distribution and extent of eastern indigo snake populations.

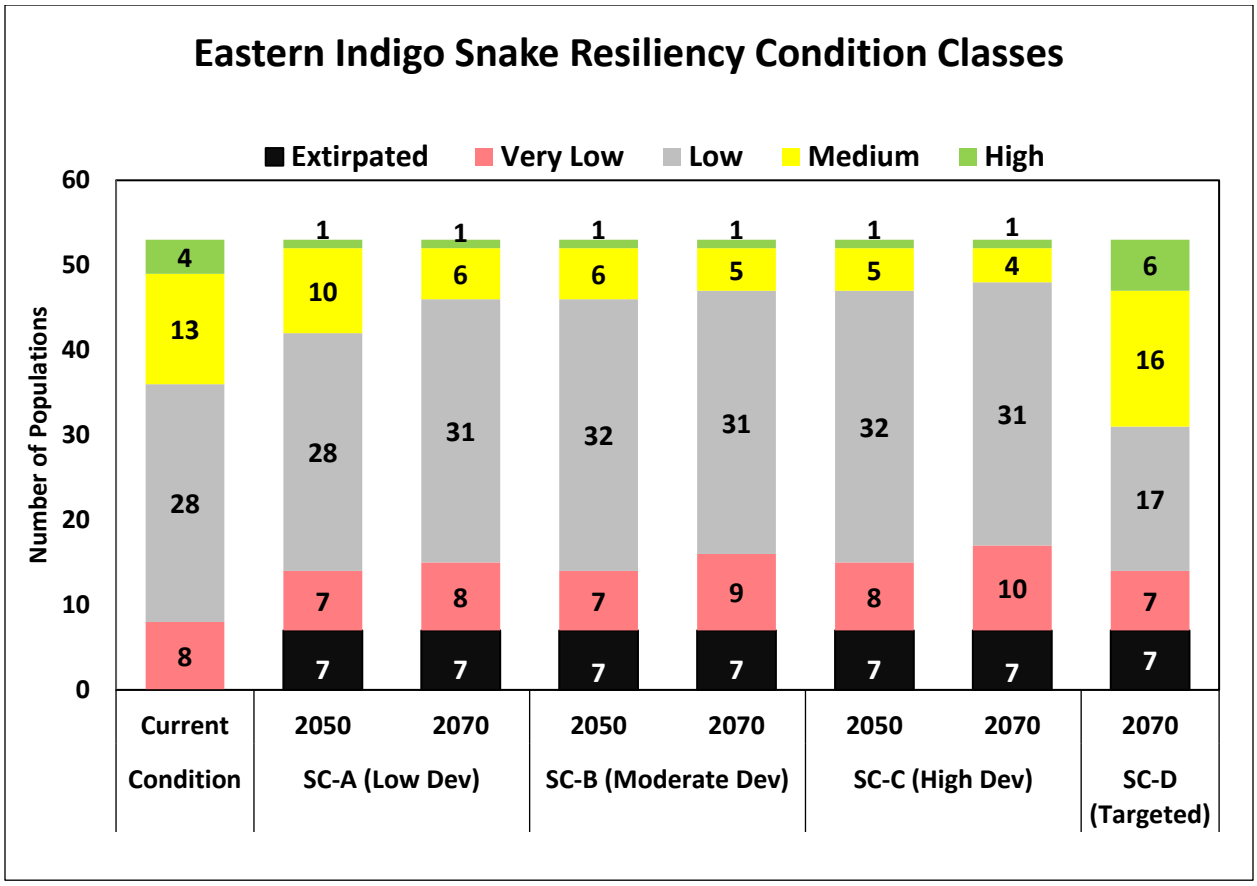

Figure 4. Comparison of the number of eastern indigo snake populations in each resiliency condition class across all scenarios (SC) and time steps (Year 2050 and 2070). Low, Moderate and High Dev corresponds with level of predicted development (urbanization). Targeted represented the targeted conservation scenario. All future scenarios incorporate the intermediate-high sea level rise scenario predicted by National Oceanic Atmospheric Administration (NOAA). There are 30 extirpated historical populations not shown on graph. Refer to the Eastern Indigo Snake SSA (USFWS 2018) for more detail on analysis and explanation of scenarios.

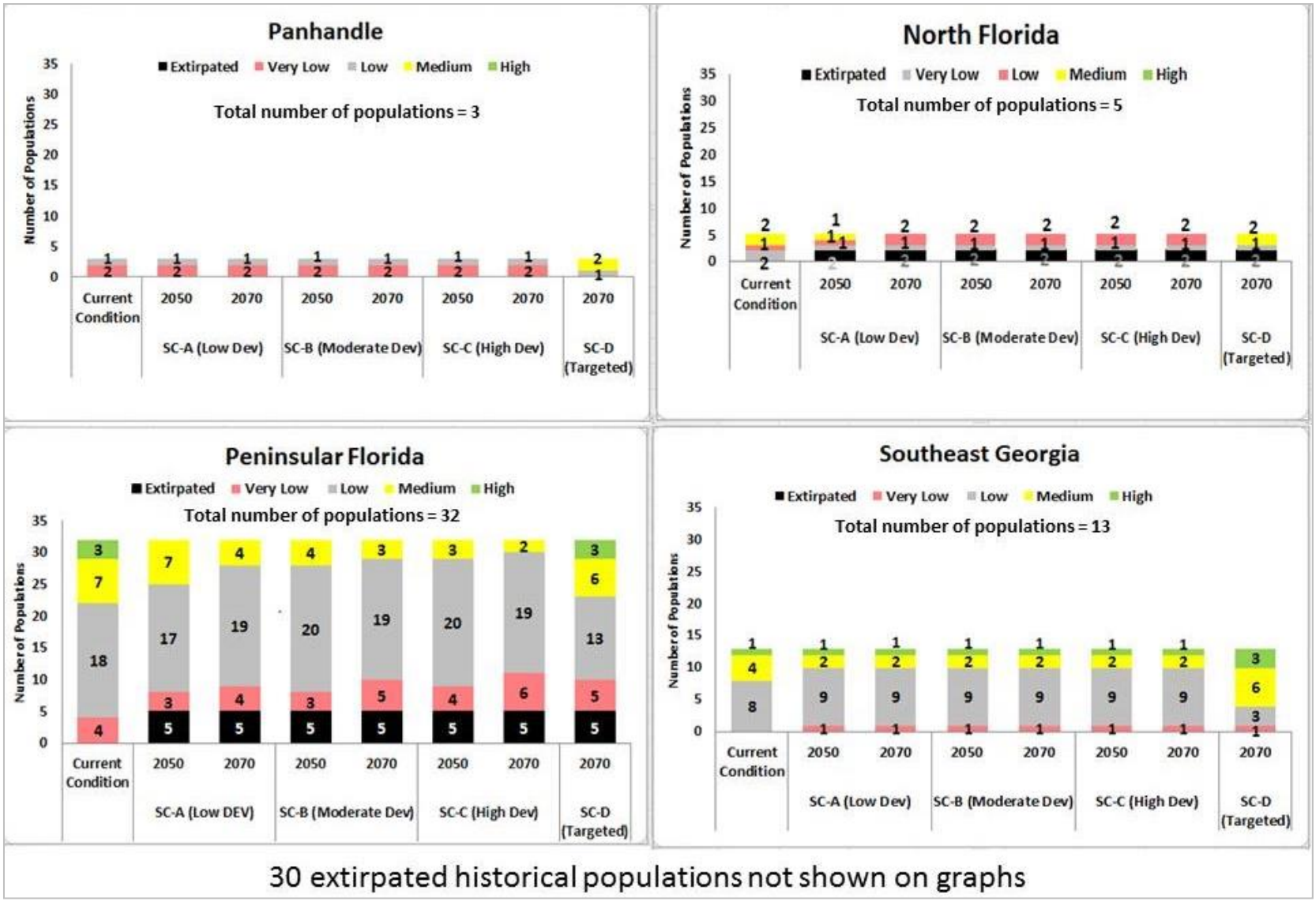

Figure 5. Future eastern indigo snake populations and their resiliency condition classes by Regions.

Table 1. Percent of current population extent (area) within each resiliency condition class by scenario.

Scenario	Resiliency Class			
	High (%)	**Medium (%)**	**Low (%)**	**Very Low (%)**
Current	17	34	45	4
Scenario A 2050 (Low Dev)	3	30	45	22
Scenario A 2070 (Low Dev)	3	25	48	24
Scenario B 2050 (Moderate Dev)	3	25	50	22
Scenario B 2070 (Moderate Dev)	3	13	59	25
Scenario C 2050 (High Dev)	3	13	60	24
Scenario C 2070 (High Dev)	3	12	59	26
Scenario D 2070 (Targeted)	14	42	20	25

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Eastern Indigo Snake (*Drymarchon corais couperi*)

Current Classification: Threatened

Recommendation resulting from the 5-Year Review

__X__ No change is needed

Review Conducted By: Michele Elmore, Georgia Ecological Services Filed Office

FIELD OFFICE APPROVAL:

Donald Imm, Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve _____Date__30 Aug 2019_____

APPENDIX A: Summary of peer review for the 2019 5-year review of the Eastern Indigo Snake (*Drymarchon couperi*)

A. **Peer Review Method:** Peer review was coordinated by the Service's North Florida Ecological Services Field Office, Jacksonville, Florida. Seven peer reviewers were selected by the Service for their knowledge of and expertise with the Eastern Indigo Snake. Responses were received from three of the seven of the invited peer reviewers.

Peer Reviewers: Dr. Brian Folt, Post-doctoral Researcher, Alabama Cooperative Fish and Wildlife Research Unit, School of Forestry and Wildlife Sciences; Multiple reviewers from the Florida Fish and Wildlife Conservation Commission; and Matt Elliott, Assistant Chief, Wildlife Conservation, Wildlife Resources Division, Georgia Department of Natural Resources.

B. Peer Review Charge: See attached text from the peer review invitation letter.

C. Summary of Peer Review Comments: All three peer reviewers agreed with the overall findings and justification of the review. One reviewer noted that, although genetics of island populations of eastern indigo snakes has not been explicitly studied, population genetics of snakes on Sanibel Island were unique compared to other populations they studied; the decision to consider eastern indigo snakes as a single species has been widely accepted; and that successful population repatriation at the two restoration sites will likely require a higher number of released snakes to achieve an acceptable low extinction risk at each site. Another reviewer noted that additional genetic research is planned to assess the diversity of the captive eastern indigo snake population compared to wild populations; the potential risk of other diseases, such as *Cryptoporidium serpentis* and Nidovirus to eastern indigo snakes; and that although state regulations prohibit collection from the wild, this type of collection continues to be a concern for the species. Another reviewer provided additional data on amount of land protected in Georgia since 2008 that is believed to support eastern indigo snake conservation efforts and provided an update on monitoring efforts. All reviewers provided clarifying comments and edits.

D. Response to Peer Review: Comments were incorporated, as necessary, specifically: 1) in Section II.C.2 the reference Folt *et al.* (2019) regarding genetic uniqueness of eastern indigo snakes on Sanibel island was added; 2) clarification added in Section II.C.4 regarding taxonomic acceptance; 3) clarification added in Section II.B.3.(2) regarding the repatriation program; 4) information added in Section II.B.3.(2) regarding the captive population genetics study; (5) in Section II.C.5.c. a discussion was added regarding *Cryptoporidium serpentis* and Nidovirus and recommended studies of pathogens in addition to snake fungal disease was added to Section IV.; (6) noted in Section II.D that collection of wild snake still occurs to some extent; and (7) eastern indigo snake habitat protected since 2008 and monitoring data in Georgia were updated in Section II.B.3(1).

Peer Review Invitation Letter Text

On May 7, 2018, the U.S. Fish and Wildlife Service published a notice in the *Federal Register* (83 FR 20092) announcing a five-year review of 35 federally listed species, including the Eastern indigo snake. The purpose of five-year reviews is to ensure that the classification of species as threatened or endangered is accurate and reflects the best available information.

Following Service current policy and guidelines on the process to conduct independent peer review, we are assisting our Georgia Ecological Services Field Office to complete peer review of the science in the 5-year review for this snake. You have provided data used to review the status of the Eastern indigo snake and are knowledgeable about it or reptiles like it. Therefore, in order to ensure that the best available information has been used to conduct this five-year review, we now request your peer review of the attached document. Specifically we ask for comments on:

• Have we assembled the best available scientific and commercial information?
• Is our analysis of this information correct and properly applied?, and
• Can you identify any additional new information on the Eastern indigo snake that has not been considered in this review?

Please note that we are not seeking your opinion of the legal status of this species, but rather that the best available data and analyses were considered in re-assessing its status.

As part of the peer review process, we must evaluate the potential for conflicts of interest with the subject species or the action. We therefore ask that you fill out the attached Conflict of Interest form and return it with any notes, comments, or questions that you are willing to provide as your peer review.

We appreciate your interest in furthering the conservation of rare plants and animals by becoming directly involved in the review process of our Nation's threatened and endangered species. Your review and comments will become a part of the administrative record for this species, and you can be certain that your information, comments, and recommendations will receive serious consideration.

We hope that you view this peer review process as a worthwhile undertaking. We ask that you review the attached draft and submit comments to the Southeast Regional Office, to Lourdes Mena. Your comments can be provided to me by email lourdes_mena@fws.gov or by letter (7815 Baymeadows Way, Suite 200, Jacksonville, FL 32256) and should be received by August 16, 2019, to help us complete the final 5-year review for signature. If you have any questions, please call Lourdes Mena at 904-731-3134. Thank you in advance for your assistance.

APPENDIX B: Summary of public comments and information received from the *Federal Register* notice initiating a 5-year status review of the Eastern indigo snake (83 FR 20092).

We received three public comments during the open comment period in 2018. These came from the Conservancy of Southwest Florida, Center for Biological Diversity, and Georgia Power Company.

1. On behalf of the Conservancy of Southwest Florida, Amber Crooks (Environmental Policy Manager) highlighted the following in her response: 1) substantial changes in habitat condition and habitat loss since our last 5-year review (2008) continues to be a significant threat to the species. For Southwest Florida, population increases and examples of large developments and road projects were provided, and 2) the inadequacy of existing regulatory mechanisms and the availability of new data. In this 5-year review and supported by the SSA (Service 2019) we included a in depth discussion regarding the significance of habitat modification and loss as a primary threat to the eastern indigo snake and that development pressures are most significant in Florida (Section II.C.5.a, and throughout). We also describe the inadequacy of ESA and state regulations to conserve and recover the species (Section II.C.5.d.), and provide key recommendations to help further the conservation of the species (Section IV). Furthermore, information regarding habitat use and movement in Florida has been incorporated into our analysis.

2. On behalf of the Center for Biological Diversity (CBD), Elise Pautler Bennett (Reptile and Amphibian Staff Attorney) provided a review of the body of scientific information that has become available since the last 5-year review (2008). This new information addresses habitat needs and use across the species' range, genetic diversity, impacts to habitat from development (including mining), and information on disease. The Service has incorporated, the literature reviewed by CBD, into this 5-year review (Section II.B.3. and Section II.C.) and the supporting SSA. In addition, CBD commented on the need for an updated recovery plan. As described in this 5-year review the Service is in the process of issuing a revised recovery plan with measurable recovery criteria (Section II.B.3.(3) and Section IV).

3. On behalf of the Georgia Power Company, Jim Ozier (Environmental & Natural Resources) provided new occurrence data for the Kings Bay Naval Submarine Base in Georgia, where a solar generating facility is located. The Service included this new occurrence record in our SSA analysis and distribution maps (Section II.C.2).