Appendix D. Reptiles and Amphibians Technical Team Report

Prepared by John B. Jensen, Team Leader

Technical Team Members

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Invited but unable to participate:
Dr. Michael Black, Georgia State University – Professor
Dr. Lance McBrayer, Georgia Southern University – Professor/Curator
Robert Moulis, Chatham County – Herpetologist
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Approach

Two one-day herp team workshops were held: Georgia Wildlife Federation Headquarters on 15 November 2013; Little Ocmulgee State Park 14 January 2014. The first meeting began with a progress report on amphibian and reptile action items identified in the 2005 SWAP to inform the team on accomplishments and continued needs (summary of accomplishments provided below). Following this report and continuing through the remainder of both meeting dates, the team was presented with the 2005 spreadsheet of high priority species to amend based on information learned since the previous effort. This spreadsheet identifies each species' abundance, range, population trend, threats, protection needs, inventory needs, monitoring needs, research needs, and importance in Georgia as it relates to global conservation of the species. This effort required the knowledge of professionals who work closely with reptiles and amphibians in Georgia and their conservation, and the team assembled for this evaluation certainly represented that need. In addition to expert opinion provided by team members, information on conservation concerns and needs was gleaned from peer-reviewed scientific literature, technical reports, and natural history museum databases.

Thirteen species from the 2005 priority list (*Graptemys geographica*, *Desmognathus aeneus*, *Desmognathus folkertsi*, *Necturus maculosus*, *Plestiodon* [formerly *Eumeces*] *egregius*, *Plethodon metcalfi*, *Plethodon shermani*, *Plethodon teyahalee*, *Plethodon websteri*, *Pseudacris brachyphona*, *Pseudobranchus striatus*, *Stereochilus marginatus*, and *Tantilla relicta*) were not selected by the team for inclusion in the 2015 priority list because they were considered either too peripheral in Georgia or not rare/threatened enough to warrant conservation attention equal to the others. In fact, the status of several of these species was unknown or poorly known in 2005, but studies and observations since then revealed enough stability to consider them of significantly lesser conservation concern. Conversely, six that were not on the 2005 list species (*Ambystoma tigrinum*, *Eurycea aquatica*, *Eurycea chamberlaini*, *Ophisaurus compressus*, *Plethodon savannah*, and *Urspelerpes brucei*) were added to the new one. The full 2015 high priority species list is shown below in Table 1.

The team also discussed the current list of state protected reptiles and amphibians and recommended changes based on current status and threats (this information is not presented here, but will be used when the state protected list is formally reviewed). Following the meeting, the team leader "cleaned-up" the spreadsheet and resubmitted to the team for final review. This finalized spreadsheet was used by the team leader as an important tool for recommending top priorities for conservation action.

Significant 2005 SWAP Priority Action Items Accomplishments

1. Conduct status survey for hellbender.

   A 2005 survey by Jeff Humphries checked stream segments in proximity to historical occurrence records in 21 areas. This contracted survey established a baseline for a long-term, landscape-level survey and population monitoring effort initiated in 2011. Primary

objectives include monitoring known populations over time and documenting additional populations from stream basins that had not been sampled before. From 2011-2014, hellbender surveys of 57 streams totaling 47.8 km of stream habitat were conducted by snorkeling and flipping rocks. Researchers caught, weighed, measured, photographed, and individually marked 350 hellbenders. Tissue samples were collected from 305 hellbenders for museum archival and for use in genetics research. Each hellbender was sampled for chytrid fungus (*Bd*) and Ranavirus. Results from the analysis of these and future samples will help in a range-wide assessment of the health of the species. A Georgia hellbender species status assessment was submitted to USFWS to assist in a range-wide assessment in response to a petition to list the hellbender under the federal Endangered Species Act. In cooperation with The Orianne Society, WRD also conducted a hellbender survey throughout much of the north Georgia mountains using environmental DNA (eDNA). In 2013, 150 water samples were collected from 98 streams, including some that had not been sampled before, plus streams with known hellbender populations, streams with historical occurrences and several streams outside of the species' known distribution in Georgia (the Tennessee River drainage). Hellbender DNA was not detected in any of the sampled streams in northwestern Georgia or any of the streams outside of the Tennessee River drainage, with the exception of one previously documented site. However, DNA was detected in 12 streams where hellbenders had not been previously documented.

2. Conduct surveys of potential habitat for bog turtle and associated species and evaluate methodology for use in other habitats in North Georgia.

   In an effort to monitor known populations and identity new bog turtle populations, an average of 150 traps per year have been set in 33 different mountain bog sites for a total of over 71,000 trap days since 2007. In 2005, the Natural Resources Spatial Analysis Laboratory (NARSAL) of UGA was contracted to conduct a GIS-based bog habitat survey of an 11 county area encompassing the Blue Ridge Physiographic Province and adjacent areas. 330 sites were initially identified in the NARSAL survey. In collaboration with the University of Georgia and Clemson University a species distribution model was built in MaxEnt software by creating a relative suitability map based on relationships between known bog turtle occurrences and the ten selected environmental characteristics typical of suitable bog turtle habitat. As a result of these two mapping efforts, over 300 sites have been ground-truthed or otherwise excluded as potential habitat for rare bog flora and fauna in Georgia; 18 separate wetland sites have been selected for bog turtle trapping surveys resulting in the discovery of 4 new bog turtle occurrences, increasing the number of known occurrences in Georgia by 40%. An additional 80 wetland sites identified through GIS, remain to be assessed for potential suitability

3. Identify potential habitat for flatwoods salamander and other high priority Coastal Plain species; survey habitats for populations of high priority species.

   Areas of suitable habitat on public and on private lands within the historical range of the flatwoods salamander, striped newt, and gopher frog were identified through numerous sources including the analysis of topographic and soil survey maps, aerial imagery, a digital elevation model, GIS-based habitat modeling, and information provided by local resource

managers, biologists, and agency staff. Surveys for pond breeding amphibians were conducted by dip-netting wetlands following ground-truthing of potential sites on the ground or by helicopter survey. Thirty-five tracts of private land were surveyed primarily for flatwoods salamanders, as well as suitable wetlands on Chickasawhatchee, Mayhaw, and Grand Bay WMAs, Dixon Memorial Forest, and Okefenokee NWR. Survey efforts failed to identify new populations of flatwoods salamanders. Opportunistic surveys for gopher frogs and striped newts detected the former at two previously unknown sites. No new striped newt sites were discovered during this period, but continued persistence was documented at previously known, extant sites.

Sean Graham conducted a WRD-sponsored status survey for the southern dusky salamander in Georgia. Only seven individuals from two sites were found in Georgia, despite widespread historical occurrences. Additional information resulting from this survey can be found in the following publication:
Graham, S. P., E. K. Timpe, and L. R. Laurencio. 2010. Status and possible decline of the southern dusky salamander (*Desmognathus auriculatus*) in Georgia and Alabama, USA. Herpetological Conservation and Biology 5:360-373.

4. Develop private landowner incentives for conservation of flatwoods salamanders.

   An analysis of the feasibility of implementing the Safe Harbor Policy as a conservation strategy for flatwoods salamander was conducted. Through interaction with private landowners while conducting flatwoods salamander surveys, it became clear that in order to gain access to many private landholdings some form of legal assurances or conservation incentives must be available. Following a thorough policy analysis, recommendations were made to the US Fish and Wildlife Service for a unique application of the Safe Harbor Policy for the flatwoods salamander that would require no additional regulative mechanism. These policy recommendations would allow for "A Priori Zero Baseline" Safe Harbor Agreements in exchange for access to a particular private property to conduct flatwoods salamander surveys. Extensive drought from 1998 to 2009, coupled with disruption of metapopulation dynamics through extensive habitat fragmentation on the landscape are thought be the primary factors in the presumed extirpation of *A. bishopi* and near extirpation of *A. cingulatum* in Georgia, thus making the implementation of conservation incentives for this species in Georgia moot. However, recommendations resulting from this policy analysis are applicable to any plant or reclusive animal species requiring direct access to private lands to survey for species presence and may still show promise in the conservation of such species.

5. Assess status of diamondback terrapin populations and determine impact of vehicle-induced mortality and incidental captures on populations.

   Dr. John Maerz, UGA Warnell School of Forest Resources, conducted a statewide survey of Georgia's tidal creeks to assess diamondback terrapin abundance. Single-year mark-recapture estimates of terrapin abundance were obtained for 29 randomly chosen tidal creeks. Researchers estimated that 88% of Georgia's tidal creeks were occupied with an abundance estimate of approximately 92,000 sub-adult and adult terrapins. Terrapin density was found to decline with increasing commercial crabbing activity and there was no measurable impact

on abundance with proximity to roads. The overall conclusion of the study was that terrapins were relatively widespread and moderately abundant in Georgia with some notable areas of high density.

6. Continue long-term monitoring of Pigeon Mountain salamander populations; conduct surveys for other high priority cave and outcrop species.

   Carlos Camp of Piedmont College and WRD staff seasonally (once per season) monitored cave-dwelling salamanders at six caves on Pigeon and Lookout mountains every year during this period and observed stable populations of Pigeon Mountain salamanders and other salamander species for which enough encounters were made to assess trends. Additional information resulting from this monitoring effort can be found in the following publications:
   Camp, C. D., and J. B. Jensen. 2007. Seasonal patterns of lipid storage in two salamander species in northwestern Georgia. Journal of the North Carolina Academy of Sciences 123:110-118.
   Camp, C. D., and J. B. Jensen. 2007. Use of twilight zones of caves by plethodontid salamanders. Copeia 2007:594-694.
   Camp, C. D., J. A. Wooten, J. B. Jensen, and D. F. Bartek. 2014. Role of temperature in determining relative abundance in cave twilight zones by two species of lungless salamanders (family Plethodontidae). Canadian Journal of Zoology 92:119-127.

   Numerous caves were surveyed for Tennessee cave salamanders but no new populations were discovered.

   The discovery of green salamanders on Rocky Mountain in the Ridge and Valley (previously unknown from this province) prompted further staff surveys throughout the Georgia portion of this province and resulted in numerous new occurrences.

7. Conduct genetic, taxonomic, and reproductive studies of high priority species. (e.g., bog turtle reproduction; loggerhead genetics; parameters of healthy alligator snapping turtle population).

   Although genetic dependent sex determination (GSD) is the likely mode of sex determination in the bog turtle, discovery of temperature dependent sex determination (TSD) in this species would have significant implications for headstarting methods used in the conservation of the southern bog turtle population. Eggs collected from Georgia's wild turtles in 2011 were used in the initiation of a multi-year cooperative study between the Chattahoochee Nature Center and WRD intended to determine GSD/TSD. However, temperature-controlled incubation of eggs for this experiment was suspended in 2012 due to limited egg availability and lack of egg variability or survival. Funding was granted in 2014 for a study intended to identify sex chromosomes in bog turtles, which would demonstrate GSD without risking the health or future reproduction of any individuals.

   Georgia DNR collaborated with Dr. Joe Nairn and Dr. Brian Shamblin, UGA Warnell School of Forest Resources, to conduct a statewide genetic mark-recapture estimate of adult female loggerhead sea turtle abundance from 2008 to 2014. A single viable egg was taken from each

nest in Georgia. Maternal DNA was extracted from egg samples, and nesting females were identified using 18 novel microsatellite loci. To date, 2,242 individual females have been identified nesting on Georgia beaches. Estimates of annual adult female abundance ranged from 288 to 733 females. Other important reproductive parameters were also estimated including site fidelity, clutch frequency, and remigration interval.

WRD conducted a long-term capture-mark-recapture study of alligator snapping turtles in Spring Creek in southwest Georgia. Because a previous survey by staff had shown that this population had the highest capture rate of surveyed populations in Georgia – suggesting it may be among the state's healthiest populations surveyed – we sought to characterize demographics here as a reference for evaluating recovery in other populations. The study ended in 2014, totaling 163 captures of 71 individual turtles in a 2.5-mile stretch of the creek. WRD and Auburn University researchers are analyzing capture-mark-recapture data from the 16-year period to examine population demographics, growth rates and longevity.

8. Investigate site fidelity and habitat use by eastern indigo snakes.

UGA–Warnell School was contracted to conduct this work and served as PhD dissertation research for Natalie Hyslop. A radiotelemetry study from 2002-2004 investigated the habitat use, survival, movements, and home ranges of the species in southeastern Georgia. 32 snakes (19 M, 13 F) at sites on Fort Stewart and adjacent private property were tracked. Annual home ranges were found to be large (male = 510 ha; female = 101 ha). Models for annual home range size estimates suggested a positive correlation with body size, negative influence of sex (being female), and negative association with habitat undergoing restoration opposed to areas used commercially. Snakes used the highest diversity of habitats in late spring and summer as they moved from their dry upland winter and early spring habitats to wetter, lowland summer ranges; however, snakes continued to periodically use upland xeric habitats throughout the warmer months. Snakes in this study maintained close association with underground shelters, especially throughout the winter. Most fall and winter locations were recorded at gopher tortoise burrows. Snakes relied less on these burrows in spring and summer. Additional information resulting from this study can be found in the following publications:

N. L. Hyslop, R. J. Cooper, and J. M. Meyers. 2009. Seasonal shifts in shelter and microhabitat use of *Drymarchon couperi* (eastern indigo snake) in Georgia. Copeia 2009:458-464.

N. L. Hyslop, J. M. Meyers, R. J. Cooper, and T. M. Norton. 2009. Survival of radio-implanted *Drymarchon couperi* (eastern indigo snake) in relation to body size and sex. Herpetologica 65:199-206.

N. L. Hyslop, D. J. Stevenson, J. N. Macey, L. C. Carlile, C. L. Jenkins, J. A. Hosteetler, and M. K. Oli. 2011. Survival and population growth of a long-lived threatened snake species, *Drymarchon couperi* (eastern indigo snake). Population Ecology DOI 10.1007/s10144-011-0292-3.

9. Restore mountain bogs; continue bog turtle headstart and population establishment efforts and use non-releasable turtles for education/outreach efforts.

   A robust field experiment was initiated in 2007: "The Efficacy of Prescribed Fire, Mechanical Woody Stem Removal, and Herbicide Application in the Restoration and Maintenance of Southern Appalachian Mountain Bog Habitats in an Early Seral State by Mimicking Natural Disturbance." The final round of data collection was completed in 2013. A manuscript analyzing the results of this study is in preparation. Vegetative composition of 20 mountain bogs (10 with documented bog turtle occurrences, 10 previously trapped without detection) has been mapped and vegetation classified according to National Wetland Inventory standards. Changes to vegetative composition and hydrologic functionality of these same sites over time are being determined through historical aerial photographic interpretation. All of these data are being collected in an effort to determine subtle environmental variables affecting habitat suitability for the bog turtle over time. A total 17 captive-reared bog turtles were released within a restored mountain bog on the Chattahoochee NF in 2004 and 2005. These turtles are progeny of a captive breeding colony of 7 wild bog turtles from 3 separate Georgia bogs. The sudden loss of all 7 turtles has severely affected Georgia's ability to produce captive-reared turtles for release. Fortunately much of the 2006 cohort of captively-reared hatchlings make up a captive breeding colony today. An effort to breed these captives was initiated in 2011. Since 2007, no viable eggs have been produced in captivity nor have any hatchlings from wild-caught gravid females survived. An outdoor bog turtle enclosure is currently under construction and a cooperatively developed standardized protocol for bog turtle headstarting has been initiated among conservation partners, both of which are expected to improve headstarting results in Georgia in the future with the ultimate objective of additional releases of headstarted bog turtles into restored habitat.

10. Address problems with state law (O.C.G.A. 27-1-28) permitting unregulated and unrestricted commercial take of freshwater turtles, and develop appropriate regulations.

    A stakeholder's group was formed and met several times to develop appropriate regulations. The Board of Natural Resources approved the recommended regulations which became official in January 2012 (O.C.G.A. 391-4-16). In summary, anyone wishing to possess more than 10 freshwater turtles in Georgia is required to obtain a commercial turtle permit and annually report details of their harvest. Commercial turtlers will be subject to annual quota limits of 100 to 1000 turtles, depending on the species. We believe that these limits are strict enough to prevent overharvest while being generous enough to allow limited commercial enterprise. And, because we now have harvest data made available to us, if these limits prove inadequate to sustain turtle populations, we will have the supportive information necessary to adjust the rules.

11. Address venomous snake exception in state law (O.C.G.A. 27-1-30) prohibiting disturbing or destroying wildlife habitats.

    Senate Bill 322, which simply struck the venomous snake exception language, passed and was signed into law making it illegal to use gasoline or other chemicals to drive rattlesnakes from gopher tortoise burrows.

12. Address problems with state law (O.C.G.A. 27-1-28) permitting unregulated and unrestricted commercial take of eastern diamondback rattlesnakes, and develop appropriate regulations.

    This action item was not addressed, but remains a priority in the 2015 SWAP revision.

13. Continue sea turtle stranding and salvage network. Monitor impacts of coastal fisheries on sea turtles and effectiveness of nest protection efforts. Consider construction of a Georgia SeaTurtle Center on Jekyll Island.

    Georgia DNR maintained a network of volunteers, managers, and researchers to monitor beaches for stranded sea turtles. Stranded sea turtles were identified by species and morphometric measurements were collected. Gross necropsies are conducted on approximately 65% of carcasses to determine sex and probable cause of death. The number of stranded sea turtles ranges from 84 to 804 annually. Major threats to sea turtles based on necropsies included incidental capture and drowning in the shrimp trawl fishery and watercraft related injuries. In order to further assess the effects of the shrimp trawl fishery on sea turtles, Georgia DNR conducted bi-monthly aerial surveys to document trawler abundance and distribution. Trawler distributions were correlated with stranding patterns to assist law enforcement personnel in planning TED compliance boardings.

    Georgia DNR maintained a network of volunteers, managers, and researchers to monitor beaches for sea turtle nesting activity. Approximately 85 % of Georgia's barrier island beaches were monitored daily from1 May through 1 October for sea turtle nesting activity. Nests deposited at low beach elevations were relocated to minimize embryo mortality from tidal inundation. Nest screening and predator control were used to minimize nest loss to predators. Nests were inventoried following hatchling emergence to assess reproductive success. Loggerhead nesting data shows a significant increasing trend in nesting in Georgia since comprehensive surveys were initiated in 1989 (n=25 years).

    Georgia DNR assisted with fund-raising and design of the Georgia Sea Turtle Center. The Georgia Sea Turtle Center opened to the public in 2007 and is the centerpiece of the sea turtle conservation program on Jekyll Island. The GSTC is an integrated conservation program that includes research, education and rehabilitation.

14. Establish or augment populations of gopher frog, striped newt, gopher tortoise and other high priority species on protected lands.

    In 2007, in partnership with Atlanta Botanical Garden, University of Georgia, The Nature Conservancy, Zoo Atlanta, U.S. Department of Defense, Joseph W. Jones Ecological

Research Center, and Bear Hollow Zoo, WRD began a project that involved collecting gopher frog eggs from healthy populations, rearing them to late-stage tadpoles or post-metamorphic froglets, and releasing them at an unoccupied but high-quality protected site at Williams Bluffs Preserve in Early County, which is within the species' historical range. The goal: Establish a self-sustaining breeding population of gopher frogs at a protected site. 5,621 gopher frogs, mostly metamorphs, have been reared and released during this period. While previous years of drought prevented mature gopher frogs the opportunity to breed in the release pond – and biologists' ability to assess the success of the project – in 2013 we were provided sufficient rainfall to fill the wetland basin. Multiple male gopher frogs were heard calling in the pond that year and a single egg mass was discovered. Males were also heard calling in 2014. Camera surveys of gopher tortoise burrows in the uplands surrounding the wetland showed juvenile and adult gopher frogs using the burrows. Together, these discoveries indicate that released juveniles are surviving to adulthood in the uplands and successfully breeding in the wetland.

Yuchi WMA, a DNR tract identified as having an unsustainably low gopher tortoise population size in its current state, was established as a recipient site for tortoises displaced by development. Thirty-six adult tortoises have been released, and radio telemetry conducted on 10 of them has shown strong fidelity to the release site. Beginning in 2014, juvenile tortoises hatched and head-started from eggs collected at stable populations are being used to further augment the population. Twelve juvenile tortoises with attached radio-transmitters were released in soft-release pens for a three-week period, then allowed free roam once they became well-acclimated to the site. Researchers with UGA are tracking the free-ranging juveniles to evaluate growth, habitat use, home range and survivorship. 20 nests collected from the stable donor sites in 2014 resulted in 142 hatchlings being raised in captivity for release in spring 2015.

Although repatriation of striped newts did not occur in Georgia during this period, Georgia striped newts and WRD staff contributed significantly to efforts in Florida. A small number of striped newts collected from the Fall Line Sandhills WMA breeding pond by staff and others established captive breeding populations at Jacksonville and Memphis zoos. 490 larvae have been produced at these two zoos and were released in an Apalachicola National Forest wetland in 2013 and 2014. Researchers have documented emigration of 36 fully developed land-bound newts from the recipient wetland.

15. Develop technical educational materials.

WRD funded and led the effort to produce the state's only comprehensive guide book to amphibians and reptiles:
Jensen, J. B., C. D. Camp, W. Gibbons, and M. J. Elliott. 2008. Amphibians and Reptiles of Georgia. University of Georgia Press, Athens, GA. 575 pp.

Brochures include:
Forest Management Practices to Enhance Habitat for the Gopher Tortoise
Venomous Snakes of Georgia
Is it a Water Moccasin? (revision/reprint)

High Priority Amphibians and Reptiles

Common Name	Scientific Name
Reticulated Flatwoods Salamander	*Ambystoma bishopi*
Frosted Flatwoods Salamander	*Ambystoma cingulatum*
Eastern Tiger Salamander*	*Ambystoma tigrinum*
One-toed Amphiuma	*Amphiuma pholeter*
Green Salamander	*Aneides aeneus*
Loggerhead Sea Turtle	*Caretta caretta*
Green Sea Turtle	*Chelonia mydas*
Spotted Turtle	*Clemmys guttata*
Eastern Diamond-backed Rattlesnake	*Crotalus adamanteus*
Hellbender	*Cryptobranchus alleganiensis*
Leatherback Sea Turtle	*Dermochelys coriacea*
Southern Dusky Salamander	*Desmognathus auriculatus*
Eastern Indigo Snake	*Drymarchon couperi*
Brown-backed Salamander*	*Eurycea aquatica*
Chamberlain's Dwarf Salamander*	*Eurycea chamberlaini*
Georgia Blind Salamander	*Eurycea wallacei*
Bog Turtle	*Glyptemys muhlenbergii*
Gopher Tortoise	*Gopherus polyphemus*
Barbour's Map Turtle	*Graptemys barbouri*
Alabama Map Turtle	*Graptemys pulchra*
Tennessee Cave Salamander	*Gyrinophilus palleucus*
Southern Hognose Snake	*Heterodon simus*
Kemp's or Atlantic Ridley	*Lepidochelys kempii*
Gopher Frog	*Lithobates capito*
Alligator Snapping Turtle	*Macrochelys temminckii*
Diamondback Terrapin	*Malaclemys terrapin*
Dwarf Waterdog	*Necturus punctatus*
Striped Newt	*Notophthalmus perstriatus*
Island Glass Lizard*	*Ophisaurus compressus*
Mimic Glass Lizard	*Ophisaurus mimicus*
Pine Snake	*Pituophis melanoleucus*
Southern Coal Skink	*Plestiodon anthracinus pluvialis*
Pigeon Mountain Salamander	*Plethodon petraeus*
Savannah Slimy Salamander*	*Plethodon savannah*
Patch-nosed Salamander*	*Urspelerpes brucei*
* = species not on 2005 SWAP	

Examples of High Priority Habitats

Southwestern Appalachians/Ridge & Valley

Caves, springs, and rock outcrops
A great diversity of salamanders, including three of high conservation concern (green, Pigeon Mountain, and Tennessee cave salamanders), depend on these habitats. Caves and rock outcrops can obviously be impacted by mining operations, a continued threat in this region. Forest moisture required by terrestrial salamanders may be compromised by land alteration. Water quality of springs and subterranean streams is threatened by septic tanks and other sources of toxins from upslope developments.

Sag ponds
Fishless, temporary wetlands are critical breeding habitats for a number of amphibians, yet they are frequently deepened and stocked with fish, or drained.

Blue Ridge

Cove hardwood forests
Salamanders reach their highest worldwide diversity in the Southern Blue Ridge, and cove hardwood habitats harbor much of this diversity. Maintenance of mesic forest conditions and low silt loads in embedded seeps and small streams is threatened by development and forestry activities that do not follow Best Management Practices (BMPs).

Mountain bogs
Primarily of concern because of the dependence on this habitat by the endangered bog turtle, although numerous other reptiles and amphibians can be found here. The majority of these habitats are formed in low mountain valleys, mostly in private ownership. Streams within mountain bogs are often channelized, diverted, or impounded, rendering them unsuitable for bog turtles. Beavers may be the primary force behind creation of these habitats, but their activities are rarely tolerated by most landowners. Maintaining these naturally successional habitats requires active management in the form of hand-clearing shrubs and hardwoods, prescribed fire, and targeted herbicide application.

Medium to large streams
Those found in the Tennessee River drainage are home to the hellbender, a huge, fully aquatic salamander that is very sensitive to stream perturbations. Siltation from improper erosion control during land clearing activities and inadequate forested buffers is perhaps the greatest threat. Accumulations of silt reduce or eliminate space between critical rock shelters, and suffocate eggs and larvae. Forestry activities should follow industry-approved BMPs to avoid impacts to streams.

Piedmont

Spring seeps

The recently discovered patch-nosed salamander is only known to occur in a few headwater streams or seeps in the upper Piedmont of eastern Georgia and adjacent South Carolina, thus protection of the surrounding forests is critical to maintaining suitable water quality.

Otherwise, the Piedmont does not contain habitats uniquely important to herps of conservation concern, and with the notable exception above, few of these species range into this province.

Southeastern Plains and Southern Coastal Plain

Isolated wetlands

Includes Carolina bays, sinkhole ponds, cypress domes, and other depressional wetlands. A number of high priority herps (gopher frog, frosted flatwoods salamander, reticulated flatwoods salamander, eastern tiger salamander, and striped newt) depend on the fishless (or lacking of large, predatory fish), temporary conditions provided by isolated wetlands. However, most of these species spend considerably more time burrowed in adjacent uplands. Conservation of these species requires attention to both wetland and upland habitat needs. These wetlands are exempt from any protection under the Clean Water Act, thus they can be filled, drained, or deepened for permanency. The adjacent uplands are often impacted by conversion to silviculture, agriculture, residential and industrial development, or are neglected, fire-suppressed, and overgrown with hardwoods. Prescribed fires in surrounding uplands should be allowed to burn into isolated wetlands, which often necessitates that burning be periodically conducted during the summer when these ponds are most often dry.

Longleaf pine-wiregrass habitats

Includes pine flatwoods, sandhills, and upland pine forest. Many species of reptiles and amphibians are endemic, or nearly so, to this broad habitat type. Thus, it is not surprising that the 97% loss of this habitat range-wide has led to drastic declines of closely associated herpetofauna. Priority species include those above that breed in isolated wetlands, plus mimic glass lizard, eastern indigo snake, southern hognose snake, pine snake, eastern diamond-backed rattlesnake, and gopher tortoise. Silviculture, agriculture, residential and industrial development, and fire suppression have all contributed to loss and alteration of longleaf-wiregrass habitats, and ultimately to declines of the aforementioned herp species. Prescribed burning on an appropriate rotation is the single best tool for maintaining these habitats, but mechanical and chemical means may be necessary to restore some sites before fire alone can be effective. Removal of longleaf pine stumps for the resin and rosin industry significantly reduces important refugia available to numerous snake species, including eastern indigo snake, eastern diamond-backed rattlesnake, and Florida pine snake. This practice should be prohibited on state lands and discouraged elsewhere.

Hammocks and other high ground within and adjacent to salt marshes

Georgia's extensive salt marshes are home to a unique and very specialized turtle of conservation concern, the diamondback terrapin. Terrapins must nest in sandy soil above the high tide level. Unfortunately, these higher grounds are premium land for developments and roads, which

reduces the available nesting sites for terrapins and leads to high mortality of females and hatchlings while crossing roads. Early successional habitats on hammocks and in secondary dune systems are also favored habitats for eastern diamond-backed rattlesnakes and island glass lizards.

Ocean beach/dunes

Georgia's ocean beach/dune habitat is critical for the recovery and maintenance of threatened loggerhead turtle populations. Loggerheads typically nest on ocean beaches between the high tide line and the front of the primary dune. Beachfront property is also perhaps the most highly prized real estate in Georgia for residential development and recreation. Human activities have resulted in a wide variety of direct and indirect impacts to this important habitat. Indirect effects include reduced sediment input to the coastal sand-sharing system as a result of the impoundment of Georgia's major river systems. In addition, the construction of jetties and shipping channels has altered natural sand movement patterns increasing erosion on some beaches. Direct impacts to beach dune habitats include coastal development and construction activities such as beach nourishment projects, shoreline stabilization (rock armoring), home construction, artificial lighting, and increased recreational use. Disallowing the construction of structures in the dynamic dunefield will reduce the need to install shoreline stabilization structures and resulting loss in available nesting habitat.

High Priority Areas

Partners in Amphibian and Reptile Conservation (PARC) developed a Priority Amphibian and Reptile Conservation Areas (PARCAs) project. PARCAs are a non-regulatory designation whose purpose is to raise public awareness and spark voluntary action by landowners and conservation partners to benefit amphibians and/or reptiles. Areas are nominated using scientific criteria and expert review, drawing on the concepts of species rarity, richness, regional responsibility, and landscape integrity. Modeled in part after the Important Bird Areas program developed by BirdLife International, PARCAs are intended to be coordinated nationally but implemented locally at state or regional scales. Importantly, PARCAs are not designed to compete with existing landscape biodiversity initiatives, but to complement them – providing an additional spatially explicit layer for conservation consideration.

PARCAs are intended to be established in areas:
- capable of supporting viable amphibian and reptile populations
- occupied by rare, imperiled, or at-risk species, and
- rich in species diversity or endemism

A meeting of amphibian and reptile experts in Georgia (listed below), most of which were also on the SWAP revision herp technical team, was hosted by WRD and convened on 12 June 2012 to determine Georgia's PARCAs. More information on the process can be found in: Apodaca, J.J., S., Spear, and C.L. Jenkins. 2014. Determining Priority Amphibian and Reptile Conservation Areas in the south Atlantic landscape, and assessing their efficacy for cross-taxa conservation. Final Report for the South Atlantic Landscape Conservation Cooperative.

Georgia PARCAs Meeting attendees (* = denotes SWAP herp team member):
Dr. J.J. Apodaca, Warren Wilson College - Professor
Dr. Lora Smith, Joseph W. Jones Ecological Research Center – Herpetologist *
Thomas Floyd, WRD – Wildlife Biologist *
Malcolm Hodges, The Nature Conservancy - Ecologist
Matt Elliott, WRD – Program Manager *
Dr. Bill Birkhead, Columbus State University - Professor *
John Jensen, WRD – Wildlife Biologist *
Dirk Stevenson, The Orianne Society – Herpetologist *
Dr. Carlos Camp, Piedmont College – Professor *
Javan Bauder, The Orianne Society – Herpetologist
Dr. Chris Jenkins, The Orianne Society - Director *

Georgia PARCAs (refer to Figure 1)

1. Lookout/Pigeon Mountains - Highest salamander species richness in GA, and only place with four species of *Plethodon*. Includes entire range of the Georgia endemic Pigeon Mountain salamander and only known Georgia site(s) for Tennessee cave salamander. Green salamanders are commonly found in rock outcrops in this area. Species endemic to karst regions such as cave salamander and southern zigzag salamander thrive here. Also includes amphibian species normally associated with Coastal Plain such as tiger salamander and southern cricket frog. Mountain chorus frogs and the one of the largest breeding populations of four-toed salamanders range-wide use sag ponds on the mountain tops.

2. Armuchee Ridges – This Ridge and Valley Province PARCA includes species endemic to karst regions, such as the cave salamander. Green salamanders occur in the rocky outcrops and brown-backed salamanders are found in artesian springs and their outflow streams.

3. Conasauga River – A high quality stream with populations of both Alabama and northern map turtles.

4. Cohutta Mountains – Perhaps the largest contiguously forested region in the state, with attendant, high salamander diversity. Also contains headwaters of Conasauga River on the western side; the eastern side contains headwaters for streams that contain hellbenders and possibly mudpuppies.

5. Rich Mountain/ Snake Nation - High salamander diversity including a genetically unique form of Chattahoochee slimy salamander. Contains headwaters for streams that contain hellbenders and possibly mudpuppies.

6. Nantahala Mountains - High salamander diversity (e.g., 6 species of *Desmognathus*). Includes salamanders having strong genetic influence from the red-legged salamander, a North Carolina endemic. Possible occurrence of pigmy salamander. Streams of the Tennessee River drainage harbor hellbenders. Includes populations of eastern milk snakes and coal skinks.

7. Upper Chattooga Basin - High salamander diversity, especially *Desmognathus* (at least 5 spp.). Only place in Georgia with southern Appalachian and southern gray-cheeked salamanders. Green salamanders occur in forested areas with rock-outcroppings.

8. Tugaloo Basin - Second highest salamander species richness in Georgia, especially genus *Desmognathus* (5 spp.). Includes all but one (in SC) known population of the locally endemic patch-nosed salamander, as well as green salamanders.

9. Paulding Forest – A uniquely intact Piedmont region with ridge-tops characterized by montane longleaf habitats, and the only Georgia PARCA representing true Piedmont ecoregion. Locally occurring mountain chorus frogs are among the interesting herps here.

10. Ft. Gordon – Uplands support gopher tortoises and southern hognose snakes, as well as the Georgia endemic Savannah slimy salamander. Streams contain excellent populations of dwarf waterdogs. Spotted turtles and pine snakes are also likely to occur here.

11. Yuchi WMA/Plant Vogtle – Contains Pleistocene beach dune-origin sandhills that are a stronghold for southern hognose and pine snakes. Gopher tortoises also present, though depleted from past human collection for food. Dwarf waterdogs, Chamberlain's dwarf salamanders, and spotted turtles are likely in the blackwater streams and riparian zones. The Savannah slimy salamander, a Georgia endemic, may occur in the uplands.

12. Pine Mountain/ Upper Flint River - An isolated Appalachian-origin ridge in the lower Piedmont that harbors species more characteristic of montane regions, such as wood frogs and spring and seepage salamanders, as well as species typically found in the coastal plain, such as eastern coral snakes. The largest populations known for Webster's salamander are found here. High priority species, Barbour's map turtle and alligator snapping turtle, are found in the river.

13. Ft. Benning/ Western Fall Line Hills – Straddling the Fall Line, Ft. Benning and the surrounding lands are a significant herp diversity hotspot. High priority species in this area include gopher tortoise, Barbour's map turtle, alligator snapping turtle, eastern diamond-backed rattlesnake, pine snake, southern hognose snake, southern coal skink, gopher frog, tiger salamander, Chamberlain's dwarf salamander, and striped newt.

14. Chickasawhatchee Swamp/Ichauway Plantation – Chickasawhatchee Swamp, a.k.a the Swamp of Toa, is the second largest wetland in Georgia and boasts populations of Florida green watersnakes (not a high priority species, but rare in GA) and alligator snapping turtles, and the larger streams in this region have Barbour's map turtles in abundance. Upland communities of longleaf pine support gopher tortoises, eastern diamond-backed rattlesnakes, pine snakes, southern hognose snakes, and non-breeding habitat for reticulated flatwoods salamanders, gopher frogs, tiger salamanders, and striped newts, all of which breed in nearby isolated wetlands. This area is underlain by the Floridan Aquifer which is home to the Georgia blind salamander.

15. Lake Seminole Region – Longleaf pine communities and embedded isolated wetlands provide habitat for gopher tortoises and eastern diamond-backed rattlesnakes. A small, remnant population of eastern indigo snakes also is found here, the only known remaining population in SW Georgia. Lower Chattahoochee and Flint rivers, as well as Spring Creek, are inhabited by good populations of Barbour's map and alligator snapping turtles. Chamberlain's dwarf salamanders are found in seepages in this region. This area is underlain by the Floridan Aquifer which is home to the Georgia blind salamander.

16. Georgia Red Hills – Premier longleaf pine-wiregrass region of GA, some of which contains virgin forest. Well-managed, primarily for the benefit of bobwhite quail and red-cockaded woodpeckers, but benefits all longleaf pine herp specialists. High priority species include gopher tortoise, eastern diamond-backed rattlesnake, pine snake, one-toed amphiuma, and tiger salamander. Included Ochlocknee River contains a healthy alligator snapping turtle population.

17. Alapaha River and Sandhills – Aeolian sandhills on east side of the river offer habitat for the following high priority species: Gopher tortoise, eastern indigo snake, pine snake, and eastern diamond-backed rattlesnake. Embedded isolated wetlands serve as breeding habitat for striped newt, gopher frog, and tiger salamander. Alapaha River is inhabited by the Suwannee River alligator snapping turtle, a distinct, newly described species that is rarer in Georgia than the species found in other drainages. Spotted turtles also occur in wetlands here.

18. Okefenokee Swamp – This is the largest wetland in Georgia and includes both embedded (islands) and adjacent upland habitats. Striped crayfish snakes and Florida red-bellied turtles are found at very few other places in Georgia. Frosted flatwoods salamander, striped newt, gopher frogs, gopher tortoises, eastern indigo snakes, eastern diamond-backed rattlesnakes, and perhaps mimic and island glass lizards all occur here.

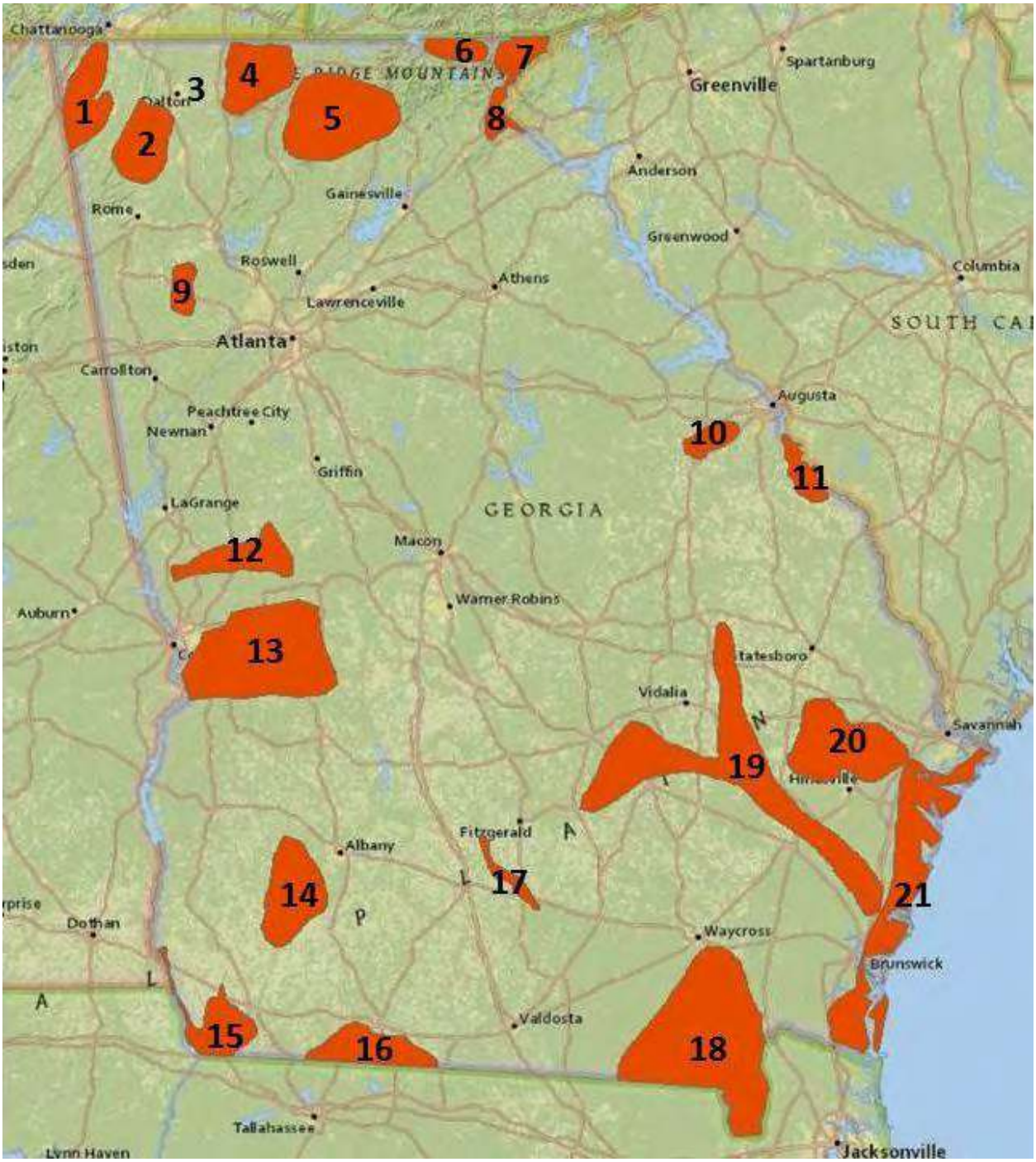
19. Altamaha-Ocmulgee-Ohoopee River Corridors – Aeolian sandhills on north and east sides of these rivers and adjacent summer habitat retreats harbor the best remaining populations of eastern indigo snakes in the state, if not in their entire range. Gopher tortoises, spotted turtles, pine snakes, and eastern diamond-backed rattlesnakes also thrive here. Isolated wetlands serve as breeding habitat for striped newt, gopher frog, and tiger salamander. Dwarf waterdogs likely occur in the streams.

20. Ft. Stewart – Largest contiguous old-growth longleaf pine-dominated ecosystem in the state, harboring the only known extant population of frosted flatwoods salamanders in Georgia. Many other rare or unique herps thrive here including gopher tortoise, spotted turtle, eastern diamond-backed rattlesnake, pine snake, southern hognose snake, gopher frog, tiger salamander, southern dusky salamander, and striped newt. The most recently documented mimic glass lizard was found at Ft. Stewart.

21. Barrier Islands and Salt Marshes – Nesting (island beaches) and/or foraging habitat (estuaries and nearshore waters) for four marine turtles (green, loggerhead, Kemp's ridley, and leatherback sea turtles). Estuaries and imbedded marsh islands are habitat for diamondback

terrapins. Other rare species found in upland areas in this region include island glass lizards and dense populations of eastern diamond-backed rattlesnakes.

Figure 1 – Georgia PARCAs



High Priority Conservation Actions

Surveys

Because most amphibians and reptiles are very cryptic in behavior, currently known occurrences of many species in the state are likely unrepresentative of their full distribution. Surveys for new populations of priority species will remain an important conservation action. A new technique that may be especially useful for our most cryptic high priority amphibians involves filtering water from aquatic habitats to detect environmental DNA (eDNA) of targeted species. This has been used successfully in Georgia for hellbenders, patch-nosed-salamanders, flatwoods salamanders, striped newts, and gopher frogs. eDNA surveys for some of these species may be expanded and we will explore the utility of this technique for other good candidates, such as Tennessee cave and brown-backed salamanders. Trained detection dogs have proved effective for detecting difficult to find reptiles and may be useful for such priority species as southern hognose snakes and mimic glass lizards. Georgia is home to 18 amphibian and reptile species that are under federal review by USFWS as candidate species or species that have been formally petitioned for listing, and we will be assisting the Service by conducting status surveys or providing status reports. Most of these status surveys are underway, some being funded by a Section 6 grant. Federal candidate species: Striped newt, gopher tortoise. Petitioned species: Gopher frog, one-toed amphiuma, hellbender, green salamander, Chamberlain's dwarf salamander, Tennessee cave salamander, Georgia blind salamander, Pigeon Mountain salamander, patch-nosed salamander, southern hognose snake, Florida pine snake, eastern diamond-backed rattlesnake, alligator snapping turtle, spotted turtle, Barbour's map turtle, Alabama map turtle.

Population Monitoring

A critical component of successful conservation efforts involves monitoring to evaluate the population stability of the target organism(s). Monitoring priority species will be done at different scales and use various methods. Some species, such as flatwoods salamander, striped newt, and gopher frog, will continue to be annually monitored for breeding activity at known, recently extant ponds. Eastern indigo snake occupancy monitoring has been employed at selected sites in the sandhills of the lower Altamaha River basin and will be periodically (every 2-3 years) continued here and expanded to other areas (likely Alapaha and Satilla river sandhills). Similarly, occupancy modeling has been used to monitor eastern hellbender populations in select mountain streams and will be continued every three years. A statewide index of abundance for diamondback terrapins, perhaps also using occupancy models, will be developed and designed to assess their trends in abundance over time. Trends in adult female sea turtle abundance will be assessed through nest monitoring programs and genetic mark-recapture sampling. Sea turtle strandings will be monitored (and necropsies performed to determine cause of death) as an index of threats in coastal marine waters. WRD is a signatory to the Gopher Tortoise Candidate Conservation Agreement, and through this has committed to monitoring tortoise population sizes and age classes of state and select private lands harboring the species every 7-10 years using line-transect distance sampling. We may also develop monitoring approaches and implementation for other priority species, such as green salamanders, spotted turtles, and one-toed ampiumas. WRD will continue to administer the North American Amphibian and Monitoring Program (NAAMP) in Georgia. This citizen science-based effort utilizes volunteers

to monitor calling activity of frogs along 73 stratified-random driving routes across the state during three survey periods each year.

Disease Screening and Monitoring

Newly emerging diseases are a growing conservation concern for many of our priority species, some of which are known to be highly susceptible while others have been unchallenged thus far but are potentially vulnerable. Diseases and disease-causing pathogens include Snake Fungal Disease (potentially harmful to all snake species), Upper Respiratory Tract Disease (affects gopher tortoises and box turtles), ranavirus (affects many amphibians and some turtles; gopher frogs are highly vulnerable based on laboratory trials), and amphibian chytrid fungi (*Batrachochytrium dendrobatidis* and *B. salamandrivorans*). Potentially or known-to-be vulnerable high priority amphibians and reptiles will be sampled for these and other emerging infectious diseases mostly as a component of on-going population surveys and monitoring efforts.

Translocation, Captive Rearing, and Head-starting

Habitat loss and the resulting fragmentation it causes have left many populations of amphibians and reptiles severely isolated. Because most of these species have very limited dispersal abilities, restoring them in areas where they have been heavily reduced (augmentation) or eliminated (repatriation) often requires translocations or captive breeding/rearing and release programs. WRD has been actively working to establish a new gopher frog population using wild-collected eggs, tadpole rearing, and releases of metamorphs. This will be continued and likely expanded to other sites. Similarly, juvenile gopher tortoises head-started from wild-collected eggs are being used to augment the small resident population on Yuchi WMA, a project that will also be continued and perhaps expanded to other sites. Augmentation of the Yuchi WMA tortoise population has also involved translocations of tortoises displaced by development elsewhere. While the cause of the displacement is a concern for this and other species, we will opportunistically salvage vulnerable tortoises and strategically use them to augment Yuchi WMA and other tortoise-depleted, but protected state lands. Captive breeding/rearing, head-starting and releases of bog turtles will also continue. Other priority species that may be future candidates for captive breeding/rearing and head-starting efforts include flatwoods salamanders, striped newts, and southern hognose snakes.

Research

Research is an integral part of many amphibian and reptile conservation efforts, in-part because for many of these species we still have more questions than answers about aspects of their life history, natural history, taxonomic status, etc. High priority species for which basic natural history remains poorly known include Chamberlain's dwarf salamander, patch-nosed salamander, Georgia blind salamander, Tennessee cave salamander, southern dusky salamander, brown-backed salamander, dwarf waterdog, one-toed amphiuma, spotted turtle, southern hognose snake, and southern coal skink. Taxonomic questions exist for green salamander (are those found in three different and widely separated physiographic provinces genetically unique?), southern coal skink (are the isolated coastal plain populations actually representative of a distinct species rather than subspecies?), and Florida pine snake (similar question as coal skink). Determining the demographic patterns and habitat use of juvenile sea turtles in coastal waters will be important to understanding patterns in seasonal abundance, and is critical for

assessing the impacts of coastal offshore development projects and other activities such as vessel interactions.

Legislation/Regulation/Enforcement

Changing existing laws and regulations, or developing new legislative or regulatory recommendations, may be necessary to ensure conservation of certain exploited amphibians and reptiles. Adding to the state list of protected species is one avenue for conservation, but that alone is not always sufficient. Concerns voiced during the technical team meetings that would require legislative or regulatory attention to adequately address include prohibiting the shooting of basking turtles (which is done indiscriminately and is a threat to map turtles), regulating the attendance of set lines ("bush-hooks"), their placement, and their immediate removal after a fishing effort (these incidentally capture and kill certain reptiles including map turtles and alligator snappers), and prohibiting or limiting commercialization (primarily for skin and venom trade) of eastern diamond-backed rattlesnakes. To further address concerns for that latter species, we will continue dialogue with the Whigham Community Club in hopes of reforming the last remaining Georgia rattlesnake roundup into a wildlife-friendly festival, as was successfully done in Fitzgerald and Claxton. The shrimp trawl fishery is the primary source of mortality for sea turtles in Georgia. Shrimpers are required to use Turtle Excluder Devices (TEDs) in all trawl nets to reduce incidental capture and drowning of sea turtles. Poor TED compliance rates have hampered sea turtle recovery efforts in Georgia. Assuring high compliance with TED regulations is necessary for population recovery. In addition, a limited-entry system for the shrimp trawl fishery should be developed to reduce overall trawling effort and interactions with sea turtles. All other trawl fisheries should be monitored for sea turtle mortality (whelk, jellyfish) and conservation measures should be put in place if mortality is observed. Applying the North American Model of Wildlife Conservation to all of our amphibians and reptiles, an idea formally approved at the 2014 AFWA Business Meeting, should be pursued in Georgia to ensure sustainable use of herpetofaunal resources.

Conservation Planning

One of the greatest threats to diamondback terrapins is drowning in commercial and recreational crab pots. To address this, a terrapin conservation plan for these crab pot fisheries will be developed and implemented. The terrapin conservation plan should include the use of Terrapin Excluder Devices (TEDs), pot soak time requirements, closure areas, removal of abandoned pots, and the monitoring of the effectiveness of conservation efforts. Another significant threat to terrapins is mortality of nesting females on coastal roadways. To address this we will continue to experimentally assess methods and develop management guidelines for reducing terrapin mortality on coastal roadways, including techniques for installing seasonal barrier fences.

Addressing/Monitoring Climate Change Impacts

Warmer average temperatures, increased drought frequency and intensity, and sea level rise are predicted outcomes of climate change in the southeastern United States that are likely to have adverse effects on herpetofauna. Effects on habitat suitability are the most wide-ranging, but in the case of most of our turtle species and the American alligator, species that exhibit temperature-dependent sex determination, warming temperatures may skew sex ratios adversely. WRD cooperators will continue to monitor the length of incubation for all sea turtle nests in the

state, which is significantly correlated with incubation temperature and sex ratio. Additionally, WRD will continue periodic qualitative surveys of sea turtle nesting habitat on all barrier island beaches, categorizing each 100 m section as erosional or depositional based on beach and dune morphological characteristics. Annual surveys are compared to determine changes in the erosional state of sea turtle nesting habitat. Researchers at UGA conducted an "Amphibian and Reptile Climate Change Vulnerability Assessment" (Barrett, K., J.C. Maerz, and N. P. Nibbelink. 2012. Amphibian and Reptile Climate Vulnerability Assessment. Attachment A In Missouri Department of Conservation (Ed.), State Wildlife Action Plan Implementation Resources and Capacity Building Tools for Amphibian & Reptile Conservation, Final Report to US Fish & Wildlife Service. Competitive State Wildlife Grant No. U-3-R-1. FBMS No. F09AP00202. Jefferson City, MO) for select southeastern species, including ten (flatwoods salamander, tiger salamander, one-toed amphiuma, green salamander, hellbender, striped newt, gopher frog, eastern indigo snake, bog turtle, and gopher tortoise) that we consider high priority in Georgia. The predictions are dire for all high priority Georgia species in showing significant reductions in climatically suitable habitat. The assessment maps indicate where climatically suitable habitat is predicted to remain in 2050, and for the striped newt and flatwoods salamander, no habitat is predicted to remain. Several of the high priority species assessed (striped newt, flatwoods salamander, hellbender, eastern indigo snake, gopher tortoise) are part of continuing population monitoring efforts in Georgia, and over time we will be able to compare observations of them from the field with the predictive models. For pond-breeding amphibians such as striped newts, tiger salamanders, and gopher frogs, creating permanent fishless wetlands by installing flexible plastic liners in natural or excavated depressions is one method to mitigate for climate change impacts that may be explored.