

Eastern Indigo Snake
Drymarchon couperi

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Southeast Region
Mississippi Ecological Services Field Office
Jackson, Mississippi

5-YEAR REVIEW

Eastern indigo snake (*Drymarchon couperi*)

I. GENERAL INFORMATION

A. Methodology used to complete the review: In conducting this 5-year review, we relied on available information pertaining to historic and current distributions, the life history, and habitats of this species. We announced initiation of this review and requested information on the species in a published Federal Register notice (see I.C.1 below). We reviewed information in our files, and solicited information from knowledgeable individuals including those associated with academia and state conservation programs. Our sources include the final rule listing this species under the Endangered Species Act; the Recovery Plan; peer reviewed scientific publications; unpublished field observations by Service, State and other experienced biologists; unpublished survey reports; and notes and communications from other qualified biologists or experts.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 for their review (refer to Appendix A). Comments were evaluated and incorporated where appropriate into this final document. No part of the review was contracted to an outside party.

B. Reviewers

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

Lead Field Office – Jackson, MS: Linda LaClaire, 601-321-1126

Cooperating Field Offices – Daphne, Alabama: Dan Everson, 251-441-5837

Panama City, Florida: Caroline Stahala, 850/769-0552

Jacksonville, Florida: Annie Dziergowski, 904-232-2580, ext. 116

Vero Beach, Florida: Marilyn Knight, 772-562-3909, ext. 297

Brunswick, Georgia: Robert Brooks, 912-265-9336, ext. 25

Charleston, South Carolina: Lora Zimmerman, 843-727-4707, ext. 226

C. Background

1. Federal Register Notice citation announcing initiation of this review: September 8, 2006. (71 FR 53127)

2. Species status: Declining (2007 Recovery Data Call)
Status assessment based on the decline in available habitat (both quantity and quality) across the range of the eastern indigo snake.

3. Recovery achieved: 1= 0-25% recovery objectives achieved (2007 Recovery Data Call). Recovery achieved assessment based on lack of ability to estimate the number of extant viable populations of the eastern indigo snake.

4. Listing history

Original Listing

FR notice: 43 FR 4026

Date listed: January 31, 1978

Entity listed: Subspecies

Classification: Threatened

5. Review History:

Five year review completed: 1992, 1984; no changes were proposed for the status of the eastern indigo snake.

Recovery Data Call: 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000

6. Species' Recovery Priority Number at start of review (48 FR 43098): 12C

Degree of Threat: Moderate with some degree of conflict between the species' recovery efforts and economic development.

Recovery Potential: Low

Taxonomy: Subspecies

7. Recovery Plan or Outline:

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 reconsider the classification of this species with regard to designation of DPSs? No.

B. Recovery Plan and Criteria

1. Does the species have a final, approved recovery plan? Yes

2. Does the recovery plan contain recovery (i.e. downlisting or delisting) criteria? No. The recovery plan does not have objective measurable recovery criteria relevant to the five listing factors since the plan was

completed prior to that requirement (U.S. Fish and Wildlife Service 1982). The recovery plan states that the ultimate recovery plan objective should be to ensure that numerous indigo snake populations exist and 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 snakes that occur in south Florida which included general criteria for the eastern indigo snake in that region (U.S. Fish and Wildlife 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 requires revision to reflect the best available information on the species' current distribution, taxonomy, and threats. At the time of listing, removal of snakes from the wild for the pet trade was a serious threat. Due to listing the snake under the Endangered Species Act (ESA), this threat has been considerably reduced. However, the threat of habitat destruction and degradation has become a much more serious threat. Thus, the protection of the Lacey Act does not provide sufficient protection to justify removal of the eastern indigo snake from the Federal List of Endangered and Threatened Species and its threatened status is still warranted. (See section 4.0 for recommendations to revise the plan).

3. **List the recovery criteria and discuss how each criterion has or has not been achieved.** Since this plan does not have criteria, we have listed below the principal recovery tasks identified in the Eastern Indigo Snake Recovery Plan and present progress made towards those recovery tasks.
 - (1) Maintain and protect existing populations of eastern indigo snakes.
Status: Due to the difficulties of observing and capturing indigo snakes, even in areas where they are known to occur, the viability of existing populations is unknown. Sites with historical and /or current (post-1999) records for the species are considered to be supporting populations of the eastern indigo snake. Habitat protection and management plans need to be implemented for sites occupied by

eastern indigo snake populations to ensure their long-term survival. Protection needs to be pursued for the remaining privately-owned sites, with primary focus on the larger populations.

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. Protected longleaf pine habitats, which the indigo occupies in Georgia and the northern part of its Florida range, are being managed by both federal and state agencies as well as non-profit groups such as The Nature Conservancy. In addition, Project Orianne has been recently initiated (2007) by a group of herpetologists, supported by a private donor in conjunction with the Wildlife Conservation Society, to develop strategies to maintain and protect populations of the eastern indigo snake in Florida and Georgia. Specific strategies are currently under development but will probably include land acquisition, habitat management, and captive propagation. At this time, establishment of an organization to specifically target eastern indigo snake conservation is being considered.

In a recent assessment of the distribution and status of the eastern indigo snake in Georgia, Stevenson (2006) reported that there are recent (1995-2006) records for 25 Georgia counties. He stated that the eastern indigo snake remains widespread in the lower and middle Coastal Plain of southeastern and south-central Georgia, and is regularly observed in habitats along the Altamaha, Canoochee, and Ochoopee rivers, and in Coffee County. The eastern indigo snake has been documented or reported recently from 13 public lands and preserves in Georgia including: Big Hammock Natural Area/Big Hammock Wildlife Management Area (WMA), Broxton Rocks Preserve, Crooked River State Park, General Coffee State Park, Grand Bay WMA, Fort Stewart Military Installation, Griffin Ridge WMA, Little Satilla WMA, Moody Air Force Base, Moody Forest Natural Area Preserve, Ochoopee Dunes Natural Area Preserve, Okefenokee National Wildlife Refuge, and Sansavilla Wildlife Management Area (Stevenson 2006).

In southeastern Georgia, research and management efforts have been on-going at the Fort Stewart Military Installation where several populations of eastern indigo snakes are protected. The Nature Conservancy (TNC) and the state of Georgia have purchased land for preserves and developed management plans for several sites known to be occupied by the eastern indigo snake. These include areas along the Altamaha River corridor such as the Barrington Tract, recently acquired by the Georgia Department of Natural Resources (GADNR), and Broxton Rocks Conservation Area protected and managed by the

collective efforts of local landowners, Coffee County (where it is located), GADNR, TNC, and other partners. Proposals developed by Project Orianna for Georgia include recommendations to purchase additional lands along this corridor which contains high quality eastern indigo snake habitat and supports a number of indigo snake populations.

In the panhandle of Florida (here defined as those areas of Florida to the west of the Suwannee River), eastern indigo snakes persist in low numbers (K. Enge, Florida Fish and Wildlife Conservation Commission (FFWCC) 2007b, Gunzburger and Aresco 2007). Public lands that support populations in this part of Florida include: Allen Mill Pond Conservation Area, Apalachicola National Forest, Blackwater River State Forest, Eglin Air Force Base, Lafayette Blue Springs State Park, Middle Aucilla Conservation Area, Troy Springs Conservation Area, Twin Rivers State Forest, and Withlacoochee West Conservation Area. Snakes are more widespread and more commonly observed in peninsular Florida. Federally-managed public lands supporting populations in this part of Florida include Avon Park Bombing Range, Big Cypress National Preserve, Biscayne National Park, Camp Blanding Military Installation, Cape Canaveral Air Station, Chassahowitzka National Wildlife Refuge (NWR), Everglades National Park, Kennedy Space Center, Lake Wales Ridge NWR, Lower Suwannee NWR, Merritt Island NWR, and Ocala National Forest. State-managed public lands in Florida with extant populations include Babcock/Webb Wildlife Management Area (WMA), Caravelle Ranch WMA, Collier-Seminole State Park, Crystal River Preserve State Park, Etoniah Creek State Forest, Goethe State Forest, Highlands Hammock State Park, Ichetucknee Springs State Park, J.W. Corbett WMA, Jonathan Dickinson State Park, Kicco WMA, Myakka River State Park, Ross Prairie State Forest, Three Lakes WMA, St. Sebastian River Preserve State Park, Tosohatchee State Reserve, Triple N Ranch WMA, Wekiwa Springs State Park, and Withlacoochee State Forest. There are records since 2001 from over 80 public lands in Florida (Enge 2007b). Sixty-nine of these conservation lands contain at least 10,000 acres (ac) (4,047 hectares (ha)) of potential habitat for eastern indigo snakes (Enge and Endries 2008).

Initial efforts to create an eastern indigo snake habitat model for the state of Florida were made by Cox and Kautz (2000). Presently, the FFWCC is building on that effort by creating a revised potential habitat map for this species in Florida based on soil type, habitat fragment size, and other habitat characteristics as well as revising the Florida GAP analysis of gopher tortoise habitat, since eastern indigos rely on gopher tortoise burrows when available (M. Endries, FFWCC, pers. comm. 2007). Recently, Matt Elliott of GADNR has put together a

habitat model for the eastern indigo snake in Georgia (D. Stevenson pers. comm. 2008). The data developed through these projects will provide useful information on sites likely to support eastern indigo snake populations.

(2) Reestablish populations where feasible.

Status: Beginning in 1976 and continuing through 1987, eastern indigo snakes were released at 18 sites within the historic range of the species (Speake 1990). These snakes were part of a captive propagation and release project conducted at Auburn University in Auburn, Alabama. Release sites included areas within the states of Alabama, Florida, Georgia, Mississippi, and South Carolina. These initial efforts to establish populations have been deemed unsuccessful based on the lack of current verifiable records (photo or specimen) for indigo snakes in these areas (Hart 2002, Irwin *et al.* 2003, Alessandrini pers. comm. 2007, S. Bennett, South Carolina Department of Natural Resources, pers. comm. 2008, Enge pers. comm. 2008, J. Jensen, GADNR, pers. comm. 2008). However, there is one published account of at least one eastern indigo snake, assumed to be a snake released during the Auburn University project, being observed since 2000 at Ichauway, Baker County, Georgia (Smith *et al.* 2006, Smith pers. comm. 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 conducting hard releases of juvenile snakes into inappropriate habitat (Godwin *et al.* 2007). A new project to establish a population has been initiated with funding provided through the State Wildlife Initiative Grant (SWIG) program and the Alabama Department of Natural Resources and is being conducted by Auburn University (Godwin *et al.* 2007). This current effort will focus on one site in Alabama on the Conecuh National Forest and will involve a soft release of juveniles into pens incorporating both wetland and upland habitat.

(3) Improve the public attitude and behavior towards the eastern indigo snake.

Status: Many herpetologists give talks to local community groups and write articles in popular wildlife magazines about snakes and the role they play in the healthy functioning of wildlife habitat. Groups, including the Gopher Tortoise Council and Partners for Amphibian and Reptile Conservation (PARC), have developed public outreach materials for snakes that include specific information about the eastern indigo snake. An eastern indigo snake conservation meeting was held in 2001 as the result of an incident where an indigo snake was killed due to ignorance of its protected status as a Federally-listed, threatened species (U.S. Fish and Wildlife Service 2001). After that meeting, a

number of projects were undertaken in Georgia and Florida to develop informational materials about the eastern indigo snake for use on public lands including signage, brochures, and posters. In Georgia, hunting brochures developed for use on Fort Stewart Military Installation were amended to include information about eastern indigo snakes. An eastern indigo snake brochure was developed and produced through the joint efforts of the U.S. Fish and Wildlife Service, Georgia Department of Natural Resources, the University of Georgia, Savannah River Ecology Lab, and PARC (Available on website: <http://www.parcplace.org/IndigoFlier.pdf>). In addition, as a result of consultations with the Fish and Wildlife Service due to the indigo snake's protected status under the ESA, many developers in Florida have designed signs and programs for workers to help protect eastern indigo snakes that may be encountered on construction sites

C. Updated Information and Current Species Status

1. Biology and Habitat –

a. Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate), or demographic trends: The broad distribution and large territory size 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. 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 mark/recapture studies. Therefore, population attributes such as sex ratio, age structure, reproductive variables, and mortality in the wild are generally unknown. Several estimates of sex ratios and size at maturity are available from wild populations. Two studies of hatchlings/juveniles (Moulis 1976, Steiner *et al.* 1983) reported sex ratios not differing from 1 male: 1 female. However, sex ratios become more male biased in adult snakes. Layne and Steiner (1996) reported an adult sex ratio of 1.54 males: 1 female for indigo snakes in south Florida. Stevenson (pers. comm. 2008) reported a ratio of 2.1 males: 1 female (63 males, 29 females), with no significant difference in recapture rates between sexes, in a study at Fort Stewart, Georgia. Maturity in wild snakes has been estimated to be attained at 60 inches (1500 millimeters) total length (Speake *et al.* 1987, Layne and Steiner 1996). Some data can be gleaned from work with captive populations, especially information on breeding. Speake *et al.* (1987) reported that two females, captive since birth, bred at 40 and 41

months of age. The average clutch size of 20 females, removed from the wild and laying eggs in the spring following their capture, was 9.4. Moulis (1976) reported a range of 4 to 12 eggs for captive females and estimated their sexual maturity to be reached at 3 to 4 years of age based on their rate of growth. Captive female indigo snakes typically lay eggs every year. In a two-year study of a wild population, three of five females studied were gravid in both years (Bolt 2006). The maximum reported longevity for a captive indigo snake of unknown sex was 25 years and 11 months (Snider and Bowler 1992).

Inferences about abundance and population trends of the eastern indigo snake have been made using data on movements and estimates of home range size (100% minimum convex polygons) developed from studies using radio telemetry. In peninsular Florida, data on home ranges for females vary from 4.75 ac (1.9 ha) to 375 ac (150 ha); male home ranges vary from 4ac (1.6 ha) to 818 ac (327 ha) (Moler 1985b, Layne and Steiner 1996, Bolt 2006, Dodd and Barichivich 2007). Summer home ranges tend to be much larger than winter home ranges. For example, in Georgia, Speake *et al.* (1978) reported an average home range size for 17 snakes from the period August through November of 241 ac (96.4 ha) with a maximum home range size of 566 ac (226.4 ha). In a more recent radio telemetry study in Georgia, Hyslop (2007) reported home range sizes of 87.5 to 885 ac (35 to 354 ha) for females and 350 to 3,825 ac (140 to 1,530 ha) for males. Most fall and winter locations of eastern indigo snakes were recorded at gopher tortoise burrows in Hyslop's study, with less reliance on these burrows in spring and summer. Analysis of habitat use suggested an avoidance of paved roads, urban areas, and deciduous forest.

Eastern indigo snakes can move considerable distances in short periods of time. Speake *et al.* (1978) reported that two snakes moved a maximum distance from release points of 2.2 miles (mi) (3.5 kilometers (km)) in 42 days and 2.4 mi (3.8 km) in 176 days. Moler (1985b) recorded long distance moves of 2,706 feet (ft) (820 meters (m)) and 5,610 ft (1700 m) for snakes moving away from their wintering dens in mid to late March. Even longer annual movements may occur. Stevenson and Hyslop (unpublished manuscript) recaptured an adult male 14 mi (22 km) from its initial site of capture, 2 years previous. Indigo snakes exhibit a homing instinct and may return annually to previously used winter dens (Speake *et al.* 1978, Moler 1985b, Speake *et al.* 1987, Stevenson *et al.* 2003, Hyslop 2007). There is some evidence of cannibalism, male territorial combat (ritualized fighting, often at or near gopher tortoise burrows that contain adult females), and little overlap in the home ranges of same-sex adults in parts of the species range (low population density) (Speake *et al.* 1987, Layne and Steiner 1996, Bolt 2006). These data

support the assumption that this large terrestrial species requires a large area to survive. Due to their large home ranges and other behavioral traits, it is estimated that habitat of at least 2,500 ac (1,000 ha) is needed to provide conservation benefits (Moler 1992).

Support for a goal of protecting large areas of contiguous habitat for the conservation of eastern indigo snakes was provided by research conducted by Breininger *et al.* (2004). They developed a model to look at the influence of edge effects on population viability of the eastern indigo snake. Using data on indigo snake populations in east-central Florida, they demonstrated that many populations had a low extinction risk if there was no further fragmentation of the remaining populations. They observed that collecting annual survival data on hatchlings represented the most important parameter needing study. Other data that affected the model and that are not available for the eastern indigo snake include female breeder survival, the proportion of females breeding that are three years of age or older, and the number of hatchlings per female. The model indicated that edge/area effects were more important to population survival than area alone. They concluded that the greatest eastern indigo snake conservation benefit would be accrued by conserving snake populations in the largest upland systems that connect to other large reserves while keeping edge/area ratios low.

Loss of native habitats that support eastern indigo snakes is continuing due to the pressures of human population growth and development within the species range. This fact supports a determination that the number of eastern indigo snake populations is likely decreasing. However, if conservation areas can be identified using what has been learned of indigo snake long-distance movements and the results of the model discussed above, the recovery of the eastern indigo snake may still be achievable.

Collecting more explicit eastern indigo snake population trend data is impossible without the ability to survey for the species. At the Eastern Indigo Snake Conservation Summit held in 2001, a group of herpetologists familiar with the species selected developing reliable survey methods as the most pressing research and monitoring need for the snake (U.S. Fish and Wildlife Service 2001).

Research has been on-going since that meeting to address this need. In 2002 and 2003, for example, a study to test the efficiency and applicability of three commonly-used herpetological survey techniques for detecting eastern indigo snakes was conducted in Brevard County, Florida (Smith and Dyer 2003). The three techniques tested were drift fence arrays with box and funnel traps, road cruising, and gopher

tortoise burrow camera surveys. All techniques were used in areas known to be inhabited by eastern indigo snakes (snakes were monitored using radio telemetry). The results of the study indicated that none of the tested techniques could be relied on to easily or efficiently detect the species. Only three eastern indigo snakes were captured after 7,738 trap nights at the drift fence. No indigo snakes were detected during road cruising surveys conducted along 926 mi (1,491 km) of occupied habitat. Lastly, the researchers concluded that using a camera to survey gopher tortoise burrows was not a legitimate survey technique. Gopher tortoise burrows comprised only a portion of potential known den sites in this study area of central Florida and often they were not suitable for survey with a camera. No indigos were detected after using a camera to observe the interiors of 438 gopher tortoise burrows. Stevenson (*et al.* 2003) concurred with this assessment that using cameras to scope burrows for eastern indigo snakes is an inappropriate survey method. In fact, in one instance a burrow was scoped with a camera and no indigo snake was observed, however, one emerged from the burrow shortly thereafter (Stevenson pers. comm. 2008).

In 2004, a new study was initiated to test the feasibility of using a scent trail to lure eastern indigo snakes into traps. Scent trails are used to detect and follow prey; male snakes use scent trails to locate females for breeding purposes (Ford and Burghardt 1993, Greenlees *et al.* 2005, Smith *et al.* 2005). Since eastern indigo snakes are ophiophagous (they eat snakes), the idea that a bait solution could be made using a prey snake species was tested (Ford and Ford 2005). Initial lab trials with captive indigo snakes were successful (Alessandrini 2005). As a result, field trials were begun as well as research on the chemical composition of bait solutions most attractive as lures (Mason *et al.* 2007). Field trials have not shown success thus far, and eastern indigo snakes continue to show an aversion to entering traps (Bolt and Weiss 2006).

One other survey method shows some promise but it may be of only limited general use. At the 2001 Eastern Indigo Snake Conservation Summit, the idea of using a dog to find eastern indigo snakes was suggested. Subsequently, a dog has been successfully trained to locate indigo snakes and has shown some promising tracking ability in the field (Dziergoswski 2006). The usefulness of this technique for detecting and monitoring indigo snake populations in the wild remains to be tested.

In the northern parts of its range in southern Georgia, over-wintering site fidelity has been documented at gopher tortoise burrows (Stevenson *et al.* 2003, Hyslop *et al.* 2006) and as a result, population

monitoring may be possible in some areas of Georgia and northern Florida (Stevenson *et al.* 2003). Population monitoring in the warmer areas of north-central and south Florida remains problematic.

b. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding): Genetic studies have only recently been initiated. An evaluation of the genetic diversity of the eastern indigo snake in peninsular Florida and southeastern Georgia, using mitochondrial DNA genetic analyses of tissue samples, is nearly complete. Samples are lacking from some areas, but the preliminary analysis indicates that there are two distinct lineages of eastern indigo snakes (Enge 2007a). There is an Atlantic Coast lineage and another lineage that encompasses all other localities including areas of southern Florida, the central ridge of Florida and the Gulf Coast drainage.

An additional study, using microsatellite DNA analysis as an assessment technique, has been initiated to compare a population of eastern indigo snakes on Fort Stewart Military Installation in southeastern Georgia with a population on the Kennedy Space Center in east-central Florida (Nairn *et al.* 2007). This research will address the need for baseline population genetic data for the eastern indigo snake in portions of its Atlantic coastal range. Habitat loss and fragmentation have been and will continue to be a major hurdle in the recovery efforts for the eastern indigo snake. However, it is unclear how these threats affect population structure and gene flow (dispersal). This study will focus on characterizing genetic population structure and gene flow in undisturbed habitats so these data may serve as a benchmark against which similar data from disturbed habitats may be compared.

c. Taxonomic classification or changes in nomenclature: At the time of listing, the eastern indigo snake was considered a subspecies, *Drymarchon corais couperi*. Currently, the eastern indigo snake is accepted by the scientific community as a separate species, *Drymarchon couperi* (Crother 2000). In 1991, Collins elevated this lineage to specific status based on allopatry and diagnosability. Subsequent work has supported this designation (Wuster *et al.* 2001).

d. Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors), or historic range (e.g., corrections to the historical range, change in distribution of the species' within its historic range): Historically, the eastern indigo snake occurred throughout Florida and in the coastal plain of Georgia, Alabama, and Mississippi (Loding 1922, Haltom 1931, Carr 1940, Cook 1954, Diemer and Speake 1983, Lohoefer

and Altig 1983, Moler 1985a). Most, if not all, of the remaining viable populations of the eastern indigo snake occur in Georgia and Florida (see discussion below).

It is unlikely the eastern indigo snake occurs currently in South Carolina or Mississippi. Two observations in the 1960's of eastern indigo snakes in southern South Carolina have been reported by L. Newbury (private landowner, pers. comm. 2007) and C. Kauffeld (R. Zappalorti pers. comm. 2007). No specimens have been found to support these observations. There is one specimen in the Mississippi Museum of Natural Science collected from Wayne County, Mississippi in 1939. The most current record for the species in this state is from two eastern indigo sightings reported from the mid-1950's on DeSoto National Forest, Perry County, Mississippi (C. Finch, Governor of state of Mississippi, *in litt.* 1977; Lohoefer and Altig 1983).

Four eastern indigo snake historical records are available from three counties in Alabama, the last reported in 1954 (Mount 1975). However, it is possible that it was more abundant than former records indicate because individuals studying the reptiles of Alabama in the early 1900's did not mention that indigos were rare (Blanchard 1920, Loding 1922). Nevertheless, by the mid-1970's herpetologists were concerned that the species had disappeared from Alabama (Mount 1975). A recent study has been conducted in Alabama to determine if evidence of the species could be verified (Hart 2002). Beginning in 2000, sites of experimental reintroductions were visited and landowner contacts made. In addition, recent anecdotal sightings and reports were researched and attempts made to determine their veracity. One report was confirmed from Coffee County (although its location within a privet hedge near a town is strange and the origin of the snake is unknown) and two highly probable observations were reported from Mobile County in appropriate habitat. Nevertheless, no eastern indigo snakes were observed by Hart (2002) during the study. He concluded that if eastern indigo snakes still occur in Alabama, they occur at such low densities that detection is improbable.

In Georgia, Diemer and Speake (1981, 1983) conducted a 2-year study to survey the distribution of the eastern indigo snake and to characterize and delineate its habitat. Between 1978 and 1980, data were gathered through questionnaires and follow-up interviews, intensive snake hunting, soil maps, vegetational analyses and satellite imagery. Over 150 man-days were spent in the field during the study. Results indicated that the stronghold for the snake was in a contiguous block of approximately 41 southeastern and south-central Georgia counties. The indigo snake populations were typically associated with

sand ridges along major coastal plain streams. The status and distribution of eastern indigo snakes in Georgia was recently reviewed by Stevenson (2006). He determined that populations of eastern indigo snakes still remain widespread in Georgia. There are recent (1995-2006) records for 25 (61%) of these 41 Georgia counties. The eastern indigo snake remains widespread in the lower and middle Coastal Plain of southeastern and south-central Georgia along xeric sand ridges bordering the Altamaha, Canoochee, and Ochoopee rivers, and in Coffee County. In Georgia, the eastern indigo snake depends on the burrows of the gopher tortoise, a species that requires these fire-maintained sandhill habitats. Although not documented, Stevenson (2006) believed indigo snakes are likely present in several other southeastern Georgia counties where suitable habitat exists. There are no historic or recent records, supported by evidence in terms of specimens or photographs, for the upper Coastal Plain or Fall Line sandhill region. There has been only one recent observation of this species in southwestern Georgia, although historically, small populations were known from the extreme southwestern portion of the state close to the Florida state line. Eastern indigo snakes occur on 13 public lands and preserves in Georgia. However, most of these areas are relatively small and some may not support viable indigo snake populations (Stevenson 2006).

In the panhandle of Florida, eastern indigo snakes persist in low numbers (Enge 2007b, Gunzburger and Aresco 2007). Based on museum specimens and field sightings, the eastern indigo snake still occurs throughout peninsular Florida, even though they are not commonly seen (Moler 1985a). In south Florida, the eastern indigo snake is thought to be more widely distributed than in other parts of its range. Given their preference for upland habitats, eastern indigos are not commonly found in great numbers in the wetland complexes of the Everglades region, even though they are found in pinelands, tropical hardwood hammocks, and mangrove forests in extreme south Florida (Duellman and Schwartz 1958, Steiner *et al.* 1983). There are no recent occurrence records for the Florida Keys.

In summary, the current stronghold for the eastern indigo snake is southeastern Georgia and peninsular Florida. The eastern indigo snake persists in the panhandle of Florida in lower numbers than these two areas. It is functionally extinct in Alabama and Mississippi. Records for the eastern indigo snake in South Carolina cannot be verified.

Adult eastern indigo snakes have very large activity ranges; most estimates of home ranges vary from several hundred to several thousand acres (hectares) and indigos can move considerable distances (See discussion above: **C. 1. a.**). Habitat use often varies seasonally

between upland and wetland areas, especially in the more northern parts of the species' range. In the more southern parts of their range, eastern indigo snakes become more habitat generalists and move among the available habitat types. Movements between habitat types may relate to the need for thermal refugia (protection from cold and/or heat (See discussion below: **C. 1. e.**)), differences in habitat use by juveniles and adults, or seasonal differences in availability of food resources. For these reasons, the species is especially vulnerable to habitat fragmentation (Breininger *et al.* 2004, Hyslop *et al.* 2006). Large areas of natural habitats, protected from roads and the fragmentation associated with development, are needed to maintain viable snake populations (Layne and Steiner 1996, Breininger *et al.* 2004).

- e. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):** The eastern indigo snake occurs in a wide range of habitat types including pine flatwoods, scrubby flatwoods, high pine, dry prairie, tropical hardwood hammocks, edges of freshwater marshes, agricultural fields, coastal dunes, and human-altered habitats (U.S. Fish and Wildlife Service 1982). Below-ground shelters are used year-round by indigo snakes as thermal refugia. In the northern part of their range, burrows are used to protect against the cold. In summer, indigo snakes use burrows as protection from heat and dry conditions since they have been shown to be susceptible to desiccation (Bogert and Cowles 1947). Throughout their range, they also use burrows for foraging, nesting, mating, and shelter prior to shedding (Stevenson pers. comm. 2008). They also move seasonally between upland and wetland habitats. Reliance on xeric sandhill habitats throughout the northern portion of the eastern indigo's range in Georgia and northern Florida can be attributed primarily to the availability of gopher tortoise burrows during winter. In wetter habitats that lack gopher tortoises, eastern indigo snakes may take shelter in hollowed root channels, hollow logs, stump holes, or the burrows of rodents, armadillo (*Dasypus novemcinctus*), or land crabs (*Cardisoma gualanhumii*) (Lawler 1977, Moler 1985b, Layne and Steiner 1996, Hyslop 2007).

Throughout peninsular Florida, the eastern indigo snake may be found in all terrestrial habitats that have not suffered high-density urban development. They are less tied to longleaf pine uplands and become more habitat generalists, although they still require below-ground refugia and use gopher tortoise burrows/habitats when these are available. Indigo snakes can be common in some hydric hammocks (Moler 1985a). In central and coastal Florida, eastern indigos are found mainly on higher elevation sandy ridges where they continue to use gopher tortoise burrows when they are available. On the sandy

central ridge of south Florida, eastern indigos use gopher tortoise burrows more (62 percent) than other underground refugia (Layne and Steiner 1996). In extreme southern Florida, these snakes are typically found in pine flatwoods, pine rocklands, tropical hardwood hammocks, and in most other undeveloped areas (Kuntz 1977). Subterranean refugia used in these areas include burrows of armadillos, cotton rats (*Sigmodon hispidus*), and land crabs; burrows of unknown origin; natural ground holes; hollows at the base of trees or shrubs; ground litter; trash piles; and crevices of rock-lined ditch walls (Layne and Steiner 1996). Eastern indigo snakes also inhabit some agricultural lands (e.g., sugar cane fields and associated canal banks) (Layne and Steiner 1996).

In south Florida, agricultural sites, such as sugar cane fields and canal banks through citrus groves, created in former wetland areas are occupied by eastern indigo snakes (Enge pers. comm. 2007). Formerly, indigos would have only occupied higher elevation sites within the wetlands. The introduction of agriculture and its associated canal systems has resulted in an increase in rodents and other species of snakes that are prey for eastern indigo snakes. The result is that indigos occur at higher densities in these areas than they did historically. A positive long-term prognosis for these populations is tied to the continuation of agriculture at these sites. In some areas, efforts to reestablish natural wetlands are in conflict with the future survival of eastern indigo snakes at these sites.

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

- a. Present or threatened destruction, modification, or curtailment of its habitat or range:** In both Florida and Georgia, the trend of urbanization is eliminating natural areas and creating islands of habitat with little or no connectivity within a landscape of unsuitable habitat. Because of its relatively large home range, the eastern indigo snake is especially vulnerable to habitat loss, degradation, and fragmentation of its habitat (Lawler 1977, Moler 1985b). Throughout the range of the species, natural communities continue to be altered for agricultural, residential, and commercial purposes, most of which are incompatible with the habitat needs of eastern indigo snakes (Kautz 1993). Extensive tracts of wild land are the most important refuge for large numbers of eastern indigo snakes (Diemer and Speake 1981, Moler 1985b).

In the more northern parts of the eastern indigo snake's range, the loss and degradation of longleaf pine forests is a threat due to this species'

close affiliation with gopher tortoises and their burrows. Natural fires are suppressed, and use of fire as a management tool by foresters has decreased (Wear and Greis 2002). Incompatible forestry practices, which reduce the number and availability of below-ground shelters such as natural ground holes, hollows at the base of trees or shrubs, and stump holes, also have a negative effect. As forest structure changes, habitat suitability decreases as the availability of below-ground shelters for the eastern indigo snake is reduced.

In central and southern Florida, the eastern indigo snake uses most of the habitat types available to it, but still prefers open, undeveloped areas (Kuntz 1977). Lawler (1977) noted that eastern indigo snake habitat has been destroyed by residential and commercial construction, agriculture, and timbering. In 1977, Lawler reported that the loss of natural habitat in Florida was increasing because of these threats and indigo snake habitat was being lost at a rate of 5 percent per year. Since 1999, the loss of natural areas in Florida has continued to rise dramatically (The Nature Conservancy 2006). 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 threat to the species since there is increased likelihood of snakes being killed by property owners and domestic pets. The effects of habitat destruction and alteration on the eastern indigo snake are likely most substantial along the Florida coasts, in the Keys, and along the high ridges of south-central Florida, where human population growth is expected to continue to accelerate. Agricultural interests (principally citrus) continue to destroy large expanses of suitable natural indigo snake habitat throughout much of southern Florida.

Thermally stable, below-ground shelter is an important habitat component of the eastern indigo snake's habitat. Shelter requirements may vary seasonally depending on the climate in which the populations occur. In more northern parts of their range, eastern indigo snakes use gopher tortoise burrows extensively. Hyslop (2007) reported that 90% of underground shelters used by eastern indigo snakes on Fort Stewart Military Installation in Georgia were gopher tortoise burrows. The decline of gopher tortoise populations represents an additional threat to the species. However, even in the Georgia study (Hyslop 2007), a number of other shelter types were used, typically in summer. These included root and stump channels, debris piles created during timber harvest and site preparation, armadillo burrows, shelters associated with fallen woody debris, and burrows created by mammals other than armadillos. Loss of these shelter types due to expansion of agriculture into forested areas, urban development, clear-cutting and site preparation during timber harvest operations, or other activities also represents a threat to the species (Wear and Greis 2002).

Eastern indigo snakes move long distances (See discussion above: **C. 1. a.**). As a result, habitat connectivity needs to be maintained. An increase in roads creates habitat fragmentation and an increase in direct mortality when snakes try to cross highways (Andrews and Gibbons 2005, Bolt 2006).

At some point, the size of fragmented habitat patches will become too small to support viable populations (See discussion above: **C. 1. a.**). The eastern indigo snake will likely persist in localities where large, unfragmented pieces of natural habitat remain. It has been suggested that eastern indigo snake populations that occur on Federal, state, or other privately managed preservation lands of at least 2,500 ac (1,000 ha), with few roads or human-altered habitats which increase habitat fragmentation and mortality, may have the best chance of long-term viability (Moler 1992, Breininger *et al.* 2005). Further research is needed to support this assertion. However, it is encouraging that 13 tracts of public land support eastern indigo snake populations in Georgia and 69 of 80 tracts of public land supporting indigo snakes in Florida are at least 10,000 ac (4,047 ha) in size.

- b. Overutilization for commercial, recreational, scientific, or educational purposes:** There was concern, at the time of listing, that publicity from the listing of the eastern indigo snake would generate an increased demand for this species, resulting in over-collecting in the wild. State and Federal law enforcement agencies have not reported a subsequent increase in cases of illegal take of eastern indigo snakes, thus it appears this effect has not materialized. Over-utilization for commercial, recreational, scientific, or educational purposes is not considered to be a threat to the species at this time.
- c. Disease or predation:** Further investigation is needed. Norton *et al.* (2004) conducted health assessments on the eastern indigo snake in southeastern Georgia. They found a high percentage of snakes examined during the winter months had skin lesions varying from superficial wounds to ones extending down to muscle tissue. The lesions were seasonal and were not observed during the summer. *Aspergillus niger* pneumonia was documented in one eastern indigo snake. The effect of these two diseases on the health of eastern indigo snake populations is unknown. A health protocol has been developed to decrease the risk of infectious disease transfer when multiple snakes are handled by researchers studying eastern indigo snakes in Georgia (Norton *et al.* 2004).

In captive populations, hatchlings do not all emerge at the same time (Alessandrini pers. comm. 2001). There may be periods of as long as

2 weeks between the beginning of hatching of the first and last neonates of a single clutch. If this phenomenon occurs in the wild, the odors present at the initiation of the hatching process could attract predators such as fire ants, skunks, raccoons, and even other snakes.

- d. Inadequacy of existing regulatory mechanisms:** The eastern indigo snake was listed because of a population decline caused by habitat loss, over-collecting for the pet trade, and mortality from gassing gopher tortoise burrows to collect rattlesnakes (U.S. Fish and Wildlife Service 1978). As a result of effective law enforcement, exploitation for the pet trade has declined but still remains a concern (Moler 1992). Gassing of burrows is illegal in both Florida and Georgia, but probably still occurs to some extent. Although still a threat, it is unlikely that gassing is having a large negative impact on most eastern indigo snake populations (Enge pers. comm. 2008, Jensen pers. comm. 2008).

Each state within the historic range of the eastern indigo snake, with the exception of South Carolina, provides some protection for the species. In Alabama the eastern indigo snake is listed as a nongame species protected by regulation (Alabama Department of Conservation and Natural Resources 2008); in Florida and Georgia as threatened (FFWCC 2007a, Georgia Department of Natural Resources 2006), and in Mississippi as endangered (Mississippi Museum of Natural Science 2001). The South Carolina Department of Natural Resources (SCDNR) 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 in South Carolina (Bennett pers. comm. 2008). The protections provided by each state vary. However, most state laws focus on prohibitions against taking eastern indigo snakes from the wild and possessing, exporting, or selling them. Through an extensive land acquisition program, only the state of Florida provides protection from some habitat destruction.

The state of Florida has protected more than 3 million ac (1.2 million ha) through its Preservation 2000 and Florida Forever programs (Florida Department of Environmental Protection 2007). In 1998, Florida voters amended the state constitution by ratifying a constitutional amendment that reauthorized bonds for land acquisition. The Florida Forever Act, implemented in 2000, reinforced Florida's commitment to acquire and conserve natural and cultural habitats and better manage these lands. This legislation benefits the recovery of the eastern indigo snake.

The Florida Fish and Wildlife Conservation Commission has completed a Gopher Tortoise Management Plan for the state of Florida

(FFWCC 2007b). The overarching conservation goal of this management plan is to restore and maintain secure, viable populations of gopher tortoise throughout the species' current range in Florida by addressing habitat loss. Objectives of the plan include increasing protected, potential gopher tortoise habitat by acquiring additional habitat and restocking gopher tortoises where they no longer occur or where densities are low. Eastern indigo snakes in Florida should benefit from these actions taken on behalf of the gopher tortoise.

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 does not provide protection against the threats of habitat destruction and degradation that continue to endanger the eastern indigo snake.

Protection is afforded to this species under sections 7, 9, and 10 of the ESA. Federally-funded projects that may cause impacts to eastern indigo snake populations are assessed to ensure these 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.

- e. **Other natural or manmade factors affecting its continued existence:** Additional human population growth will increase the risk of direct mortality of the eastern indigo snake from property owners, domestic animals, and highway mortality. Pesticides that bioaccumulate through the food chain may present a potential hazard to the snake as well. Pesticides or herbicides used on crops or for silviculture would pose a pulse effect to the indigo (Speake 1993). Secondary exposure to rodenticides used to control black rats may also occur (Speake 1993). In populations with low numbers of individuals, any additional threats to its survival could cause local extirpations.

Declines in gopher tortoise populations are negatively affecting eastern indigo snake populations, especially in the northern areas of the snake's range. Gopher tortoises are declining due to loss of both quantity and quality of their habitat. Loss of tortoise habitat quantity is occurring due to human population growth and development and conversion of native habitat to agriculture. Loss of tortoise habitat quality is occurring through management activities which result in the reduction of below-ground retreats and reduction in the herbaceous groundcover that is the food source for the tortoise. The use of all-terrain vehicles (ATVs) in sandhill habitats of the tortoise can also destroy groundcover and soil stability (Lawler 1977).

D. Synthesis – At the time of listing, very little was known about the distribution and habitat use of the eastern indigo snake. Progress has been made in gaining a better understanding of both the quantity and quality of habitat needed. Although natural habitats continue to be lost and degraded, strides have been made in bringing large continuous blocks of habitat into public ownership. In Georgia, 13 tracts of public land support eastern indigo snake populations. In Florida, 80 tracts of public land support indigo snakes and 69 of these sites are at least 10,000 ac (4,047 ha) in size.

Appropriate management of occupied eastern indigo snake sites continues to be a challenge. Fire suppression, in particular, is affecting many of the remaining natural areas. Implementing long-term management on lands occupied by indigo snakes is necessary if recovery is to be achieved. Public agencies are attempting to conduct ecosystem management on their lands but improvements in consistent implementation are needed.

Eastern indigo snakes are tied to the use of gopher tortoise burrows and their longleaf pine habitat in the northern parts of their range (southeastern Georgia and the panhandle of Florida). Due to loss of longleaf pine forests in these areas, and the subsequent decline in gopher tortoises, eastern indigo snakes have also declined. As efforts move forward to protect the gopher tortoise, indigo snakes will benefit. For example, the recently completed Gopher Tortoise Management Plan for Florida addresses gopher tortoise habitat loss and has as an objective acquiring additional habitat for them.

A new captive propagation project has been initiated in Alabama using the lessons learned from a previous project undertaken in the 1980's. An attempt will be made to establish an eastern indigo snake population on the Conecuh National Forest where longleaf pine restoration work has been successful. Monitoring of the released juveniles will be an important component of the project. Since it is likely the eastern indigo snake is functionally extinct in Alabama, a population established here will be a first step towards recovery in the state. Future captive propagation efforts will build on this work.

At present, it appears likely an organization will be formed, financed by a private donor, to support eastern indigo snake conservation. Efforts of this group, begun as Project Orianna, will focus on land acquisition of occupied eastern indigo snake habitat in southeastern Georgia, captive breeding, and habitat management of eastern indigo snake sites.

Due to difficulties in surveying for eastern indigo snakes, an estimate of numbers of these snakes still extant is not possible. Since the listing of

this species under the ESA, it is likely that some populations have declined and others have been lost as a result of habitat loss and fragmentation. However, there is a lack of quantitative evidence supporting this trend. Additional studies of populations on protected sites are needed to learn more about the demographic features that structure a viable population. Nevertheless, it is clear from recent records that the indigo snake is still widely distributed across areas of southeastern Georgia and peninsular Florida. In addition, it is encouraging that a large number of occupied sites are properties of public agencies and private organizations working towards appropriate management of their land base. At this time, the eastern indigo snake continues to meet the definition of a threatened species under the ESA.

III. RESULTS

A. Recommended Classification:

No change is needed. Although threats to its habitat continue to increase, the eastern indigo snake continues to be widely distributed across southeastern Georgia and Florida. Additional information provided above under “Synthesis”.

B. New Recovery Priority Number 11C

The Recovery Priority Number should be changed from 12C to 11C to reflect this change in taxonomy.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Initiate long-term monitoring on selected protected sites across the range of the species.
2. Identify differences in factors limiting the recovery of the eastern indigo snake across its range.
3. Work to obtain protection and develop appropriate ecosystem management plans for sites on privately-owned lands.
4. Continue to study options for reestablishing eastern indigo snakes in areas where the species has been extirpated.
5. Use Geographic Information System (GIS) data to look at 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.
6. 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.

7. Conduct research using radio telemetry of female indigo snakes to get a better understanding of demographic variables. Identify nest site location, fecundity, and hatching success.
8. Continue efforts to develop reliable and efficient survey methods.
9. Expand on the initial efforts by Breininger *et al.* (2004) to determine the appropriate size, acceptable fragmentation level, habitat types, and geographic location for eastern indigo snake reserves across the species' range.
10. Establish techniques to provide public education on the values, attributes, and protected status of the eastern indigo snake.
11. Revise recovery plan and establish recovery criteria.
12. Officially adopt the change in nomenclature of eastern indigo snake to the species *Drymarchon couperi*.

V. REFERENCES

- Alabama Department of Conservation and Natural Resources. 2008. Nongame species protected by Alabama regulations. 220-2-.92 Nongame species regulation. 4 pp. [Available on the web: <http://www.outdooralabama.com/watchable-wildlife/regulations/nongame.cfm>]
- Alessandrini, D. 2005. Bait trail testing using captive eastern indigo snakes, *Drymarchon couperi*. Powerpoint presentation provided to U.S. Fish and Wildlife Service, Jackson, Mississippi. 42 pp.
- Andrews, K. M., and J. W. Gibbons. 2005. How do highways influence snake movement? Behavioral responses to roads and vehicles. *Copeia* 2005:772-782.
- Blanchard, F.N. 1920. A black *Pituophis*. *Copeia* 80:30-33.
- Bogert, C.M., and R.B. Cowles. 1947. Results of the Archbold expeditions. No. 58. Moisture loss in relation to habitat selection in some Floridian reptiles. *American Museum Novitates* 1358:1-55.
- Bolt, M.R. 2006. The eastern indigo snake (*Drymarchon couperi*): What we know, what we think, and what we need. Powerpoint presentation for U.S. Fish and Wildlife Service, Vero Beach Field Office.
- Bolt, M.R. and S.K. Weiss. 2006. Using corn snake pheromones as bait for eastern indigo snakes. Unpublished report submitted to U.S. Fish and Wildlife Service, Jackson, Mississippi Field Office. 2 pp.
- Breininger, D.R., M.L. Legare, and R.B. Smith. 2004. Edge effects and population viability of eastern indigo snakes in Florida. Pgs. 299-311 *in*: H.R. Akcakaya, M. Burgman, O. Kindvall, P. Sjorgren-Gulve, J. Hatfield, and M. McCarthy, eds.

Species Conservation and Management: Case Studies. Oxford University Press, New York, New York.

- Carr, A. E., Jr. 1940. A contribution to the herpetology of Florida. University of Florida Publications, Biological Science Series: Volume III, No. 1.
- Collins, J.T. 1991. Viewpoint: A new taxonomic arrangement for some North American amphibians and reptiles. *Herpetological Review* 22:42-43.
- Cook, F.A. 1954. Snakes of Mississippi. Mississippi Game and Fish Commission; Jackson, Mississippi.
- Cox, J.A. and R.S. Kautz. 2000. Habitat conservation needs of rare and imperiled wildlife in Florida. Office of Environmental Services, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 156 pp.
- Crother, B. I. (ed.). 2000. Scientific and standard English names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. Society for the Study of Amphibians and Reptiles, Herpetological Circular No. 29. Shoreview, MN. Iv + 82 pp.
- Diemer, J.E., and D.W. Speake. 1981. The status of the eastern indigo snake in Georgia. Pages 52-61 in R. Odum and J. Guthrie, eds. Proceedings of the nongame and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.
- Diemer, J.E., and D.W. Speake. 1983. The distribution of the eastern indigo snake, *Drymarchon corais couperi*, in Georgia. *Journal of Herpetology* 17(3):256-264.
- Dodd, C.K., Jr. and W.J. Barichivich. 2007. Movements of large snakes (*Drymarchon*, *Masticophis*) in north-central Florida. *Florida Scientist* 70:83-94.
- Duellman, W.E., and A. Schwartz. 1958. Amphibians and reptiles of southern Florida. *Bulletin Florida State Museum, Biological Science* 3:181-324.
- Dziergowski, A. 2006. E-mail forwarding information regarding the dog used to find indigo snakes.
- Enge, K. 2007a. E-mail dated September 25, 2007 discussing preliminary genetics work of indigo snakes in Florida and Georgia.
- Enge, K. 2007b. E-mail dated November 28, 2007, discussing status of eastern indigo snakes in Florida.

- Enge, K. and M.J. Endries. 2008. Poster entitled: Status of the Eastern Indigo Snake (*Drymarchon couperi*) in Florida. Published by the Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.
- Florida Department of Environmental Protection. 2007. February 2007 report of the Florida Forever program prepared for the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida. 547 pp. [Available on the web: <http://www.dep.state.fl.us/lands/FFAnnual/default.htm>]
- Florida Fish and Wildlife Conservation Commission. 2007a. Florida's endangered species, threatened species, and species of special concern. 7 pp. [Available on the web: <http://www.myfwc.com/imperiledspecies>]
- Florida Fish and Wildlife Conservation Commission. 2007b. Gopher tortoise management plan, *Gopherus polyphemus*. September 2007. [Available on the web: <http://www.myfwc.com/imperiledspecies/plans.htm>]
- Ford, D.F. and N.B. Ford. 2005. Tests of the feasibility of using corn snake trail pheromones as attractants for indigo snakes. Unpublished report to the U.S. Fish and Wildlife Service, Jackson, Mississippi. 9 pp. + table.
- Ford, N.B. and G.M. Burghardt. 1993. Pgs. 140-141 *In*: R.A. Seigel and J.T. Collins, eds. Snakes. Ecology and Behavior. The Blackburn Press, Caldwell, New Jersey.
- Georgia Department of Natural Resources. 2006. Chapter 391-4-10; Protection of endangered, threatened, rare, or unusual species. 9 pp. [Available on the web: <http://georgiawildlife.dnr.state.ga.us/assets/documents/StrikethroughRulesMasterAug06.pdf>]
- Godwin, J., C. Guyer, and V. Johnson. 2007. Captive propagation for the purpose of recovery of the eastern indigo snake into its native range in Alabama. 12 pp. + appendices.
- Greenlees, M.J., J.K. Webb, and Richard Shine. 2005. Led by the blind: Bandy-bandy snakes *Vermicella annulata* (Elapidae) follow blindsnake chemical trails. *Copeia* 2005:184-187.
- Gunzburger, M.S. and M.J. Aresco. 2007. Status of eastern indigo snake in the Florida panhandle and adjacent areas of Alabama and Georgia. Unpublished report to U.S. Fish and Wildlife Service, Jackson, Mississippi. 15 pp. + figures.
- Haltom, W.L. 1931. Alabama reptiles. Alabama Geological Survey and Natural History Museum, Paper No. 11:1-145.
- Hart, B. 2002. Status survey of the eastern indigo snake (*Drymarchon corais couperi* Holbrook), black pine snake (*Pituophis melanoleucus lodingi* Blanchard), and

- southern hognose snake (*Heterodon simus* Linnaeus) in Alabama. Unpublished report prepared by the Alabama Natural Heritage Program for the Alabama Department of Conservation and Natural Resources, Montgomery, AL. 49 pp.
- Hyslop, N.L. 2007. Movements, habitat use, and survival of the threatened eastern indigo snake (*Drymarchon couperi*) in Georgia. Unpublished PhD dissertation.
- Hyslop, N.L., M. Meyers, and R.J. Cooper. 2006. Movements, survival, and habitat use of the threatened eastern indigo snake (*Drymarchon corais couperi*) in southeastern Georgia. Final report of GDNR.
- Irwin, K.J., T.E. Lewis, J.D. Kirk, S.L. Collins, and J.T. Collins. 2003. Status of the eastern indigo snake (*Drymarchon couperi*) on St. Vincent National Wildlife Refuge, Franklin County, Florida. *Journal of Kansas Herpetology* 7:13-20.
- Kautz, R.S. 1993. Trends in Florida wildlife habitat 1936-1987. *Florida Scientist* 56:7-24.
- Kuntz, G.C. 1977. Endangered species: Florida Indigo. *Florida Naturalist*:15-19.
- Lawler, H.E. 1977. The status of *Drymarchon corais couperi* (Holbrook), the eastern indigo snake, in the southeastern U.S.A. *Herpetological Review* 8(3):76-79.
- Layne, J.N., and T.M. Steiner. 1996. Eastern indigo snake (*Drymarchon corais couperi*): summary of research conducted on Archbold Biological Station. Report prepared under Order 43910-6-0134 to the U.S. Fish and Wildlife Service; Jackson, Mississippi.
- Loding, H.P. 1922. A preliminary catalog of Alabama reptiles and amphibians. Alabama Geological Survey and Natural History Museum, Paper No. 5:1-59.
- Lohofener, R. and R. Altig. 1983. Mississippi herpetology. Mississippi State University Research Center Bulletin 1, National Space Technology Laboratory Station, Mississippi. p. 21.
- Mason, R.T., R. Cressman, A. Cole, and R. Parker. 2007. Efficacy of using corn snake skin lipids as an attractant for kingsnakes, a surrogate ophiophagous model for indigo snakes. Unpublished report to U.S. Fish and Wildlife Service, Jackson, Mississippi. 15 pp. + figures.
- Mississippi Museum of Natural Science. 2001. Endangered species of Mississippi. Mississippi Department of Wildlife, Fisheries and Parks, Museum of Natural Science, Jackson, Mississippi. 4 pp.
- Moler, P.E. 1985a. Distribution of the eastern indigo snake, *Drymarchon corais couperi*, in Florida. *Herpetological Review* 16(2):37-38.

- Moler, P.E. 1985b. Home range and seasonal activity of the eastern indigo snake, *Drymarchon corais couperi*, in northern Florida. Final performance report, Study E-1-06, III-A-5. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.
- Moler, P.E. 1992. Eastern indigo snake. Pages 181-186 in P.E. Moler, ed. Rare and endangered biota of Florida, volume III, Amphibians and Reptiles. University Press of Florida; Gainesville, Florida.
- Moulis, R. 1976. Autecology of the eastern indigo snake, *Drymarchon corais couperi*. Bulletin of the New York Herpetological Society, Vol. 12 No. 3 & 4.
- Mount, R.H. 1975. The reptiles and amphibians of Alabama. Auburn University Experimental Station; Auburn, Alabama.
- Nairn, C.J., B. Shamblin, D. Stevenson, and T. Norton. 2007. Population genetics of eastern indigo snakes (*Drymarchon couperi*) in Georgia and Florida: a microsatellite analysis. (proposal) 6 pp.
- Norton, T.M., R. Poppenga, N. Stedman, D. Stevenson, T. Chen, M. Oliva, M. Mitchell, E. Jacobson, E. Dierenfeld, C. Cray, T. Gross, M.S. Sepulveda, S. Telford, S. Gibbs, K. Zack, E. Baitchman, L. Durden, and N. Hyslop. 2004. Health assessment in the eastern indigo snake (*Drymarchon corais couperi*) in southeastern Georgia. Unpublished update for U.S. Fish and Wildlife Service and Georgia Department of Natural Resources permits, June 2004. 8 pp. + appendices.
- Smith, L.L., D.A. Steen, J.M. Stober, M.C. Freeman, S.W. Golladay, L.M. Conner, and J. Cochrane. 2005. The vertebrate fauna of Ichauway, Baker County, Georgia. Southeastern Naturalist 5:599-620.
- Smith, R.B. and K.J. Dyer. 2003. Preliminary testing and comparison of herpetological survey techniques for eastern indigo snakes (*Drymarchon couperi*). Unpublished report submitted to U.S. Fish and Wildlife Service, Jackson, MS. 15 pp. + figures.
- Smith, T.L., G.S. Bevelander, and K.V. Kardong. 2005. Influence of prey odor concentration on the poststrike trailing behavior of the northern Pacific rattlesnake. Herpetologica 61:111-115.
- Snider, A. T. and J. K. Bowler. 1992. Longevity of reptiles and amphibians in North American collections. Second edition. Herpetological Circular No. 21, Society for the Study of Amphibians and Reptiles, Lawrence, Kansas. 40 pp.

- Speake, D.W. 1990. Evaluation of eastern indigo snakes restocking attempts. Unpublished report submitted to U.S. Fish and Wildlife Service, Jackson, MS. 8 pp.
- Speake, D.W. 1993. Indigo snake recovery plan revision. Final report to the U.S. Fish and Wildlife Service, Jackson, Mississippi.
- Speake, D.W., D. McGlincy, and C. Smith. 1987. Captive breeding and experimental reintroduction of the eastern indigo snake. Pages 84-90 in R.R. Odum, K.A. Riddleberger, and J.C. Ozier, eds. Proceedings of the third southeastern nongame and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division, Athens, Georgia.
- Speake, D.W., J.A. McGlincy, and T.R. Colvin. 1978. Ecology and management of the eastern indigo snake in Georgia: A progress report. Pages 64-73 in R.R. Odum and L. Landers, eds. Proceedings of rare and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 4.
- Steiner, T.M., O.L. Bass, Jr., and J.A. Kushlan. 1983. Status of the eastern indigo snake in southern Florida National Parks and vicinity. South Florida Research Center Report SFRC-83/01, Everglades National Park; Homestead, Florida.
- Stevenson, D.J. 2006. Distribution and status of the eastern indigo snake (*Drymarchon couperi*) in Georgia: 2006. Unpublished report to the Georgia Department of Natural Resources Nongame and Endangered Wildlife Program, Forsyth, GA. 10 pp. and appendices.
- Stevenson, D.J., K.J. Dyer, and B.A. Willis-Stevenson. 2003. Survey and monitoring of the eastern indigo snake in Georgia. Southeastern Naturalist 2:393-408.
- The Nature Conservancy. 2006. Protecting wild Florida: Preserving the best and last wilderness of Florida, forever. A report by the Florida Chapter of The Nature Conservancy. 25 pp. + appendices. [Available on the web: http://www.nature.org/wherewework/northamerica/states/florida_forever_report.pdf]
- U.S. Fish and Wildlife Service. 1978. Endangered and Threatened Wildlife and Plants. Listing of the Eastern indigo snake as a threatened species. Federal Register 43:4026.
- U.S. Fish and Wildlife Service. 1982. Eastern indigo snake recovery plan. Atlanta, GA. 23 pp.
- U.S. Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. 23 pp.

- U.S. Fish and Wildlife Service. 2001. Eastern Indigo Snake Conservation Summit: Research and Outreach Needs. Summary notes from meeting facilitated by the U.S. Fish and Wildlife Service, Georgia DNR, and Florida FWCC and held at White Oak Plantation, Yulee, Florida. 14 pp.
- Wear, D.N. and J.G. Greis. 2002. Southern forest resource assessment: summary report. Gen. Tech. Rep. SRS-54. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. 103 pp.
- Wuster, W., J.L. Yrausquin, and A. Mijares-Urrutia. 2001. A new species of indigo snake from north-western Venezuela (Serpentes: Colubridae: *Drymarchon*). Herpetological Journal 11:157-165.

Peer Reviewers:

Dirk Stevenson
414 Club Drive
Hinesville, GA 31313

Becky Bolt
Dynamac Corp.
Mail Code DYN-1
Kennedy Space Center, FL 32899

Kevin Enge
Florida Fish and Wildlife Conservation Commission
Wildlife Research Lab
4005 South Main St.
Gainesville, FL 32601

Paul Moler
7818 SW CR 346
Archer, FL 32618

**U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW
of
EASTERN INDIGO SNAKE**

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

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change is needed

Appropriate Listing/Reclassification Priority Number, if applicable: _____

Review Conducted By: Linda LaClaire

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve *Cary Hoquist* Date 4-18-08

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

Approve *Nancy E. DeShazo* Date 4/29/08

APPENDIX A: Summary of peer review for the 5-year review of Eastern indigo snake (*Drymarchon corais couperi*)

A. Peer Review Method: The draft 5-year review document was sent to biologists at affected FWS field offices (Daphne, Alabama; Panama City, Florida; Jacksonville, Florida; Vero Beach, Florida; Brunswick, Georgia; and Charleston, South Carolina). These offices were asked to forward the document for review to biologists at National Wildlife Refuges (with actual/potential eastern indigo snake habitat) within each field office's area of responsibility. In addition, the document was also sent to four independent peer reviewers including: Dirk Stevenson, eastern indigo snake researcher recently employed at Fort Stewart Military Installation, Georgia; Becky Bolt, wildlife biologist/eastern indigo snake researcher, Dynamac Corp, Kennedy Space Center, Florida; Kevin Enge, herpetologist with the Florida Fish and Wildlife Conservation Commission; and Paul Moler, herpetologist recently retired from the Florida Fish and Wildlife Conservation Commission.

B. Peer Review Charge: The following cover letter was sent along with the draft 5 year review (excluding the signature page) to the peer-reviewers:

On September 8, 2006, the U.S. Fish and Wildlife Service published a notice in the Federal Register announcing a 5-year review of 14 federally listed species, including the eastern indigo snake (*Drymarchon couperi*). The purpose of the 5-year review is to ensure that the classification of species as threatened or endangered is accurate and reflects the best available information.

You have provided data used to review the status of this species, and you have been identified as knowledgeable about this species. Therefore, in order to ensure that the best available information has been used to conduct this 5-year review, we now request your peer review of the attached document. Specifically we ask for comments on the validity of the data used, and identification of any additional new information on any of these species that has not been considered in this review. Please note that we are not seeking your opinion of the legal status of these species, but rather that the best available data and analyses were considered in reassessing their status.

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. Please give me a call if you have any questions (601-321-1126). Please feel free to respond by email or letter. Thank you for your assistance.

Sincerely,

Linda LaClaire
Wildlife Biologist
U.S. Fish and Wildlife Service
6578 Dogwood View Parkway
Jackson, MS 39213

C. Summary of Peer Review Comments/Report – All peer reviewers supported the analyses and information in the document. Editorial comments, as well as additional recent (2008) data, were provided by several peer reviewers; the South Florida, Jacksonville, Brunswick, and Charleston Field Offices; and Merritt Island National Wildlife Refuge.

D. Response to Peer Review – Changes were made in the document, where appropriate, based on editorial comments and the new data provided by reviewers. There was no disagreement expressed by any of the reviewers.