Appendix J. Monitoring Technical Team Report

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Technical Team Members

Team Leaders
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Brian Davis, GA Department of Transportation – Ecologist
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Team Members participating through email and correspondence
Analie Barnett, The Nature Conservancy – Landscape Ecologist
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Dirk Stevenson, Orianne Society – Assistant Conservation Scientist; Herpetologist
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Joe DeVivo, U.S. Park Service – Southeast Coast Network I&M Program Coordinator
Chelsy Miniat, USDA Forest Service Southern Research Station – Coweeta Hydrologic Lab Project Leader
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Executive Summary

As part of the 2015 Georgia State Wildlife Action Plan (SWAP) Revision, a monitoring technical team was assembled to determine ways to improve monitoring efforts in Georgia. Based on meetings and discussions with monitoring team members, a list of actions to improve monitoring was created and then ranked to create a priority subset of monitoring improvement actions. Other SWAP technical teams gave input on their top ranked monitoring actions, which along with discussions with team leaders, were assessed to determine overlapping monitoring needs and priorities.

Throughout this process, we found that the most consistent theme encompassing actions to improve monitoring was improving coordination state-wide, and regionally, among professionals conducting monitoring and management. Improving coordination involves a variety of actions that were emphasized by the monitoring team and other SWAP technical team leaders. These actions include tying monitoring to adaptive management, hiring a GA DNR monitoring coordinator, improving internal GA DNR communication related to monitoring, using standardized monitoring protocols and data forms when possible, improving sharing of protocols and data, and using technology to increase efficiency of engaging and training citizens and volunteers to assist with monitoring projects. We believe that all of these goals are achievable within the 5-10 year period covered by this SWAP Revision.

Because the monitoring improvement actions promoted by the monitoring team are often related, implementation of one action will often result in the success of another. For example, development of online tools will enable a greater capacity for protocol and data sharing. However, coordinating and improving monitoring statewide would be a significant time and resource commitment. Therefore, meeting the challenge of improving rare species and habitat monitoring likely hinges on hiring a monitoring coordinator. In particular, we find that the concept of tying monitoring to adaptive management requires careful consideration for the optimal level of implementation within GA DNR, mainly because of the necessity for status and trends monitoring in determining rare species status. However, working in an adaptive management framework is important because it is conducive to an institutional culture of constant assessment of monitoring results and communication of management implications.

Monitoring and an adaptive approach to species and habitat management are more important than ever considering uncertain future conditions with potential anthropogenic impacts and climate change. We propose that an adaptive management approach should be integrated throughout state monitoring programs, with results of monitoring informing conservation actions. Advances in technology will be integral to developing more rigorous monitoring/adaptive management programs. Overall, communication and coordination about monitoring and management should be emphasized within GA DNR and should incorporate partners to allow for conservation success.

Introduction

Monitoring is critical to the work of researchers, biologists, and practitioners in the conservation field. From the collection of basic qualitative data by conservation managers to the analysis of complex long-term datasets by statisticians, monitoring can shape conservation and management actions in a significant and positive way. Well-designed monitoring can show status and trends over time in species, natural communities, and ecosystems; document the implementation and efficacy of conservation and management actions; guide decisions regarding conservation and management actions; and provide knowledge about the biology of the species and systems monitored (The Nature Conservancy 2009, Larsen 2013).

Because of its importance in conducting sound conservation and management, monitoring is essential to the implementation of statewide conservation strategies such as the Georgia State Wildlife Action Plan (SWAP). The 2005 SWAP discussed the significance of monitoring and highlighted monitoring in the adaptive management framework (Georgia SWAP 2005), whereby monitoring is designed to indicate whether conservation objectives are being met, and informs whether particular conservation actions should be continued or changed (Elzinga et al. 1998). The 2005 SWAP gave guidance on how to prioritize species for monitoring, and gave a list of actions that would improve efficiency and efficacy of monitoring in Georgia. These actions included recommendations such as improving volunteer networks for monitoring, utilizing available databases of partner agencies, requiring monitoring to be a component of conservation projects, integrating new technologies and GIS resources into monitoring, and working internally and with partners to create efficient, easy-to-use monitoring protocols (Georgia SWAP 2005).

Progress has been made in many of those actions since 2005. An incomplete list of examples follows: To engage citizen scientists, the volunteer network of the breeding bird survey has been expanded, and also used as a model for annual frog and bat monitoring. The Georgia Plant Conservation Alliance has developed a network of trained volunteers who help with rare plant monitoring state-wide, and with research on specific high priority projects such mountain pitcher plant bog restoration. Certain grants, such as the Multi-State Sandhills Restoration Grant, require monitoring for completion, and through this grant management effects on breeding birds, gopher tortoise, and vegetation community of the sandhills ecosystem have been tracked since 2009 on thousands of acres. GA DNR freshwater aquatic biologists have used GIS analysis of survey metadata improve prioritization of watersheds for monitoring. Extensive baseline habitat mapping and classification projects have been completed, focusing especially on sandhills communities, state parks, and the eleven-county coastal region. Monitoring of longleaf pine ecosystem restoration has improved understanding of the effects of GA DNR's land management, including site preparation methods, timber management, and prescribed fire in extremely fire-suppressed sites, which has subsequently been applied to improving GA DNR strategies for restoration of this critical ecosystem. And, to address the need for a simple, broadly-applied protocol, a fire effects photo monitoring program has been implemented in 25 state parks and natural areas state-wide. For this program, local staff collect data and submit it to a centralized repository of photos, and the data manager organizes chronological documentation of fire effects for each conservation property.

It is clear that across Georgia, monitoring of species, natural communities, and landscapes is conducted at many scales by multiple agencies and organizations. However, knowledge of monitoring programs in Georgia is not yet well-cataloged, nor is there an established mechanism for communicating about monitoring programs and results within the GA DNR nor among its partners. Certain partner agencies have developed rich monitoring programs and networks, such as the Inventory and Monitoring Network of the U.S. Fish and Wildlife Service (http://www.fws.gov/Refuges/NaturalResourcePC/IandM/), the Southeast Coast Network of the National Park Service (http://science.nature.nps.gov/im/units/SECN/), the Forest Inventory and Analysis Program of the National Forest Service (http://www.fia.fs.fed.us/), and the Fire Research and Management Exchange System, or FRAMES (https://www.frames.gov/). These programs provide important examples for monitoring strategies, protocol design, data management, and results reporting. Also over the past decade, rapid development in computer technologies has occurred, making available convenient, reasonably priced and ergonomic tools for digital data collection and management. The need to effectively use and coordinate these resources to improve monitoring is great, as development and other pressures on Georgia's natural resources continue to increase, while simultaneously conservation and restoration programs continue to expand in scope and acreage.

Considering these factors, it was imperative to update and create new monitoring strategies to include in the revision of the Georgia SWAP for 2015. Therefore a monitoring technical team was convened to focus on monitoring issues for Georgia's rare species and habitats. The purpose of the monitoring technical team was to create a synthesis of how species, habitats, and conservation actions are currently being monitored in the state and to develop strategies to monitor more effectively in the future. The goals of the monitoring team were to assess the most significant gaps in monitoring in Georgia, what steps are critical and practical to improve monitoring in the next 5-10 years in Georgia, and how the Georgia Department of Natural Resources (GA DNR) can collaborate with partners to achieve these steps.

This monitoring chapter of the 2015 SWAP revision serves two functions. Primarily we make recommendations on how to improve monitoring in Georgia based on the work of the SWAP monitoring technical team. In addition, we begin the process of summarizing the priority monitoring projects and programs of the Nongame Conservation Section and key partners within the state. Both sections describe the current status of rare species and habitat monitoring in Georgia and provide an initiation point for collaborations and information gathering. We hope that this chapter will encourage new coordination for improved monitoring among DNR and its partners.

Methods

The SWAP Revision monitoring technical team members were selected across different organizations based on their prior experience with monitoring. Professionals who conduct monitoring or have some expertise in monitoring including design, data collection, data storage, data analysis, and results reporting, were contacted to participate. The final team included a range of monitoring experience and was comprised of taxa experts, ecologists, researchers, conservation managers, and statisticians. Each team member submitted information about their monitoring work or monitoring work carried out by their organization.

The monitoring technical team assembled for a single-day meeting at Little Ocmulgee State Park in McRae, Georgia in order to: 1) Learn about existing projects and their objectives; 2) Discover overlapping priorities for monitoring in the next 5-10 years; and 3) To make plans on how to coordinate resources for improvement of monitoring of rare species and communities in Georgia. At the meeting, GA DNR Nongame Conservation biologists gave an overview of past and current Nongame monitoring projects in Georgia. Also, representatives from the National Park Service and U.S. Fish and Wildlife Service Inventory and Monitoring Networks gave presentations on their monitoring projects. In the afternoon, the team split out into five breakout groups to address the following questions:

What steps do you see as most practical and critical to improve monitoring of rare species and communities in Georgia? How can we coordinate resources to implement these steps over the next 5 to 10 years?

- How can we improve protocol design, data collection, and analysis of monitoring projects?
- What suggestions do you have to improve sharing of monitoring results with scientists, land managers, and others who can apply them?
- How can we improve our engagement of citizen scientists in monitoring projects?
- How can we use qualitative monitoring information?

After the breakout group discussions, the team reconvened to review each group's responses to the questions. Ideas were recorded and placed in a spreadsheet.

After the meeting, ideas were reviewed and overlapping concepts were combined. They were categorized and organized into a monitoring actions table (Table 1). The monitoring actions table was then sent out to the team for review. Team members were asked to rank the importance of each numbered action based on these seven ranking criteria: 1) providing multiple benefits for high priority species/habitats, 2) addressing un(der)funded needs, 3) overall importance of Georgia efforts, 4) timeliness or urgency, 5) connections with other conservation actions, 6) building public support for wildlife conservation, and 7) probability of success. Responses were then used to edit the monitoring action table and determine the most important monitoring actions in the table.

Once we had feedback from the team members, we held individual discussions with various technical team members to refine the highest priority actions and develop insights on how these actions can be applied to rare species and ecosystem conservation. In particular, insight was especially needed on pragmatic application of adaptive management and monitoring in the rare species monitoring context, and on the development of a monitoring coordinator position within GA DNR.

Also, the monitoring team leaders sought feedback from other SWAP technical teams on their highest monitoring priorities and their methods for determining these priorities. We found that this feedback was critical for assessing how the monitoring actions fit within the current context of monitoring conducted by GA DNR biologists, and to refine the prioritization of the monitoring actions. The results of this process are listed in Table 2.

Results

Selection of actions to improve monitoring

The breakout sessions provided monitoring actions that were grouped into five categories. These categories are: ways to improve coordination and communication of monitoring activities, prioritization of monitoring to optimize resource allocation, monitoring design and data collection, data reporting, and citizen and volunteer involvement in monitoring projects (Table 1).

Table 1. Actions to improve monitoring in Georgia

Improve coordination and communication of monitoring activities

1. Improve awareness among scientists about monitoring work that supports conservation in Georgia
    a. Conduct regular meetings of monitoring biologists in key agencies
    b. Conduct an inventory of ongoing rare species and habitat monitoring programs in the state. This includes research, surveys, and databases maintained by academic institutions and agencies. Create a database that is easily accessible and updatable
2. Improve internal GA DNR communication related to monitoring
    a. Conduct regular meetings of DNR Biologists working on similar issues (e.g. land management, species monitoring, freshwater streams) to share monitoring programs and address problems in monitoring. Meetings should include field tours. Include the Environmental Protection Division, Parks Division, and Private Lands Program where appropriate
    b. Maintain a database of qualitative information regarding land management and land management decisions for high priority properties
    c. Maintain a database of rare species and habitat monitoring conducted within GA DNR
3. Communicate SWAP priorities to universities and other research institutions for potential collaboration
    a. Create a concise list of SWAP monitoring priorities to disseminate to universities and other research institutions.
    b. Relate priorities to potential funding opportunities.
4. Improve sharing of protocols and data
    a. Develop an easily accessible mechanism to share protocols and data
    b. Identify current monitoring protocols that work for state objectives. Where no standard protocol exists, work with other agencies and universities to create standardized protocols for species and ecosystems. Move toward greater consistency across state boundaries (e.g., Index of Biological Integrity, National Bobwhite Conservation Initiative)
    c. Coordinate with agencies that regularly collect rare species data (Department of Transportation, National Park Service, U.S. Forest Service, U.S. Geological Survey) to improve rare species monitoring
5. Hire a GA DNR monitoring coordinator to compile data, increase collaboration, improve and standardize agency protocols, and coordinate funding opportunities

Improve prioritization of monitoring to optimize resource allocation

6. Determine realistic monitoring frequencies for high priority species and habitats
7. Determine data gaps for priority habitats and species to help set monitoring priorities
8. Establish and share clear monitoring priorities to enable greater collaboration with other institutions

Improve monitoring design and data collection

9. Use technology to increase information that can be obtained from photos and to improve access to the data.
    a. Use photo monitoring with simple quantitative data collection for rapid assessment of management effects. Use local personnel or volunteers to expand data collection capacity.
    b. Where applicable, use remote sensing of spatial data to monitor habitats
10. Tie monitoring to adaptive management
    a. Include trigger points in protocols, i.e. design monitoring to include agreed upon actions that are engaged when certain conditions are detected
    b. Identify specific courses of action that would be implemented when monitoring questions are answered
    c. Consider thresholds and variability, rather than only the mean as important measures. Increased variability could indicate a catastrophic event
11. Census important reference sites and relate to management and monitoring
12. Monitor common species along with rare species to prevent rarity
    a. Use strategies such as Index of Biological Integrity (IBI) and Floristic Quality Indices (FQI) that includes both rare and common species
13. Use standardized monitoring protocols and data forms when possible
    a. Collect data on at least one main variable across different monitoring projects.
    b. Include the statistical approach in monitoring designs
    c. Require a standard format for maintaining all metadata relating to monitoring project rationale, objectives, techniques used, data format, and summary of findings throughout the project
    d. Archive protocols and all associated data in a central location
    e. Use protocols for storing qualitative data established by institutions such as the Joseph W. Jones Ecological Research Center, National Park Service, and U.S. Fish and Wildlife Service
14. Capture qualitative data on management results. Compile information from managers; conducting periodic and exit interviews may be a useful way to collect this data

Improve monitoring data reporting; make results accessible to the appropriate end-user

15. Use the outreach capacity of organizations that emphasize public education such as the Joseph W. Jones Ecological Research Center, the Longleaf Alliance, and Rivers Alive to improve monitoring data reporting
16. Provide short-term feedback from monitoring projects to participating landowners and managers. This will allow for greater future collaboration and adaptive management
17. Develop a website to make reports accessible to land managers and biologists

Involve citizens and volunteers in monitoring projects
18. Use technology to increase efficiency of engaging and training citizens and volunteers to assist with monitoring projects a. YouTube videos to share protocols b. Smart-device apps to engage large numbers of citizens (e.g. EDDMaps for invasive species) c. Recognize contributions of individuals or communities with social media d. Create a mechanism for quick data entry to reduce work load of the coordinating biologist 19. Incorporate monitoring into Master Naturalist programs 20. Use the Environmental Education Alliance to reach teachers with programs for monitoring in school classrooms. 21. Reciprocate monitoring participants' efforts with rewards, both tangible (certificates, badges, books, gift certificates) and intangible (knowledge, accolades)

After the monitoring action table (Table 1) was sent out to technical team members for review, nine team members ranked and/or gave feedback on the monitoring actions. Of the nine, only six members provided ranking for each monitoring action. In addition, we had in-depth discussions with ten scientists, some additional to the original team, regarding their use of monitoring and priorities for improving monitoring. After this process, some of the actions in Table 1 were refined. So although we did not have explicit feedback on the monitoring conservation actions from a majority of the monitoring technical team, we feel that between the detailed information gathered at the meeting and the conversations we held, we have developed a consensus on the most critical actions to improve monitoring. It should be noted, however, that many technical team members felt uncomfortable ranking each of the 21 actions, finding many of the actions to be equally important and also finding it difficult to rank specific actions ahead of others.

There were six actions from the table above which were most frequently ranked as the most important. They are listed here in order of rank: 1) Tie monitoring to adaptive management; 2) Hire a GA DNR monitoring coordinator; 3) Improve internal GA DNR communication related to monitoring; 4) Use standardized monitoring protocols and data forms when possible; 5) Improve sharing of protocols and data; and 6) Use technology to increase efficiency of engaging and training citizens and volunteers to assist with monitoring projects.

Monitoring priorities of other SWAP technical teams

Many of the technical teams included monitoring priorities in their section of the SWAP Revision (Table 2). After discussing how these priorities were selected with technical team leaders and reviewing the priorities, we found that each group included monitoring actions based on different needs, though there were similarities in many of the goals and some teams had overlapping priorities.

Status and trends monitoring is a significant component of the Georgia DNR's species conservation programs. This type of monitoring is necessary to track populations of high priority species over time, and allows biologists to detect potential threats and assess the need for conservation measures. When determining how these types of monitoring projects were

prioritized, we found that some were initiated prior to the start of the SWAP Revision process, such as Indigo Snake monitoring on the Altamaha, while others were determined as priority monitoring actions by SWAP Revision technical teams. Some priority species groups, such as sea turtles, have had a long history monitoring and will continue to be monitored while a greater focus can be placed on management strategies to help increase populations. For other programs such as bat monitoring, only recently has there been a higher level monitoring intensity, due to the devastating threat of the disease, White Nose Syndrome. In this case, biologists are still learning about species biology, so the greatest monitoring need is to determine population status and trends, while developing more standardized protocols and increasing information sharing capacity across state boundaries.

Some species are given high priority for monitoring as a result of legal agreements, such as Candidate Conservation Agreements. A Candidate Conservation Agreement (CCA) is a voluntary conservation agreement between the U.S. Fish and Wildlife Service and one or more public or private parties as a way to reduce threats and conserve candidate species. Under these agreements, species populations are monitored to determine the effectiveness of conservation measures. In Georgia, the Gopher Tortoise and Georgia Aster have been prioritized for monitoring to fulfill the requirements of CCAs.

Monitoring response to management, especially prescribed fire, was a significant priority for some teams, including the habitat restoration and bird teams. The Georgia DNR fire management program is central to the conservation of many fire-adapted species and habitats in the state, thus monitoring the effects of fire management is critical to understanding the success of this program. Another shared goal was the need for baseline landcover/habitat data. Both the Ecosystems/Habitat Mapping and Climate Change Adaptation teams expressed the need for this type of information in order to monitor landscape level changes over time and to help model the effects of land use and climate change on species and habitats in the state.

Monitoring priorities for many teams reflect several of the ideas mentioned by the Monitoring Technical Team as actions to improve monitoring (see Table 1). A significant overlapping need is the improvement of standardized protocols and a greater capacity for the sharing of these protocols and monitoring data. This is mentioned as a high priority monitoring action for many taxa, including birds, plants, mussels, and bats. Related to these goals is the improvement of online tools, including methods to collect data and share monitoring information. For example, the habitat restoration team prioritized the use of EDDMaps, an online tool used to detect and monitor infestations of invasive species. Also, the habitat restoration team would like to take advantage of advances in online technologies to improve monitoring protocol and data sharing for photo monitoring in fire-adapted habitats.

Table 2. List of monitoring priorities for each of the SWAP Revision technical teams

Technical Team	Monitoring Priorities
Reptiles and Amphibians	1. Gopher tortoise population monitoring using Line Transect Distance Sampling on all inventoried state lands and select private lands at intervals no less than every five years but no greater than every 10 years. This is required by the tortoise Candidate Conservation Agreement to which WRD is a party. 2. Occupancy monitoring of eastern indigo snakes at select sites in the lower Altamaha River sandhills region. This effort, contracted out to Orianne Society, has taken place annually for the past three years, but will likely be extended to a greater interval. 3. Continue 3 year occupancy monitoring cycle of eastern hellbender populations at known sites, including disease screening 4. A statewide index of abundance for diamondback terrapins will be developed to determine trends in abundance over time 5. 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.
Birds	1. Pursue coordinated monitoring and data storage for seabirds across the Southeast states to better understand status and trends. Prioritize using a shared database such as the Avian Knowledge Network to serve as a central clearinghouse for data storage and dissemination for many of our bird conservation efforts. 2. Continue participating in national/international coordinated efforts such as the Breeding Bird Survey, U.S. Nightjar Survey, and International Shorebird Survey. 3. Develop a regional survey/monitoring protocol for wading birds. 4. Develop and implement monitoring protocols for secretive marsh birds. Make these protocols compatible with similar efforts in other parts of the Southeast or the species' range. 5. Monitor the effectiveness of management, particularly prescribed fire, on bird populations.
Mammals	1. Annual monitoring of caves with populations of bats currently affected or likely to be affected by White Nose Syndrome 2. Annual summertime monitoring of gray bats and southeastern bats in caves 3. North Atlantic Right Whale: satellite tagging to study movement and habitat use; seasonal aerial and boat photo-ID surveys and genetics sampling for population monitoring 4. Bottlenose Dolphin: Boat photo ID surveys to assess abundance, vital rates, residency patterns and stock structure; capture-release studies and remote biopsy sampling to assess health of dolphins

	in Brunswick area 5. Monitoring spotted skunks with camera "traps" 6. Monitoring pocket gophers with mound counts
Fishes and Freshwater Invertebrates	1. Evaluate status and distribution of high priority snails 2. Surveys for petitioned aquatic species 3. Update GA Dept. of Transportation Mussel Sampling Protocol 4. Continued aquatics species monitoring in high priority watersheds, where numerous high priority species can be targeted in one project.
Terrestrial Invertebrates	1. Inventory to obtain baseline information for priority species and for species habitat associations 2. Develop invertebrate-based Indices of Biotic Integrity [IBI] for specific high priority habitats
Plants	1. Monitor high priority plant species and habitats when scientific uncertainty and/or stakeholder disagreement exists about suitability of management actions (e.g. *Lindera melissifolia* and *Ceratiola ericoides* population response to prescribed fire, and timber harvest for restoration of prairies at Oaky Woods WMA). 2. Monitor select populations for which regulatory conservation agreements exist to document success or failure of the agreements (e.g. *Symphyotrichum georgianum*) 3. Monitor high-priority *in-situ* population augmentation or introductions (e.g. *Arabis georgiana, Echinacea laevigata, Rhus michauxii, Sarracenia* species). 4. Develop a standard DNR-wide protocol for monitoring suites of rare species that occur in specific high priority rare habitats, in particular in coastal plain seepage bogs of the sandhill habitat.
Habitat Restoration	1. Expand and improve DNR's fire photo monitoring program. a. Incorporate simple quantitative data collection methods associated with the photo points for high priority sites, especially where land managers desire more information. b. Include Game Management biologists and Wildlife Management Areas. c. Use technology to improve photos and increase information that can be obtained from then (e.g. vegetation cover, canopy cover). d. Create a geodatabase of the fire monitoring points e. Develop an online mechanism for uploading photos and data points to a centralized system f. Include reference sites of high priority habitats 2. Where there are significant questions related to the management of high priority habitats and/or species, initiate adaptive management vegetation monitoring projects 3. Organize and complete a unified "lessons learned" report that includes the multi-faceted monitoring and research that has been conducted in the longleaf pine ecosystem by DNR Nongame

	Conservation Section biologists. This compilation could be published by the DNR and made available to landowners and research institutions. 4. Continue incorporating and promoting online tools such as EDDMaps that can be used for early detection of invasive species, to track the spread of invasives, and to monitor occurences over time. 5. Foster invasive species working groups such as the Coastal CISMA to help track invasive species at a regional level.
Ecosystems/Habitat Mapping	1. Conduct landcover mapping for the state, particularly the Coastal Plain. This baseline data along with future mapping can be used to track changes in the landscape over time, including land use, climate change, and restoration activities. 2. Incorporate new remote sensing technologies where appropriate to monitor habitats at the local scale. 3. Use field surveys and monitoring to inform habitat mapping and vice versa. Data collected during field surveys can serve as valuable reference points for landcover mapping efforts. Also, habitat maps can be used to inform monitoring by directing surveys and detecting landscape level changes undetectable by fine-scale monitoring programs.
Climate Change Adaptation	1. Similar to the Ecosystems/Habitat Mapping team, the highest priority is to map natural communities throughout the state. Mapping products can be used as a baseline to monitor vegetation response to climate change and to strengthen climate change adaptation models of resiliency, sea level rise, and impacts on species. 2. Establish data loggers in rivers and streams. These loggers can be used to create more accurate models for fish and other aquatic species susceptible to climate change. Engage the Georgia River Network to help establish data loggers throughout the state. 3. Conduct basic plant phenology monitoring to evaluate long-term change related to climate change. Integrate monitoring efforts with those of national phenology monitoring networks. 4. Monitor depressional wetlands, maritime communities, and other habitats sensitive to climate change. Continue monitoring salt marsh transects to determine the effects of sea-level rise on coastal habitats.

Discussion

The Georgia DNR and its partner organizations conduct a wide range of monitoring activities on a regular basis. These actions, including ecological research, species and habitat status and trends monitoring, and management effectiveness monitoring, are critical to our mission to conserve priority wildlife and their habitats. However, during the process of evaluating current monitoring strategies, it became clear that better organization and a more strategic approach would improve the overall value and effectiveness of monitoring in the state. Here we discuss some approaches to improve monitoring of species and habitats in Georgia, and outline the highest ranked priority actions for monitoring improvement based on the work of the Georgia SWAP Revision monitoring technical team. We give emphasis to mechanisms that are feasible on the time frame of 5 to 10 years.

In many ways, each of the monitoring conservation actions listed in Table 1 cannot exist as a single action. All are intertwined, and development of one will facilitate development of another. For example, tying monitoring to adaptive management relies on improving communication about monitoring, as those who are conducting monitoring must successfully coordinate with those who set management objectives, and with those who can change management actions. New technologies subsequently are essential to improving coordination and standardizing protocols, especially for species and habitats whose status is determined across a region that is larger than one agency's purview. This is one reason the monitoring actions were difficult to rank. It is also a strong argument for centralizing the efforts to improve monitoring in one agency with state-wide perspective and networking capacity such as GA DNR, because the actions must occur across many specializations and roles in the conservation arena. Without centralization of efforts, the coordination required to carry out these actions would not likely occur.

Develop a monitoring coordinator position

Therefore, to improve efficiency and efficacy of monitoring in Georgia, our highest priority action is to hire a state-wide monitoring coordinator. Because of the complexity of the biological monitoring network in Georgia and because so many of the priority monitoring actions depend on good communication, having a person dedicated to coordinating monitoring improvement actions is critical to their successful implementation. Biologists who are responsible for conducting monitoring in their specialized fields would not have it in their current job priorities to coordinate among the diverse array of monitoring professionals in Georgia.

Key responsibilities of a monitoring coordinator would include review and compilation of monitoring plans and protocols within Georgia DNR; inventory of monitoring programs outside of GA DNR; facilitate communication between resource management, administrative, and monitoring staff to develop adaptive management protocols that are consistent with GA DNR priorities and policy; development of mechanisms for sharing monitoring programs and data in Georgia; consult on and set standards for protocol development, protocol documentation, data management, and reporting within GA DNR; outreach to academic institutions to develop opportunities for collaborative adaptive management projects; and provide venues for sharing of results, technologies, and ideas across GA DNR, such as in a periodic symposium advertised internally and externally.

Tie monitoring to adaptive management

Tying monitoring to management actions was the highest ranked monitoring action from the monitoring technical team. In contrast, status and trends monitoring without specified management actions is the most commonly listed type of project for GA DNR (Table 2). However, these projects are often tied to management in an informal manner. For example, populations of a shorebird species are monitored annually and have shown a steady decline in the past ten years since monitoring was initiated. A decision is made to burn habitats associated with the species to decrease shrub encroachment and expand the preferred open, grassy habitat. After the prescribed fire, bird populations are monitored to examine response to management.

In a rigorous adaptive management framework, also called "active adaptive management," monitoring is designed not only to determine trends but also to learn about the species or habitat of concern (e.g. Larson 2013, Westgate et al. 2013). Hypotheses are tested about how the monitored system functions, or about which management approaches are optimal (Westgate et al. 2013). It is considered an important strategy because management actions, which are usually time-critical, can be conducted at the same time as research to understand key biological concepts for conservation (Nichols and Williams 2006, Westgate et al. 2013).

There are a number of challenges to implementing adaptive management (see especially Westgate et al. 2013). A primary challenge for GA DNR is the lack of simple institutional control over management options—especially at the landscape or watershed level. At this level, GA DNR staff frequently cannot execute management actions for rare species and habitats even when monitoring indicates management is critically needed for conservation of the resource (B. Albanese, P. Lanford, and T. Morris, pers. com.). Other challenges include difficulties in managing and measuring effects on extremely rare and/or hard to detect species (T. Morris pers. com.), lack of expertise and resources for experimental design and statistical analysis (T. Keyes pers. com. and Kruse and Thompson pers. obs.), and lack of space and resources for replicating management treatments (Kruse and Thompson pers. obs.).

Because they require additional staff resources and expertise, careful prioritization of adaptive management projects is necessary. Active adaptive management is highest priority when there is scientific uncertainty, high risk, and conflict about management actions (Larson 2013), and these projects must be carefully designed to measure only the most pertinent environmental variables to answer the specific high priority questions the monitoring is being implemented to answer (Larson 2013). For GA DNR, opening avenues of collaborations with academic researchers for adaptive management projects could provide an important tool for learning about our high priority biological systems at the same time as we are managing them.

A less rigorous framework, an "adaptive approach" (*sensu* Westgate et al. 2013), is more congruous with rare species and habitat monitoring in Georgia. In an adaptive approach, monitoring is tied to management by incorporating management objectives into specific population indicators that will be measured (Elzinga et al. 1998, The Nature Conservancy 2009). For example, if reduction of shorebird nest failures by 30% is a management objective, measuring nest failures should be the highest priority of a monitoring protocol, rather than measuring any other feature of that shorebird population. The sampling protocol subsequently

must be designed so that it is possible to detect the desired amount of change in nest failure rate with a statistical test. The data will then be capable of demonstrating whether the management objective has been met, and therefore whether management actions need to be modified. In this way, specific monitoring results feedback directly into decisions about the status of priority species and habitats, and the management actions that will be taken for their conservation.

An adaptive approach takes place qualitatively in management actions all the time, as managers make skilled observations and implement actions based on their observations. The advantage of tying monitoring of specific variables to specific management objectives is that a focus on the most critical indicators of rare species and habitat status is ensured (Kirkman, pers. com). This approach gives a way to communicate rare element status and the effects of management to a broader audience. Focusing on key management-oriented variables is more efficient than an approach where multiple variables are measured for their general interest, with no clear *a priori* idea of how the data are to be used. Thus monitoring is designed for decision making, producing data that are used for assessing the effectiveness of management actions, ultimately reducing management and conservation uncertainty (Sutter 2014).

Although all monitoring projects conducted by GA DNR will not directly feedback to an immediate management decision, underpinning the monitoring program with an adaptive management philosophy will promote a holistic approach to monitoring projects that utilizes sound science. A monitoring program that emphasizes adaptive management will continually be vigilant for opportunities to improve conservation actions for rare species and habitats. Such a program will prioritize effective monitoring design, constant assessment of monitoring results, and insist that biologists and managers communicate implications for conservation, whether action can be taken now or ideas are being advocated for the future (R. Sutter, pers. com).

Therefore we advocate that a monitoring coordinator work in an adaptive management framework, and develop departmental guidelines as to when, and at what level, adaptive management monitoring should be conducted by GA DNR or through contracts with academic research institutions.

Improve sharing and standardization of protocols and data forms

This action was ranked third highest priority by the monitoring technical team, but was the singular most important action for improving monitoring when discussing monitoring with leaders of the taxonomic technical teams. For some priority species groups, such as bats, monitoring technologies are not developed to the extent that statistically strong data can be collected and there is a lack in available experts to conduct the monitoring (T. Morris, pers. com.). For these types of species, the most important actions to improve monitoring are development of strong regionally standardized protocols and strong data management and sharing. Organized records that are kept systematically, with strong metadata that clearly describe the work flow, protocols, and functioning of the database, can be employed across organizations for generations. This is critical for understanding long-term trends and for eventual development of adaptive management protocols when technology improves.

Other priority species and habitats have relatively well-developed technologies and protocols for monitoring, but have wide ranges such that monitoring is often performed by multiple

organizations. Protocols tend to vary within and across state boundaries. Examples include certain high priority shorebirds, the gopher tortoise, and longleaf pine ecosystem restoration that occurs on private lands. Standardization and sharing is equally important for monitoring these entities so that efforts are not duplicated and that data can be compared across their geographic ranges.

One mechanism for sharing protocols suggested by the monitoring technical team is a searchable internet database that partners could use to post and access information related to their specific monitoring projects. As an example, the National Biological Information Infrustructure (NBII) was an online database that provided access to monitoring information as one of its components (Wikipedia 2014). Funding for NBII was discontinued in 2012, but information about its development and structure could be accessed as a model for a simpler project focusing only on sharing protocols.

Another mechanism is for biologists to reach out directly to partners who already collect rare species data to work together to modify and standardize protocols to meet joint objectives. This mechanism is already recognized as critical for improving monitoring. For example, working with GA Dept. of Transportation to standardize their mussel sampling protocol is a high priority conservation action for the updated Georgia SWAP. In particular, the monitoring team noted the need for standardizing monitoring of the vast longleaf pine ecosystem restoration projects occurring on private lands throughout the state.

Improve internal GA DNR communication related to monitoring
Internally, GA DNR exemplifies similar challenges to coordination of monitoring that exist state-wide. Among the divisions of the agency, there is lack of awareness of monitoring projects and associated challenges, even among biologists studying the same ecological systems. For example, the Private Lands Program, Game Management Section, and Nongame Conservation Section conduct longleaf pine restoration but there is little opportunity for communication regarding results of their restoration projects and how they are monitored. As GA DNR is a large agency, good communication can be difficult to achieve. In particular, those coordinating monitoring often work separately from site managers, or may have different philosophical approaches to management. In an adaptive management framework communication is especially critical to facilitate standardization of management objectives, prioritize management activities, and enable managers to adapt management actions based on monitoring results.

Improving coordination of monitoring within GA DNR will serve as a model for coordination of monitoring among partners state-wide. Therefore we rank this as the fourth highest priority monitoring improvement action. Two mechanisms for communication will be used in combination, by developing a department-wide online database of monitoring projects, and special-interest topics presented at department-wide meetings.

The objective of the online database is not only to share monitoring reports, but to provide a standardized system to store protocols, data, qualitative information regarding land management results, and metadata about projects. Metadata provide the documentation necessary for a project to be carried on regardless of staff and resource availability, and should be required for all monitoring projects. Important metadata include project rationale, objectives, techniques used,

data format, sampling dates, and summary of findings throughout the project. Implementation would likely occur in a two-phase process, with the first phase to develop the system for posting project reports and qualitative management results, and the second to develop the system for storing and accessing protocols, data, and metadata.

The objective of GA DNR monitoring meetings is to share ideas on how to meet monitoring goals in an environment where peer-review of projects is cultivated. Peer-review provides an internal mechanism for improving monitoring and conservation projects. The meetings can be informal or structured, but should include all disciplines that use monitoring and staff of Wildlife Resources, Environmental Protection and State Parks Divisions. The meetings will provide a venue to discuss monitoring issues, share protocols and results, demonstrate new monitoring technologies, and to coordinate monitoring with management staff. Staff who monitor overlapping ecological systems should meet separately, either concurrently or at another time in the field. Due to the effort required to establish these meetings, we envision that a monitoring coordinator is essential to their success.

Incorporate technology and citizen-scientist networks to improve monitoring
With the ubiquity of smart phones, tablets, and other electronic handheld devices, there is increasing opportunity to collect valuable field data electronically for survey and monitoring projects. Many of these devices can use cellular phone service or GPS to give accurate location information. Also, the ability to take and store field notes electronically and take pictures with a camera on the same device greatly simplifies field data collection. It is critical to incorporate this technology into monitoring work in ways that will be useful and efficient. Furthermore, because so many citizen scientists and volunteers already own these types of devices, there are great possibilities to create networks of people collecting valuable data for conservation. An excellent example of such a network is the invasive species detection application EDDMaps. EDDMaps is an easy to use web-based mapping system for documenting distributions of invasive species. This application allows smart phone users to collect field data on an invasive species occurrence and track infestations through time. These remote data collection technologies should be considered for other monitoring programs, particularly where volunteers can be engaged.

Another improvement in technology is a greater ability to share information online. Online tools can now be used for easy data entry and for the rapid transfer of data to others. Improving online tools to allow for easier access to protocols, simple data entry, and sharing of data and reports with others should be a high priority for the DNR and other agencies. Social media and video-sharing websites can be used to make monitoring more transparent, by alerting people or groups about monitoring or for sharing protocols. They can also be used to improve training, coordinating, and data sharing for citizen scientist and volunteer networks involved in monitoring habitats and species.

Some other technologies have advanced in recent years and can now be considered when collecting field data. For example, a University of Georgia graduate project is currently using unmanned aerial vehicles, also known as drones, to assess vegetation recovery after prescribed fire in dune grasslands on Little Saint Simons Island. Only recently have these vehicles become more affordable and readily available for monitoring applications, although new regulations and potential privacy issues should be taken into account. GIS technologies and online mapping tools

such as Google Earth are making community and landscape level changes easier to track. The availability of high resolution aerial imagery and detailed elevation data such as LiDAR allows for more detailed habitat mapping. It is necessary to continue promoting aerial imagery and LiDAR flights in Georgia to help improve mapping and monitoring efforts over the next 10 years.

In recent years, the DNR's photo-monitoring program has been greatly expanded to help monitor the effects of prescribed fire in fire-adapted habitats on State Parks and other state lands. Camera technology should be researched to determine if simple quantitative data can be derived from photos taken at these established photo-points. The photo points could also be used for additional quantitative data collection for assessing whether broad management goals have been met.

Conclusions

Improvement of monitoring statewide is a challenging topic, particularly for the breadth of disciplines that must be involved. Across Georgia's diversity of species and habitats, there are varied obstacles to successful monitoring. Aside from resource limitations for monitoring, these obstacles include species detection difficulties, populations that range far outside state boundaries, and the inability to enact adaptive management. Monitoring professionals have approached solutions in multiple ways, often without a collaborative process. Despite these difficulties, monitoring has become more important in natural resource management institutions for documentation of conservation actions and whether these are successful—for accountability, learning, and public education objectives.

The monitoring technical team provided an abundance of ideas for improving monitoring. All members of the monitoring technical team were adamant that, first and foremost, coordination of efforts is critical to improving monitoring in Georgia. Most of the monitoring actions that were ranked highest include steps toward meeting that broad goal, including hiring a monitoring coordinator, developing an online database to share protocols region-wide, holding regular GA DNR monitoring symposia, and creating an internal database for standardized metadata relating to all GA DNR monitoring projects.

For the monitoring technical team, working in an adaptive management framework was also high priority. There are clear reasons why strict adaptive management is not appropriate for all rare species and habitat conservation actions. However, we advocate that working in an adaptive management framework will encourage sound science and protocol design in monitoring and timely incorporation of monitoring results into conservation actions.

Finally, it is clear that new technologies are abundant and provide many exciting opportunities to facilitate all of the priority monitoring actions developed here, by increasing accessibility to protocols, data, and results that can be used by volunteers, scientists, managers, and administrators alike.

From the ideas documented in this chapter, and from the enthusiasm for sharing monitoring projects and ideas we witnessed during this project, it is clear that conservation professionals are

passionate about the quality of rare species and habitat monitoring in the state. We are eager to work together to increase effectiveness of this important aspect of conservation biology.

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Table 3. Conservation partner organization monitoring priority table (to be developed)

Partner Organization	**Monitoring nexus**	**Types of projects and available resources**
U.S. Fish and Wildlife Service – Ecological Services (USFWS ES):	Track results of management and special programs on rare species and habitats; provide data for rare species conservation and regulation as required by federal legislation	1. Changes in populations and habitat after management implementation, esp. for aquatic habitat restoration, plant or mussel population augmentation; 2. Trends in rare or special concern plant and wildlife populations, and in their habitats, especially freshwater aquatics, birds, bats, and rare plants; 3. Success of stream restoration for mitigation; 4. Development of protocols and supervision of their implementation
U.S. Forest Service (USFS) – Chattahoochee and Oconee National Forest	In Georgia the USFS manages approximately 865,000 acres of federal lands for many purposes, and is required by law to protect and monitor rare species and habitats on these lands	1. Monitors or assists GA DNR in monitoring of rare plants, rare freshwater aquatic species, migratory and rare birds, and bats on National Forest lands; 2. Database of rare species occurrences on the National Forest
U.S. Forest Service (USFS) – Southern Research Station	Forest ecology research	Conducts research relevant to forest threats, disturbance regimes, and fire ecology; research questions are developed both in response to management and basic science needs
U.S. Forest Service (USFS) – Forest Inventory and Assessment (FIA)	Assesses condition of forests in the U.S. and projects future conditions for the next 5-10 years	Monitors status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership
Enduring Conservation Outcomes, LLC	Consulting on and development of monitoring and adaptive management protocols	Consults on establishing monitoring objectives, identifying indicators, developing study and sampling designs, analyzing, interpreting and communicating results, including qualitative data, and integrating monitoring results into adaptive management
GA Dept. of Transportation	Tracks rare species occurrences related to transportation projects. Minimizes impacts to rare species and habitats within proposed road construction corridors	Conducts surveys for rare species located with proposed road projects. Monitors potential transportation impacts to rare species located within transportation corridors or DOT lands. Works with GA DNR, USFWS, and other conservation organizations to minimize impacts to rare species in proposed or current transportation corridors.
U.S. Geologic Survey – Cooperative Research Unit, University of Georgia, Athens	Facilitates research between natural resource agencies and universities, provides technical assistance and consultation on natural resources issues	Current staff have expertise in: 1. Consultation on how to connect monitoring to decision making and reducing critical uncertainties 2. Connecting management questions to monitoring objectives, for example, as in evaluation of harvest policies; 2. Quantitative models of population responses to natural and anthropogenic influences; 3. Design of adaptive management frameworks for agencies

Dept. of Defense – Fort Benning, Gordon, and Stewart Army Bases	Protects and conserves rare species and their habitats on military bases in accordance with Dept.of Defense's military missions	Monitors rare species located on military bases. The primary focus of monitoring are federally listed and candidate species such as the Red-cockaded Woodpecker and Eastern Indigo Snake. However, state-listed or special concern species are also tracked. Restoration activities such as prescribed fire are emphasized to improve and maintain habitats for rare species.
Natl. Park Service – Southeastern Inventory and Monitoring Network	Facilitate collaboration and information sharing for monitoring and management among National Parks; establish a region-wide integrated program for natural resource monitoring	1. A long-term biological monitoring program, called "Vital Signs Monitoring" is in place to track key indicators of ecosystem integrity at National Parks. Biological components are land bird, vocal anuran, and vegetation community monitoring, with standardized protocols for each. 2. Grants are available for studies that apply to the parks and adjacent lands.
Georgia Dept. of Natural Resources – Coastal Resources Division	Manages and monitors coastal marshes, beaches, waters, and marine fisheries in Georgia	Monitoring of various marine fisheries, oyster reefs, salt marsh plant and animal communities, and marsh dieback. Some specific marine fisheries monitoring projects include trawl surveys of finfish and invertebrates in estuaries, eel surveys, and important recreational finfish monitoring. CRD also monitors oyster reef restoration and living shoreline projects. Regular "drop ring" sampling is used to monitoring plant and animal communities associated with tidal river levees.
Georgia Dept. of Natural Resources – State Parks Division	Helps restore and maintain natural communities on state parks, including conducting prescribed burns in fire-adapted habitats	With assistance from WRD Nongame Conservation Section, photo monitoring of fire-adapted habitats have been established on the majority of Georgia's state parks. Local parks staff conduct the monitoring annually or biennially.
Georgia Dept. of Natural Resources – Environmental Protection Division (GA EPD)	Monitoring of environmental quality to inform condition of natural resources and their regulation	An example project with close ties to Wildlife Resources is EPD's wetland monitoring program. The goal is to assess wetland quality and function throughout the state. As part of this work, various indicators of wetland condition are being investigated for development of a rapid wetland assessment method.
Sapelo Island National Estuarine Research Reserve	Research, stewardship, and sound management of coastal resources	1. High resolution mapping of marsh vegetation; 2. Detection and monitoring of invasive animal and plant species and their ecosystem effects; 3. Reproductive success of wading shorebirds; 4. Oyster reef ecology
Project Orianne	Conservation of the Indigo Snake and its habitat; conservation of high priority reptile species	1. Monitors Indigo Snake populations throughout S. GA; 2. Monitors Gopher Tortoise on select properties; 3. Monitors high priority snake species throughout GA; Surveys for spotted turtles throughout GA.

The Nature Conservancy – Georgia Field Offices	Biodiversity conservation and land stewardship	Monitor rare species and community responses to management on Nature Conservancy lands. Conducts inventories and monitoring on military bases and Army Compatible Use Buffer (ACUB) lands. Coastal priorities include monitoring critical maritime forests, living shorelines, wetlands, and oyster reefs.
The Nature Conservancy – Eastern Science Division	Develops spatially explicit data on natural habitats and communities at the regional level, beyond state boundaries, for conservation planning	1. Resilience of terrestrial communities to climate change; 2. River and stream habitat classification; 3. Protected lands database; 4. Floodplain assessments
Joseph J. Jones Ecological Research Center	Understand and demonstrate excellent natural resource management and conservation in the southeastern U.S. coastal plain	Ecology of longleaf pine woodlands and their wildlife, including wetlands and aquatic resources; research on the problem of natural resource management and environmental quality
U.S. Fish and Wildlife Service – Refuges Inventory and Monitoring Network	Monitor the status and trends of fish, wildlife, and plants in each refuge; integrate the monitoring system with the broader scientific community; provide data to inform adaptive management and conservation planning	1. Developing standard protocols across all refuges (e.g. amphibian community monitoring); 2. Developing an integrated data management system for storage of protocols, reports, management plans, and historical data; 3. Baseline data to evaluate impacts due to climate change and other long term environmental stressors in coastal and marine habitats; 4. Monitoring of federally listed species in the refuge system; 5. Fire risk, fire ecology, and prescribed fire monitoring; 6. Invasive species monitoring; 7. Bird surveys