Florida Keys Case Study on Incorporating Climate Change Considerations into Conservation Planning and Actions for State Listed and SGCN in the Florida Keys Incorporating Climate Ch...

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Incorporating Climate Change Considerations into Conservation Planning and Actions for State Listed and SGCN in the Florida Keys

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Cover photo: White crowned pigeon Courtesy of David Allen Sibley

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Abstract

The low-lying Florida Keys are at ground zero for impacts from rising seas. Perhaps the most at-risk natural resources are the endemic terrestrial species with no good bridges to suitable habitats outside the Keys. It is our responsibility as a society to recognize that each species has an intrinsic value, and this obliges us to at least incorporate this ethic into making informed decisions on how best to conserve these species as they confront an uncertain future. The Florida Fish and Wildlife Commission in partnership with the U.S. Fish and Wildlife Service, Stetson University, and The Nature Conservancy used stakeholder based workshops with local resource agency managers to examine possible in situ and ex situ adaptation strategies to address the vulnerabilities of a suite of 32 state listed plant and animal Species of Greatest Conservation Need (SGCN), at specific sea level rise intervals (i.e., 1, 2, 3, and 4 ft.). The workshop participants identified strategies that will increase the adaptive capacity of each species and help to identify when we've reached the trigger point for implementing ex-situ strategies. We incorporated the expert opinion of researchers, resource managers, and adaptation experts to create implementable adaptation actions tailored to each species. At each interval of sea level rise, we outlined expected impacts identified potential adaptation actions, established trigger points for action, and determined needed monitoring efforts. The stakeholders also prioritized adaptation options at each sea level interval, as well as those adaptation actions needed now. In some instances, other threats were higher priority to a species survival than sea level rise. These threats include feral cat predation, habitat development and fragmentation, invasive species, mosquito spraying, and illegal collections.

Magnificent Frigatebird (left), and the Keys mole skink by Jonathan Mays

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Finally, we would also like to make a special acknowledgement to David Allen Sibley of Sibley's Guides who provided illustrations of each project bird with the hopes that they will assist in raising awareness to climate change impacts to birds (personal correspondence 3/7/2019). These illustrations can be found throughout the report.

Executive Summary

While there are many important findings outlined in this document, we have selected few below that we believe to be of the highest importance.

For most species there is sufficient existing knowledge to develop and implement robust decisions: We found that a majority of the species that we examined had sufficient life-history and distribution information available to develop and implement adaptation actions in the face of threats from sea level rise. There were only a small number of species for which there was insufficient knowledge to fully identify the consequences of climate change thus limiting the ability to develop effective adaptation actions.

Some species may face more immediate risk from non-climate stressors than climate-based stressors: This is especially true in the case of predation from outdoor cats. While outdoor cat predation is an immediate threat, its interaction with climate change must also be considered. For example, suitable habitat for many at-risk species will likely shrink under sea-level rise thus increasing interactions with cats. Beyond the issue of cats, it is important to consider other non-climate stressors when planning for climate change adaptation (e.g., pollution, human disturbance, and loss of habitat from coastal development).

Scenario planning is an important tool for addressing uncertainty and ultimately overcoming planning paralysis: This project used scenarios in a way that was unique – identifying adaptation options along the trajectory of incremental sea level rise. In this approach, sea level rise intervals served as trigger points for applying adaptation actions. Managers and other decision-makers without direct experience with climate change adaptation planning or climate change-based models (e.g. SLAMM) may require approaches that help them interpret possible alternative futures and how to contextualize impacts and generate adaptation solutions.

We must focus more on what to do and less on when it will happen: Removing the element of time from sea level rise adaptation planning may reduce the mental block that can be associated with specific time periods. Additionally, time steps that are further from the present may be more abstract to planners and, therefore, harder to plan for. When time steps are integrated into the adaptation planning, we suggest that efforts focus on inevitable outcomes

Don't remake the wheel: Build upon existing management activities which may or may not focus directly on climate adaptation (e.g., prescribed fire regimes). Furthermore, climate adaptation actions that were developed for one species may be appropriate for other species, especially those that share similar life histories or vulnerabilities.

There are many categories of barriers to implementing climate adaptation work: While implementation of climate change adaptation has been attempted, it is often met with barriers that range from social to legal to economic to technical. Identifying, understanding, and overcoming these barriers will be an important step towards accomplishing climate change adaptation goals.

Agency missions, governance structures, and funding mechanisms need to be reviewed to ensure they are robust to changing conditions: Agencies and their divisions need to review their missions to ensure that they are forward-looking rather than focused on resisting change. Effective adaptive management requires sufficient flexibility in governance structures including rule-making and development of legislation to provide or support new and innovative approaches should conditions change. Additionally, current funding streams that are available for management are often one-time funds tied directly to specific goals and objectives with little flexibility thus reducing the ability of management to be adaptive.

Don't make assumptions about public tolerances for adaptation: Without direct public input or human dimensions work, we should not assume what the public wants. Wildlife managers may have different perceptions and tolerances for adaptation actions than the public. Therefore, we should not dismiss any action due to the assumption that the public will not like or tolerate it. Effective adaptation implementation requires a comprehensive understanding of the motivations of people. Adaptation must be incorporated as components of managing the human landscape. For example, it is unlikely that the majority of society will place a higher value on wildlife than on human health; therefore, adaptation should consider integrating the priorities of multiple sectors into a holistic adaptation that benefits both wildlife and humans.

There are many tough ethical questions and decisions that will need to be addressed: As certain habitats continue to contract due to sea level rise, wildlife conservation managers and biologists will be faced with many ethical questions. For example, when do you move a species outside of its historic range? When is extinction allowable? Is hybridization an acceptable outcome? When should assisted evolution be viewed as a viable adaptation approach? We must begin these difficult conversations now.

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Introduction

Climate change has become a serious threat across the U.S. and the terrestrial species inhabiting the low-lying Florida Keys will be among those most threatened by its impacts. One of the most consequential threats they face is a rising sea associated with increasing global temperatures. These rising temperatures have resulted in melting of polar ice and the thermal expansion of the oceans. The 2019 projections from the Southeast Florida Regional Climate Change Compact project that we can expect from 10” to 17” of sea level rise by 2040 and 21” to 54” by 2070. Species in the Florida Keys’ already have limited available habitat which will decline further as the ecological zone within which these species survive becomes narrower. With over 50 species occurring in the Florida Keys that are designated as federally listed, state listed, or SGCN, wildlife management organizations are faced with the challenge of achieving their mandate to conserve these species in an ever more hostile environment.

To further exacerbate the problem, many of the species will also be exposed to additional threats associated with urbanization including alterations to hydrology, disruption of natural fire regimes, and the introduction of invasive species. These threats may have enormous consequences for the continued persistence of the animals that inhabit the terrestrial environment of the Florida Keys, especially those that are endemic to the region. What makes these anthropogenic driven threats more troublesome is that, for many species, there are no good options for long-term survival within their native ranges without extreme human interventions. The choices we are faced with will be difficult and, in some cases, unsatisfactory. How those decisions are made, and when to implement the most extreme solutions, is one of the more vexing problems that wildlife managers must address.

In recent years, scientists and managers have begun examining adaptation options to address climate-associated vulnerabilities for wildlife species (Rowland et al. 2014, Stein et al. 2014). Developing and implementing adaptation strategies is the first critical step in planning for the survival of species at risk of extinction due to climate change. The Intergovernmental Panel on Climate Change (IPCC) defines ‘adaptation’ as an “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities” (IPCC, 2014). Using approaches that identify, develop, and implement robust strategies based on this approach to adaptation enhances the probability for survival of the many vulnerable species.

The Florida Fish and Wildlife Conservation Commission (FWC) has long recognized that climate change threatens the long-term survival of species endemic to the Florida Keys and further recognized the need to develop robust strategies to ensure their survival. Through the State Wildlife Grants Program, FWC has funded climate change adaptation projects that have primarily focused on the marine environment (i.e., the Florida Keys Marine Adaptation Projects: KeysMAP [Vargas Mereno et al. 2013], and KeysMAP2 [Glazer et al. 2017]). Taken as a whole, those projects provide the basis for the development of a holistic approach that integrated management and science. This process was developed based on the outcomes of multiple climate adaptation projects that brought together managers and scientists to:

1) define the question to be addressed,
2) identify the relevant and plausible future scenarios to be examined,
3) review the state of the science associated with each scenario,
4) identify adaptation options,
5) identify triggerpoints to inform when to implement the options, and
6) create monitoring plans and to help inform when those adaptation options should be implemented (Figure 1).

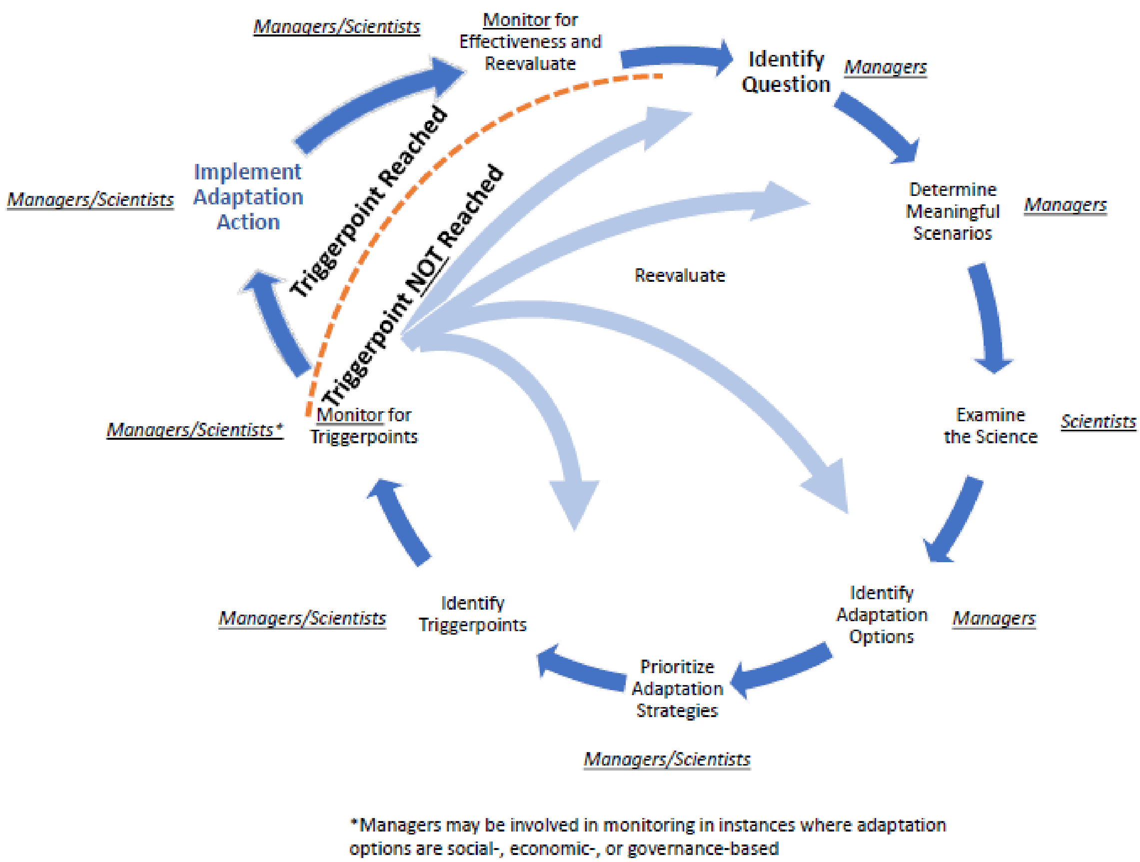

Figure 1. The KeysMAP process for climate change adaptation planning. The approach identifies the roles of managers and scientists in the process of identifying priorities and desired outcomes. This approach places an emphasis on identifying triggerpoints for adaptation and developing monitoring programs to identify when triggerpoints are reached and uses scenario planning as a tool to visualize plausible alternative futures.

This process was recently adapted for the terrestrial environment in the FWC State Wildlife Grant which examined scenarios in the Big Bend region of Florida with the goal of providing context and decision-support networks to 1) managers of the State's Wildlife Management Areas, 2) State parks in the region, and 3) federal wildlife refuges.

The U.S. Fish and Wildlife Service (FWS) built on this process by supporting a project conducted by FWC to examine Florida Keys terrestrial endemics that are listed under the

Endangered Species Act. The FWS project titled Keys Terrestrial Adaptation Planning (KeysTAP) was designed to examine the vulnerabilities of suites of species and to generate potential adaptation options for their conservation under the threats associated with sea-level rise (Benedict et al. 2018). Some results of KeysTAP were utilized to strengthen the process and results within this project.

Unfortunately, many adaptation plans are at scales that are very broad and therefore have limited relevance for implementing projects designed for finer spatial scales. For example, strategies identified in the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAS: http://wildlifeadaptationstrategy.gov) are purposefully scaled at national and regional levels, but the plan recognizes that successful adaptation needs to be stepped down to the local level. For this reason, it is critical to develop plans that are scaled appropriately for the area under investigation (e.g. KeysMAP, the Monroe County Climate Action Plan, the Monroe County Sustainability Action Plan, and the Energy and Climate section of the Monroe County Comprehensive Plan).

For this project, we sought to examine climate adaptation at even finer scales by addressing the vulnerabilities of single species, or suites of species with shared vulnerabilities or life histories, in specific locations (i.e., The Florida Keys, Marquesas, and Dry Tortugas). The adaptation options we identified in this project may have been developed after reviewing one species but likely have much broader applicability both within and outside the Florida Keys.

This project focused on the priorities outlined in Chapter 4 of Florida's State Wildlife Action Plan "Florida Adapting to Climate Change" (Florida Fish and Wildlife Conservation Commission 2012) and builds on the foundational knowledge developed in projects detailed in that chapter and other resources developed since 2012 (e.g., -Florida Adaptation Guide 2016, Reece et al. 2013, Vargas Mereno 2013). The project study site encompasses several habitats identified in Chapter 6 of Florida's State Wildlife Plan as being under the greatest overall threat (Florida Fish and Wildlife Conservation Commission 2012), including Pine Rocklands, Natural Pineland, and Mangrove Swamp. Many identified impacts from Climate Change are considered to have significant relevance to habitats and species in the Florida Keys.

Florida Purplewing (left) by Susan F Kolterman and Keys ring necked snake (right) by Jonathan Mays.

Project Objectives

The objectives of this project were to develop climate change adaptation strategies and actions for SGCN and their habitats threatened by climate change in the Florida Keys, and for agencies and NGOs to incorporate adaptation planning into their immediate and long-range planning and implementation efforts. This project focuses on non-federally listed species, building upon a planned similar USFWS project addressing federally listed species. Specifically, the objectives included:

1. Develop 5 adaptation strategies designed to address suites of species (coarse filters)
2. Develop 8 species-specific strategies that are not addressed by coarse-filter strategies (fine filters)
3. Identify 5 suite-specific and 8 species-specific trigger points that inform the implementation of adaptation strategies
4. Develop 6 monitoring programs to inform when triggers are reached
5. Identify gaps in knowledge that are required for adaptation strategy development

Methods

This project was designed to examine the potential vulnerabilities of terrestrial state-listed threatened and endangered species and SGCN in the south Florida region which encompasses the insular Florida Keys, Marquesas, and the Dry Tortugas. Conditions were examined under future sea levels intervals (i.e., 1 ft, 2 ft., 3 ft., and 4 ft.). The sea level intervals were selected because models indicate that they will likely occur (Southeast Florida Regional Compact 2015), with some projections showing potential for 6 feet by 2100. These intervals also provided tangible benchmarks that were easy to understand by the participants in the study. Since it is not known exactly when these intervals will occur, we removed the variable of time from our planning efforts. By using the predefined sea level intervals as the 'triggerpoints', we attempted to remove the variable of time which experience from previous projects suggests adds a layer of confusion and inevitably requires significant time to consider.

To examine potential changes to the Key's habitats under sea level rise, we employed the Sea Level Affecting Marsh Models (SLAMM). This model utilizes digital elevation data, digital habitat maps, and estimated rates of natural changes to sediments (i.e. accretion & erosion rates) to simulate the impacts of sea level rise on coastal habitats by forecasting resulting habitat changes. Due to the large spatial scale of the Florida Keys (approx. 220 miles or 355 km), the SLAMM model was run separately on four zones: 1. The Upper Keys, 2. The Middle Keys, 3. The Lower Keys, and 4. The Dry Tortugas and Marquesas. This provided a finer spatial scale thus facilitating the evaluation of high-resolution changes in habitats through each interval of sea level rise. Furthermore, the distribution of many project species is limited to very localized areas (e.g. brown noddy and sooty tern only nest on the Tortugas) so this granularity provided the ability to examine potential impacts to individual species at relevant spatial scales; larger spatial-scale maps would have decreased our ability to detect relevant habitat changes. Through this approach we aimed to identify actionable adaptation options for sustaining species at each predetermined sea level interval.

Our approach was workshop-based with each of 2 workshops focusing on specific natural resource audience and on specific steps in the adaptation planning process (Fig. 1). This built on similar stakeholder-based scenario-planning workshop efforts by FWC that were focused on the Keys and south Florida estuarine/marine ecosystems (i.e., KeysMAP 1 and 2; Vargas Moreno et al. 2013, Glazer et al. 2017), and in the Big Bend area of Florida (Benedict et al. 2017). The latter project targeted state and federal resource managers working on federal refuges and state wildlife management areas. Each of these projects combined modeling (i.e., SLAMM), and the input of species and natural resource management experts. In the Keys project, participants worked together in small group activities to brainstorm the potential consequences of sea level rise at the pre-determined intervals and develop adaptation options. A secondary benefit of this project aimed to provide Florida Keys resource managers with the tools to incorporate adaptation strategies into their planning processes and make tough decisions in the face of rising sea levels.

Figure 2. Project Region. This map illustrates the breadth of the project region, and the five planning zones that correspond to SLAMM models used throughout the project.

This project focused on the evaluating the long-term survival prognosis and the development of adaptation plans for over 30 species of plants and animals in the terrestrial habitats of the Florida Keys (Table 1). Species were selected due to their state designation for protection, their endemism to the Keys, and/or the importance of the Florida Keys to their life history. The list of species also provided the opportunity to consider the impacts of sea level rise on multiple taxonomic groups (i.e., mammals, birds, reptiles, invertebrates, fish, and plants). After input from project participants, two species were added to the project (the least tern and yellowwood tree).

Table 1 Project Species. The species and subspecies of animals and plants in the Florida Keys that were examined in this project. Species are listed by their taxa, and their current State designation for protection (T=Threatened; E= Endangered; SGCN=Species of Greatest Conservation Need; DL=Delisted).

TAXA	COMMON NAME	SCIENTIFIC NAME	STATE STATUS
Mammals	Pallas' Mastiff Bat	*Molossus molossus*	SGCN
	Lower Keys Cotton Rat	*Sigmodon hispidus exsputus*	SGCN
	Key Vaca Raccoon	*Procyon lotor auspicatus*	SGCN
	Torch Key (Key West) Raccoon	*Procyon lotor incautus*	SGCN
Birds	Bridled Tern	*Sterna anaethetus*	SGCN
	Brown Noddy	*Anous stolidus*	SGCN
	Least Tern	*Sternula antillarum*	T
	Mangrove Cuckoo	*Coccyzus minor*	SGCN
	Masked Booby	*Sula dactylatra*	SGCN
	Magnificent Frigatebird	*Fregata magnificens*	SGCN
	Great White Heron	*Ardea Herodias occidentalis*	SGCN
	Reddish egret	*Egretta rufescens*	T
	Roseate spoonbill	*Platalea ajaja*	T
	Sooty Tern	*Sterna fuscata*	SGCN
	White-crowned pigeon	*Patagioenas leucocephala*	T
	Wilson's Plover	*Charadrius wilsonia*	SGCN
Reptiles	Florida brown snake	*Storeria victa*	T
	Florida Keys mole skink	*Plestiodon egregius egregius*	T
	Key ringneck snake	*Diadophis punctatus acricus*	T
	Rim rock crowned snake	*Tantilla oolitica*	T
	Peninsula ribbon snake	*Thamnophis sauritus sackenii*	DL
	Red rat snake	*Pantherophis guttatus*	DL
	Striped mud turtle	*Kinosternon baurii*	DL

Invertebrates	Florida tree snail	*Liguus fasciatus*	DL
	Palatka Skipper	*Euphyes pilatka klotsi*	SGCN
	Dingy Purplewing	*Eunica monima*	SGCN
	Florida Purplewing	*Eunica tatila tatilista*	SGCN
	Big Pine Key Conehead Katydid	*Belocephalus micanopy*	SGCN
	Keys Short-winged Conehead Katydid	*Belocephalus sleighti*	SGCN
	Keys Scaly Cricket	*Cycloptilum irregularis*	SGCN
Fish	Key silverside	*Menidia conchorum*	T
Plants	Keys jumping cactus	*Opuntia abjecta*	E
	Bullsuckers	*Opuntia ochrocentra*	
	Yellowwood	*Zanthoxylum flavum*	E

During the initial phase of the project we sought to address objectives 1, 2, & 5:

Objective 1. Develop 5 adaptation strategies designed to address suites of species (coarse filters)
Objective 2. Develop 8 species-specific strategies that are not addressed by coarse-filter strategies (fine filters)
Objective 5. Identify gaps in knowledge that are required for adaptation strategy development

The initial phase of the project focused on a workshop with participants from multiple State and federal agencies, universities, and NGOs. The goal was to understand the potential impacts to coastal and terrestrial habitats at specific SLR intervals, to anticipate the impacts to state listed terrestrial species, and to develop adaptation options to mitigate the anticipated impacts. Among the habitats we considered were pine Rocklands, tropical hardwood hammock, Keys tidal rock barrens, mangrove swamp and buttonwood forest, freshwater wetlands, beaches and shorelines, tidal flats, and Keys cactus barrens. Species distributions and habitat associations were evaluated alongside SLAMM habitat-change projections that were developed for the Keys, Marquesas, and Dry Tortugas to better understand possible future habitat distribution. Species distribution maps were based off current data (i.e., expert input, FWC species distribution maps, and Florida Natural Resource Inventory maps), while SLAMM outputs provided maps of current landcover distribution, and potential changes to habitats associated with 1ft, 2ft, 3ft, and 4ft of sea level rise. In addition to geographical representation of change associated with each SLR interval, percentages of increase/decrease for each habitat were calculated for each interval (attached supplemental materials – Keys_SLAMM_Summary_Tables). Map representations of SLAMM projections can also be found in the attached supplemental material titled: SLAMM models.

To encourage participants to think about future landscape changes, they were first asked to describe any impacts of climate change and human development that they have already observed within the Florida Keys (Appendix I). This exercise was intended to highlight the fact that climate change isn't just a future problem; rather, it is already putting pressure on the Keys habitats and species. Participants were then subdivided into two groups with one team focused on mammals and reptiles, and the other focused on plants, birds, fish, and invertebrates. Each group utilized the SLAMM maps and species distribution models to project all expected impacts to each species based on their knowledge. To ensure that each species was adequately represented by an expert, participants with knowledge on multiple taxa were encouraged to move among groups when needed. Each team was asked to assign a scribe to record their discussions on worksheets. Once completed, participants from each group were given the opportunity to comment on, or add to, the results of the other group. By outlining impacts, participants highlighted what can happen if no action is taken. Taken together, this provided the foundation for the development of adaptation actions.

Groups were then reconvened in plenary to share and discuss their results. After reviewing the impacts to the species, each team was asked to generate species-specific adaptation approaches. Participants were asked to consider a wide range of possible actions that 1) buy the species more time, and 2) may fall outside current management and social norms (e.g., managed relocations outside their natural range.) Species with more life-history information made it possible for workshop participants to generate area-specific adaptation actions tailored to that species (i.e., fine filter approach). However, if data gaps were so significant that they prevented specific adaptation actions from being generated, more general adaptation actions were proposed (i.e., coarse filter approach). The coarse filter actions were classified based upon their utility for a wider range of species, whereas fine filters were those that were more species-specific.

White crowned pigeon (left) by Johnathan Mays, and Keys jumping cactus (right) photo by Jimmy Lange.

During the secondary phase of the project we sought to address objectives 3, 4, & 5:

Objective 3. Identify 5 suite-specific and 8 species-specific trigger points that inform the implementation of adaptation strategies.
Objective 4. Develop 6 monitoring programs to inform when trigger points have been reached
Objective 5. Identify gaps in knowledge that are required for adaptation strategy development

Following the exercise focused on developing adaptation actions, participants were asked to identify trigger points that will inform when to implement each adaptation action. Trigger points for adaptation actions were defined as either 1) when measurable impacts to species populations occur (e.g., 50 % population reduction, reproduction reductions, reproduction failure), or 2) when a detrimental level of habitat loss occurs (e.g., 2/3 habitat loss by 2ft of sea level rise). Each trigger point was based upon impacts identified by participants that are associated with a given sea level rise interval. The triggerpoints provide guidance for when a given action needs to be implemented. For example, early adaptation actions may focus on maintaining a species for persistence within its historic range until 75% loss of its habitat occurs. Once that trigger point is reached, efforts might shift to for example genetic storage in zoos, habitat transformation, or assisted migration. If a species had too many data gaps, species-specific trigger points were not generated. Participants concluded that without sufficient life history information or population estimates, no meaningful triggerpoints could be established. These instances represented significant and meaningful data gaps and priority areas for future research.

Once trigger points were identified, participants were asked to generate associated monitoring plans or determine information currently being monitored that may inform decision-making. These monitoring plans were generated based upon two concepts: monitoring for trigger points and monitoring the success of adaptation actions. In theory, once the proposed monitoring program identified that a trigger point had been reached, corresponding adaptation actions would be implemented for a species or suite of species. Then the second form of monitoring would be implemented to track the progress or success of those adaptation actions. These monitoring plans were designed to track in part freshwater availability, loss of available habitat, or changes in a species population. For example, a reduction of 50% in nesting success may trigger an action to build artificial nesting sites. While working through this exercise, participants took note of species that share similar habitat(s) or life histories. These species were then lumped together into coarse filter monitoring programs (e.g., mangrove nesting birds). Species specific results can be found in Appendix 2.

Peninsula ribbon snake (left) and Roseate spoonbill (right). Photos by Jonathan Mays.

Utilizing the information generated in the first stage of the project, we sought to further address objectives 1 and 2.

1. Develop 5 adaptation strategies designed to address suites of species (coarse filters)

2. Develop 8 species-specific strategies that are not addressed by coarse-filter strategies (fine filters)

During the first phase of the project, the participants generated an extensive list of adaptation actions, covering a wide range of habitats and species. These results provided the groundwork to complete objectives 1 & 2, but further refinement and prioritization was necessary. We needed to reduce the list of adaptation actions to a manageable number and subsequently categorize each into coarse and fine filters. To add value to this process, we needed the input of the conservation practitioners who will potentially implement these actions. We determined this would be best done with a wide range of stakeholders from throughout the Keys and South Florida, including those from the Florida State Parks, National Wildlife Refuges, FWC managed lands, Monroe County, and city properties.

In contrast to the participants in the first workshop, workshop 2 participants represented managers from city governments, state agencies, federal agencies, and NGOs. Participants were placed in break out teams to review the recommendations from participants in Workshop 1 and develop them further where possible. By including key managers from each entity, we ensured that a diversity of managers' perspectives was considered. Taken as a whole, this provided a holistic overview for how each type of organization may contribute to the execution of identified actions. The diverse perspectives also increased the likelihood that the appropriate organization or group of organizations needed to implement an action was present. This was especially critical given that in many cases, the identified actions required that those charged with the management of protected species work across jurisdictional boundaries.

The project team felt that actions generated from the federal Keys Terrestrial Adaptation Planning project (KeysTAP; Benedict et al. 2018) undoubtedly had applicability for the state listed and SGCN within this project, especially considering that KeysTAP focused on the development of adaptation actions for federally listed terrestrial species in the Florida Keys, and followed a similar process. Therefore, we incorporated adaptation actions that were developed for that project into the current project when relevant. To incorporate adaptation actions from both projects, we developed a matrix of climate adaptation actions on one axis, and state and federal species along the other (Table 2). Each action corresponded to a species or suite of species.

Table 2. Adaptation Action Matrix. This table shows a subset of federally listed (orange), SGCN, and state listed species (green) alongside coarse filter adaptation actions (blue) developed during the federal project and aimed at the conservation of federal species. An X within the table denotes where a federal adaptation action would benefit one of the SGCN or state listed species.

	Federally listed species				**State listed an SGCN**				
Adaptation Action	Roseate tern	Miami blue butterfly	Lower Keys marsh rabbit	Keys tree cactus	LK cotton rat	Sooty tern & brown noddy	FL Purplewing	FK Mole skink	Bullsuckers
Nursery propagation for planting on higher elevation lands, private lands,		X		X			X		X

and urban landscapes.									
Create rooftop habitat with materials for nesting.	X					X			
Immediate shift in habitat management from fire suppression to fire management					X				
Research needed on genetics of mainland vs Keys populations, dispersal, and viability of nursery propagation			X		X		X	X	X
Restrict mosquito spraying in specific areas		X					X		
Educational campaign for feral cat control	X		X		X	X		X	
Maintain or improve canopy roads		X			X				
Mitigate or improve migration barriers to the mainland		X							

All actions were placed into one of three classifications: Fine Filter, Coarse Filter, and Ex-situ (Attached supplemental materials – Coarse Filter Matrix, Fine Filter Matrix, and Ex-situ Matrix). The Ex-situ matrix, which means “offsite” was added to capture actions specifically aimed at moving species outside their native range. We felt that these classifications would help to clarify intent of each action to the participants and those hoping to utilize the products of this projects.

Key Vaca raccoon (left). Photo by Adam Fagen. Striped mud turtle (right). Photo by Jonathan Mays

In our first exercise focused on integrating KeysTAP adaptation actions, participants were asked to determine if the adaptation actions aimed at federal species would benefit any of the state project species. This information was recorded within each matrix. Participants were also asked to evaluate the adaptation actions generated during Workshop 1 for state listed and SGCN to determine if they may apply to other state listed or SGCN.

After evaluating each adaptation action, participants prioritized the adaptation action based upon benefit to state listed and SGCN. Actions were prioritized separately within the fine filters, coarse filters, and ex-situ matrices. Within the fine filters, participants prioritized for actions that addressed species whose need was greatest. Within the coarse filter actions, participants were asked to prioritize the actions with the widest applicability to state listed and SGCN species (i.e., which actions have the greatest potential impact). Finally, within the ex-situ matrix, participants were asked to prioritize actions for species with the greatest perceived need. Many participants noted that while they could see the utility in many of the ex-situ adaptation actions, current agency guidelines, social perceptions, and politics may not allow for their implementation, at least in the near term.

Following prioritization, the group discussed the concept of managing for change vs managing for persistence in the Florida Keys. For the purposes of this exercise, managing for change was defined as active management targeted towards expected future conditions. In contrast, management for persistence was defined as managing to maintain the distributions of species within their historic ranges. Both approaches are intended to slow the impacts of sea level rise in critical areas thus buying species time. However, managing for change or managing for persistence may only be effective to a certain interval of sea level rise beyond which either the critical habitat disappears, or total inundation occurs. Participants were asked when each management style may be advantageous, when they may be injurious, and when you would need to switch from one style to another.

Participants then evaluated the risks of a select group of prioritized adaptation actions. Whereas each action was developed to assist in the long-term survival of individual species, it was understood that an action may have unexpected consequences. For example, habitat modifications for one species may reduce available habitat for another. Risks were also considered by examining the potential financial implications of adaptation actions, social pushback or outcry, or impacts to the built environment. We further discussed the risk of inaction. For most, inaction will ultimately result in extinction or complete loss of the species' habitat. We also sought to understand which actions have the highest potential payoff, and which are associated with the most risk. We felt that this information was essential when prioritizing actions and activities.

Finally, in plenary, we discussed the perceived barriers to implementing the prioritized actions. Participants were asked to determine what may stand in the way of implementing specific actions based upon current political norms, agency policies, and social atmosphere. Barriers may also be limitations in our understanding of the species ecology, lack of practitioners' technical ability, or the action's expected risks or impacts to the natural environment.

Results

Changes already observed

A number of Workshop 1 participants identified specific changes to the focal species that were already observed (Appendix 1). For example, the participants confirmed likely shifts in habitats which will lead to changes in plant species composition in ecotone zones and hammock areas on northern Key Largo. These changes were noted even in salt tolerant species and were attributed to increased inundation and higher tides. Participants also noted how changes in sea level have already impacted the physical environment surrounding these species leading to habitat loss (e.g., Keys tree cactus).

Specific changes to habitats and species were also identified. Beaches have receded; berms have shifted; thatch palms and joewood trees have seen localized die-offs. In specific locations, both mangroves and buttonwoods have died whereas in other locations, they have increased. A number of birds have shifted their distribution to the mainland including spoonbills

Impacts to species under sea level rise
Our second exercise provided further understanding of the likely impacts to each species under multiple intervals of sea level rise. Species with more fixed ranges, such as brown noddy and sooty terns, resulted in more easily identifiable and specific impacts. The impacts to the more cryptic species and those with data gaps were not as clear, though their habitats will experience the influences of sea level rise all the same. The final exercise of Workshop 1 provided adaptation actions, trigger points, and suggested monitoring efforts for each of these species.

To illustrate the process for identifying impacts, adaptation strategies, trigger points and monitoring programs, we are using the example of the brown noddy and sooty tern.

Brown Noddy and Sooty Tern example

Brown noddy (left) and Sooty tern (right) Illustrations provided by David Allen Sibley. The Brown Noddy (Anous stolidus) and Sooty Tern (Sterna fuscata) are tropical tern species that are highly pelagic, but nest annually on Bush Key and the Dry Tortugas (Figure 3). While their breeding range in the United States is limited, both species occur throughout the Caribbean and additional tropical islands. Their diets are comprised of fish and squid on the surface of the sea

Figure 3. Dry Tortugas and Marquesas. This figure illustrates the Dry Tortugas around Garden Key (left) and the Marquesas Key (right) via satellite image. These keys reside in the Gulf of Mexico, west of Key West.

For this project, the brown noddy and the sooty tern were evaluated together as they are colonial nesters and occupy the same nesting areas of the Dry Tortugas. Due to the low elevation of the Dry Tortugas, there is a potential loss more than 2/3 of available nesting areas at the 2ft of sea level rise trigger point (Table 3).

Table 3. Brown Noddy and Sooty Tern. The results of each exercise focused on the brown noddy and sooty tern. The first column (blue) contains consequences of sea level rise as determined by participants. The second column (green) contains proposed adaptation actions. The final column (orange) notes any trigger points or needed monitoring.

Consequences of Sea Level Rise

- 1 ft. Ocean beach habitat increases but may not be suitable for nesting. 2/3 loss of undeveloped dry land. Loss of nesting shrubs.
- 2 ft. Only ~ 6 % of undeveloped dry land left.
- 3 ft. Habitat gone

Adaptation Actions

- Building floating habitats with substrate and shrubby plant species for nesting
- Raise elevation of existing habitat to match rising seas
- Convert abandoned building rooftops for nesting with substrate and shrubby plant species

Trigger Points and Monitoring

- Study nesting success, recruitment rate, and sustainability
- If nesting success falls below a sustainable level (determined by data gaps), enact adaptation actions
- Revaluate species on a global level- updated population surveys and risk analysis

Complete habitat loss will likely occur between 2-3ft of sea level rise (Figure 4). These sites may be lost sooner due to increasing stochastic events. For example, hurricanes, which are intensifying may result in total inundations when combined with sea level rise (Mousavi et al.

2011). Since this is the only known North American breeding site for both species, interventions will be necessary to maintain breeding within the United States.

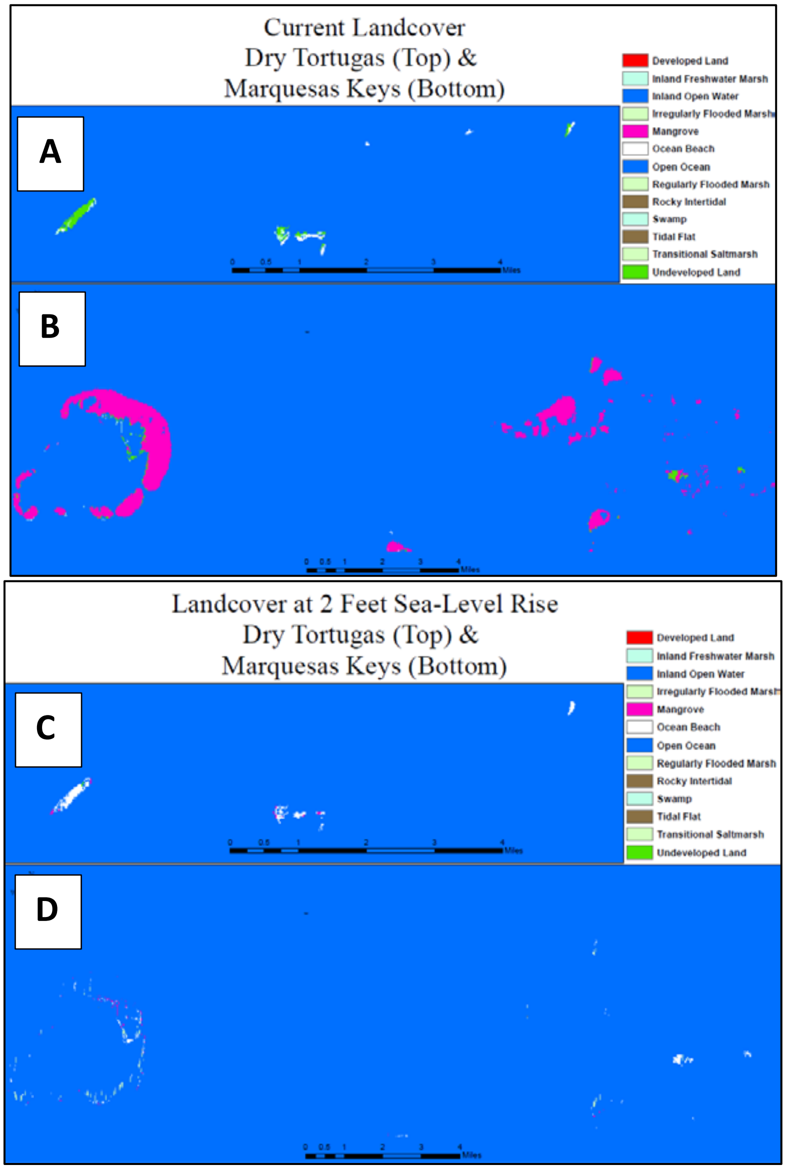

Figure 4. Dry Tortugas and Marquesas current terrestrial habitat classifications. The current terrestrial habitats of the Dry Tortugas (A) and the Marquesas (B). Under 2 ft of SLR, the habitats change dramatically with almost all land converted to beach in the Dry Tortugas (C) and total loss of mangroves in the Marquesas (D). Habitat changes were derived from SLAMM modeling.

Before taking any adaptive actions for these species, experts felt it would be necessary to evaluate the status of each species throughout the entirety of their range. If the two species were common throughout their ranges outside the US, then no action may be needed. However, if the species is decreasing in its range outside the US, then adaptive actions would be necessary. Workshop participants discussed adaptation options ranging from those that buy the species more time, to those that provide longer term solutions. For example, adding substrate to current nesting grounds to build up the elevation. This option buys the species more time but is not a permanent solution. The potential costs of getting equipment out to the Tortugas and Marquesas to carry out this task also limits the efficacy of this option. In contrast, building floating platforms or elevated platforms with the desired substrate and anchoring them near current nest sites has the potential to last longer, and could be built offsite. Floating platforms would rise to match rising seas but would be limited in scale. Elevated platforms would need to be built tall enough to provide long term escape from rising seas. Both actions are aimed at the persistence of the brown Noddy and sooty tern within the Tortugas or immediate area. If facing a complete loss in North American breeding grounds, managers will need to explore translocation options or attracting these birds to new locations. While this may be possible, participants felt that human activity and development may prevent these species from relocating closer the Florida Keys.

<u>Adaptation action matrix</u>
The matrix exercise in Workshop 2 examined 55 species in the Florida Keys, and at least 82 proposed adaptation actions. Table 3 contains a subset of adaptation actions and species that will benefit from them. This table contains a subset of evaluated for the complete matrix, see Table 6.

Of the 55 species that we examined, 21 were federally listed, and the remaining 33 were state listed or SGCN. Across the federal and state lists there were 14 species of birds, 11 species of plant, 11 species of invertebrates, 9 species of mammals, 9 species of reptiles, and 1 species of fish. While several species did not have actions generated for them in workshop 1 due to insufficient information, the matrix exercise in workshop 2 allowed participants to evaluate the potential benefits to these species from adaptation actions suggested for other species by applying the coarse filter approach. A list of the 55 species can be found in Table 4.

For these 55 species, 85 adaptation actions were evaluated. Of the 85, 37 were designated as fine filter actions and 33 actions were designated as coarse filter adaptation actions. Fine filter actions were those developed for a distinct area or species, and coarse filters actions were those developed for larger geographic areas or several species. The remaining 14 adaptation actions were designated as ex-situ in that they focus on conservation of species outside of their historic range. A list of these actions can be found in Table 5.

Following the prioritization of adaptation actions, the project team selected a group of priority actions for risk evaluation. One of these actions was creating rooftop habitat in South Florida and the Florida Keys that includes low shrubby species of plants and cacti for brown noddy and sooty tern nesting. This action also included decoys of each species in the artificial habitat. Participants felt that this action wouldn't be needed until at least 1ft of sea level rise when the Tortugas habitat would be highly reduced and nesting viability greatly decreased. The greatest risk of this action was the potential for it to simply not work. Participants believed that the lack of sooty tern or brown noddy nesting on the mainland and Florida Keys was not due to potential available nesting habitat, but rather due to proximity to human activity. Participants concluded that this increased the likelihood that other species would occupy these created rooftop nests, further limiting the target species from successfully nesting.

If rooftop nests were successful, participants believed that attracting the terns to the Keys and mainland would expose them to new threats. As an example, snack foods brought by tourists have attracted more gulls to the Dry Tortugas. The gulls, which were previously uncommon in the Dry Tortugas, began predating on tern nests. After discussing the risks of this action, participants determined that building up the habitat on the Tortugas may be more feasible. It was also noted that eventual abandonment of homes and infrastructure in the Florida Keys may open new habitat for both species. While rooftop habitats in the Keys and mainland were not ideal for the noddy or the sooty tern, many participants felt that this action would likely benefit the least tern or the federally listed roseate tern. Other notes on the brown noddy and sooty tern can be found in Table 2 and Appendix 2.

Due to the large volume of adaptation action and species with tables 4 and 5, we developed a matrix to display the results of Workshop 2. This matrix contains all coarse filter, fine filter, and ex-situ adaptation actions over each interval of sea level rise, and the species that each action may benefit (Table 6). Some actions and their utility to specific species correspond directly to an interval of sea level rise, while others remain applicable no matter the interval of sea level. To further the utility of the matrix, the results of the prioritization efforts were also included.

Table 4. Matrix Species Key. This table represents the species organized review during the matrix exercise in Workshop 2. The blue columns list the federal species examined in a previous grant focused on climate adaptation actions. The green column represents the species examined by this state wildlife grant. This table also serves as the species key to the matrix in Table 6.

Federal Species		State Species	
Sp. 1: Key Deer **Sp. 2:** Key Largo Cotton Mouse **Sp. 3**: Silver Rice Rat **Sp. 4**: Key Largo Woodrat **Sp. 5**: Lower Keys Marsh Rabbit **Sp. 7**: Roseate Tern **Sp. 8**: American Crocodile **Sp. 9:** Indigo Snake **Sp. 10**: Keys Tree Snail **Sp. 11**: Miami Blue Butterfly **Sp. 12**: Bartram's Hairstreak **Sp. 13**: Schaus' s Swallowtail **Sp. 14**: Semaphore Cactus **Sp. 15**: Keys Tree Cactus **Sp. 16**: Blodgett's Silverbush **Sp. 17**: Thoroughwort	**Sp. 18**: Wedge Spurge **Sp. 19**: Garber's Spurge **Sp. 20**: Sand Flax **Sp. 21**: Big Pine Partridge Pea	**Sp. 22**: Mastiff Bat **Sp. 23**: Lower Keys Cotton Rat **Sp. 24**: Key Vaca Raccoon **Sp. 25**: Torch Key Racoon **Sp. 26**: Bridled Tern **Sp. 27**: Brown Noddy **Sp. 28**: Mangrove Cuckoo **Sp. 29**: Masked Booby **Sp. 30**: Magnificent Frigatebird **Sp. 31:** Great White Heron **Sp. 32:** Reddish Egret **Sp. 33:** Roseate Spoonbill **Sp. 34:** Sooty Tern **Sp. 35:** Least tern **Sp. 36:** White Crowned Pigeon **Sp. 37:** Wilson's Plover **Sp. 38**: Red Rat Snake **Sp. 39:** Florida Brown Snake	**Sp. 40:** Florida Keys Mole Skink **Sp. 41**: Ringneck Snake **Sp. 42:** Rim Rock Crowned Snake **Sp. 43:** Ribbon Snake **Sp. 44:** Mud Turtle **Sp. 45:** Florida Tree Snail **Sp. 46:** Palatka Skipper **Sp. 47:** Dingy Purplewing **Sp. 48:** Florida Purplewing **Sp. 49:** Big Pine Key Conehead **Sp. 50:** Short Wing Conehead **Sp. 51:** Scaly Cricket **Sp. 52:** Keys Silverside **Sp. 53:** Yellow-wood **Sp. 54:** Keys Jumping Cactus **Sp. 55:** Bullsuckers

Table 5. Matrix Adaptation Actions Key. The coarse, fine, and ex-site actions developed in the Workshop 1 and examined during Workshop 2. Column A (left) contains 33 coarse filter adaptation actions. Column B (center) contains 37 fine filter adaptation actions. Column C (right) contains 14 ex-situ adaptation actions. This table also serves as the action key to the matrix in Table 6.

A: Coarse Filter Actions	*B: Fine Filter Actions*	*C: Ex-Situ Actions*
1. Nursery propagation for planting on higher elevation lands, private lands, and urban landscapes.	1. For American crocodiles; Create artificial nesting sites	1. Managed relocation within the Keys, but outside of historic range
2. Create mechanical disturbances in the hardwood hammocks to mimic natural disturbances.	2. For semaphore cactus; Research needed on reproduction genetic work and pollination	2. Research on potential recipient community impact (mainland), so species might be introduced to mainland Florida (or additional sites)
3. Refine projections of habitat availability spatially	3. For Big Pine partridge pea; Transplant to Little Pine Key and No Name Key	3. For bullsuckers and jumping cactus; Create ex-situ populations now
4. Immediate shift in habitat management from fire suppression to fire management	4. For Schaus swallowtail; design and implement monitoring of adult butterflies	4. Move species to mainland sites, determined by previous work
5. Research needed on genetics of mainland vs Keys populations, dispersal, and viability of nursery propagation	5. For Miami blue butterfly; Introduce host plants and butterflies to Lignum Vitae Key, Key Largo, Big Pine Key	5. Establish a captive breeding and assurance populations where possible (e.g. Smithsonian)
6. Research needed on salt tolerance, dispersal, pollinators, seed storage/germination (viability), and genetics to make decisions on intensity or need of collection/translocation	6. For Stock Island tree snail; Research the extent of the population in the Upper Keys	6. Assisted migration to the Upper Keys and eventually South Florida
7. Need for annual monitoring of populations to assess next steps	7. For American crocodiles; Research the assumption that range is expanding	7. For Bartram's hairstreak; relocate to pine rocklands in the Bahamas
8. Utilize SLAMM to inform reintroduction, and restoration efforts	8. For Indigo snake; Focus efforts outside of the Keys	8. For Schaus swallowtail; reintroduce to mainland
9. Educational campaign for feral cat control	9. For Key deer; Establish captive populations now	9. Seed banking
10. Maintaining freshwater resources; Identify most vulnerable sites and monitor for salinity	10. For roseate tern; Supplement rocky and sandy substrate on abandoned bridges and infrastructure	10. Gene banking
11. Fill in mosquito ditches	11. For dingy purplewing; Promote planting of gumbo limbo tree	11. Assisted evolution via genetic alterations (gene editing, selective breeding, or hybridization)
12. Restrict mosquito spraying	12. For Florida purplewing; Make crabwood more available for private planting	12. Creation of novel habitats with translocations of species and habitat characteristics into another
13. Seeds would be collected for ex-situ seed banking, future augmentations (as needed), and reintroduction into historic ranges	13. For Florida tree snail; Eliminate New Guinea flatworm	13. “Jurassic Park” established on mainland for Keys species
14. Create legislature to protect invertebrates that are not currently listed	14. For Palatka Skipper; Work with Monroe County to develop smaller wetlands at higher elevations	

15. Propose listing for CITES
16. Create artificial freshwater wetlands on higher elevation areas
17. Restore and enhance current available freshwater wetlands; select plants ideal for listed species
18. Remove rubble from mangrove sites that are reduce or prevent mangrove growth
19. Prevent military overflights and human disturbance around Marquesas
20. Prevent new development in tropical hardwood hammock and target it for conservation purchase
21. Need for federal listing
22. Need to fill data gaps; too large to recommend specific action
23. Acquire high ground sites throughout Keys
24. Acquire/purchase lands like Boot Key and Big Torch Key
25. Seed collection amount and timing may need to shift
26. Burn rockland habitats on Little Pine Key, and No Name Key
27. Implement feral cat control measures
28. Seagrass restoration and protection in new shallow areas
29. Plant mangroves
30. Knock down abandoned buildings in the Keys for nesting
31. Create floating islands with hardwood hammock species
32. Strategic retreat; Buy out private landowners, rolling easements
33. Raise elevation of existing habitats to match sea level rise

15. For Tortugas; Prevent visitors from feeding gulls, which prey upon tern chicks and eggs
16. For Reddish egret; Create mud flats where possible
17. For bullsuckers; Exclude Key deer from strongholds
18. For bullsuckers, jumping cactus, and yellow-wood; Research into pollinators - currently unknown
19. For Florida Keys mole skink; Research ability to move with beach berms, and survival of storm impact
20. For yellow-wood; promote and propagate as a landscape plant
21. For yellow-wood; Target coastal berms for planting in the Lower Keys
22. For sooty tern and brown noddy; Create floating habitats or convert rooftops - would require substrate and small shrubby plant species
23. For Key tree cactus; Collect germ plasm from other areas of Big Pine and introduce to Upper Big Pine Key
24. For wedge spurge; Reintroduce to Little Pine Key and No Name Key
25. For Miami blue butterfly; Focus reintroduction efforts on mainland instead of Keys
26. For Stock Island tree snail; Reintroduce to Stock Island and Lower Keys where possible
27. For American crocodile; Monitor nesting success, and sex ratios
28. For Key Largo woodrat; Fence off areas of current occupancy to reduce predation from cats and pythons
29. For semaphore cactus; Collect germ plasm
30. For masked booby; Fill Hospital Key with substrate

14. Creating new islands and translocating species to new islands

	31. For magnificent frigatebird; build artificial nesting trees in current location, and expand to other islands 32. For Florida Keys mole skink; Nourishing and creating berm habitat - assisted migration of berms 33. For Key deer; Create freshwater drinking station infrastructure 34. For Roseate tern; Create floating nesting habitats 35. For sand flax; Genetics work, salt tolerance, augment populations, and increased fire 36. Education and outreach on species specific impacts 37. Make all host plants more available to public

Table 6. Climate adaptation matrix. This matrix corresponds actions from Table 5 with species from Table 4. Table 6.A. represents all coarse filter adaptation actions and the species that may benefit by from that action. All action numbers correspond directly to an action within Table 5 (e.g. Coarse Filter 1 = Nursery propagation for planting on higher elevation lands, private lands, and urban landscapes). Species numbers correspond to species numbers in Table 4 (e.g. 1 = Key Deer and 35 = least tern). The final column labeled PV (Priority Votes) represents the number of votes an action received during the prioritization exercise in Workshop 2. The number of votes is written in Roman numerals to distinguish them from species numbers in the other columns. The top 3 actions under each category are highlighted in green.

Adaptation Option Category	Current	1ft	2ft	3ft	4ft	PV
	Sea level intervals					
Coarse Filter 1	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 46, 47, 48, 53, 54, 55	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 46, 47, 48, 53, 54, 55	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 46, 47, 48, 53, 54, 55	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 46, 47, 48, 53, 54, 55	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 46, 47, 48, 53, 54, 55	II
Coarse Filter 2	13, 14	13, 14				
Coarse Filter 3	All	All	All	All	All	VI
Coarse Filter 4	1, 12, 18, 21, 23, 46	1, 12, 18, 21, 23, 46	1, 12, 18, 21, 23, 46			II
Coarse Filter 5	1, 21, 23, 38, 40, 49, 50, 53, 54, 55					IV
Coarse Filter 6	14, 15, 16, 17, 18, 19, 20, 21, 53, 54, 55					III
Coarse Filter 7	10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 45, 46, 47, 48, 49, 50, 52	All	All	All	All	V
Coarse Filter 8	All	All	All	All	All	VI
Coarse Filter 9	2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43	2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43	2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43	2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43	2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43	II
Coarse Filter 10	1, 3, 5, 23, 24, 25, 40, 44, 46	1, 3, 5, 23, 24, 25, 40, 44, 46	1, 3, 5, 23, 24, 25, 40, 44, 46			II
Coarse Filter 11	5	5	5			I
Coarse Filter 12	10, 11, 12, 13, 45, 46, 47, 48, 49, 50, 51	10, 11, 12, 13, 45, 46, 47, 48, 49, 50, 51	10, 11, 12, 13, 45, 46, 47, 48, 49, 50, 51			IV
Coarse Filter 13	16, 17, 18, 19, 20, 21, 53, 54, 55	16, 17, 18, 19, 20, 21, 53, 54, 55	16, 17, 18, 19, 20, 21, 53, 54, 55	16, 17, 18, 19, 20, 21, 53, 54, 55	16, 17, 18, 19, 20, 21, 53, 54, 55	I
Coarse Filter 14	45, 46, 47, 48, 49, 50, 51					III
Coarse Filter 15	45					
Coarse Filter 16	1, 3, 5, 23, 44, 46	1, 3, 5, 23, 44, 46	1, 3, 5, 23, 44, 46			II
Coarse Filter 17	1, 3, 5, 23, 24, 25 44, 46	1, 3, 5, 23, 24, 25, 44, 46	1, 3, 5, 23, 24, 25, 44, 46			II
Coarse Filter 18	28, 30, 31, 32, 33, 36	28, 30, 31, 32, 33, 36	28, 30, 31, 32, 33, 36	28, 30, 31, 32, 33, 36	28, 30, 31, 32, 33, 36	
Coarse Filter 19	26, 27, 29, 30, 34, 35, 36	26, 27, 29, 30, 34, 35, 36	26, 27, 29, 30, 34, 35, 36			V
Coarse Filter 20	2, 4, 9, 10, 14, 36, 39, 40, 41, 43, 45, 47, 48	2, 4, 9, 10, 14, 36, 39, 40, 41, 43, 45, 47, 48	2, 4, 9, 10, 14, 36, 39, 40, 41, 43, 45, 47, 48	2, 4, 9, 10, 14, 36, 39, 40, 41, 43, 45, 47, 48	2, 4, 9, 10, 14, 36, 39, 40, 41, 43, 45, 47, 48	V
Coarse Filter 21	32, 37, 42, 53, 54					II
Coarse Filter 22	49, 50, 51, 52					I
Coarse Filter 23	2, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 29, 20, 21, 36, 37, 38, 39, 40, 41, 2, 43, 44					VII
Coarse Filter 24	1, 3, 5, 7, 28, 36, 37, 46					IV

PV: column header of the last column.

Coarse Filter 25	*16, 17, 18, 19, 20, 21, 53, 54, 55*					*II*
Coarse Filter 26	**1, 18, 21, 24, 25, 38, 41, 42, 43, 46, 47, 49, 50, 51, 53, 54, 55**	**1, 18, 21, 24, 25, 38, 41, 42, 43, 46, 47, 49, 50, 51, 53, 54, 55**	**1, 18, 21, 24, 25, 38, 41, 42, 43, 46, 47, 49, 50, 51, 53, 54, 55**			**III**
Coarse Filter 27	**2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43**	**2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43**	**2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43**	**2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43**	**2, 3, 4, 5, 23, 24, 25, 34, 35, 37, 38, 39, 40, 41, 42, 43**	**V**
Coarse Filter 28		**31, 32**	**31, 32**	**31, 32**	**31, 32**	**I**
Coarse Filter 29		**3, 24, 25, 28, 30, 31, 32, 33, 36**	**3, 24, 25, 28, 30, 31, 32, 33, 36**	**3, 24, 25, 28, 30, 31, 32, 33, 36**	**3, 24, 25, 28, 30, 31, 32, 33, 36**	
Coarse Filter 30		**7, 8, 35, 37**	**7, 8, 35, 37**	**7, 8, 35, 37**	**7, 8, 35, 37**	**II**
Coarse Filter 31		**2, 4, 9, 10, 13, 15, 36**	**2, 4, 9, 10, 13, 15, 36**	**2, 4, 9, 10, 13, 15, 36**	**2, 4, 9, 10, 13, 15, 36**	**III**
Coarse Filter 32		**40**				**V**
Coarse filter 33		**26, 27, 29, 30, 34, 35**	**26, 27, 29, 30, 34, 35**	**26, 27, 29, 30, 34, 35**	**26, 27, 29, 30, 34, 35**	**I**

Adaptation Option Categories	Current	1ft	2ft	3ft	4ft	PV
Fine Filter 1	**8, 34, 35, 37**					**II**
Fine Filter 2	**14**					
Fine Filter 3	**21**					
Fine Filter 4	**12, 13, 46, 47, 48**					**VII**
Fine Filter 5	**11, 12, 46, 47**					**I**
Fine Filter 6	**10**					
Fine Filter 7	**8**					
Fine Filter 8	**9, 22**					**1**
Fine Filter 9	**1**					
Fine Filter 10	**7, 35, 37**					**IV**
Fine Filter 11	**47**					**III**
Fine Filter 12	**48**					**V**
Fine Filter 13	**10, 45**					**V**
Fine Filter 14	**1, 3, 5, 46**					**II**
Fine Filter 15	**7, 26, 27, 34, 35**					**IX**
Fine Filter 16	**32**					**I**
Fine Filter 17	**55**					
Fine Filter 18	**53, 54, 55**					**IV**
Fine Filter 19	**10, 37-43**					**IX**
Fine Filter 20	**17-21, 53**					
Fine Filter 21	**53**					**I**
Fine Filter 22		**27, 34**				**VIII**
Fine Filter 23		**15**				
Fine Filter 24		**18**				
Fine Filter 25		**11, 42**				
Fine Filter 26		**10**				
Fine Filter 27		**7, 8, 26-37**				
Fine Filter 28		**2, 3, 4, 5, 23, 37**				**I**
Fine Filter 29		**14**				
Fine Filter 30		**29**				**II**
Fine Filter 31		**27, 30**				**III**
Fine Filter 32		**40**				**II**
Fine Filter 33			**1, 23, 24, 25**			
Fine Filter 34			**7, 35, 37**			**IV**
Fine Filter 35			**20**			
Fine Filter 36	**All**	**All**	**All**	**All**	**All**	**XII**
Fine Filter 37	**11, 12, 13, 46, 47, 48**	**11, 12, 13, 46, 47, 48**	**11, 12, 13, 46, 47, 48**	**11, 12, 13, 46, 47, 48**	**11, 12, 13, 46, 47, 48**	**I**

Adaptation Option Categories	Current	1ft	2ft	3ft	4ft	*PV*
Ex-Situ Action 1	1-21, 22-28, 30-33, 35					I
Ex-Situ Action 2	1-21					IV
Ex-Situ Action 3	53, 54, 55					IV
Ex-Situ Action 4		1-21	1-21	1-21	1-21	I
Ex-Situ Action 5		11, 12, 13, 39-44, 46				VIII
Ex-Situ Action 6		39-44				VI
Ex-Situ Action 7			12, 14			
Ex-Situ Action 8			13			
Ex-Situ Action 9	14-21, 53, 54, 55					XXV
Ex-Situ Action 10	1-5, 10-13					XXVI
Ex-Situ Action 11	14, 15					
Ex-Situ Action 12						
Ex-Situ Action 13						
Ex-Situ Action 14		7, 26, 27, 29, 34, 35, 37				XXIV

The final exercise of Workshop 2 generated perceived barriers to climate adaptation in the Florida Keys and examples were presented of adaptive projects cut short by those barriers. Barriers were associated with 7 categories: Social, Technical, Administrative, Political, Legal and Governance, Economic, and Environmental. For example, social barriers included feral and outdoor cat control methods, perceived misuse of conservation dollars, and concern over unintended impacts to homes. However, participants also noted that a lack of action to save species from climate change may receive public outcry. Participants also noted that some stakeholders may believe that acting on climate change and sea level rise are political statements.

Participants also shared examples of projects that have been stopped by barriers (Table 7). One project involved creating tern nesting habitat on the old 7-mile bridge for the roseate tern, similar to those options associated with the brown noddy and sooty tern. This project was not implemented due to lack of permitting from the managing agency of the bridge. Since this structure is a protected historic feature of the Florida Keys, modifications are currently prohibited. It was also thought that introducing the necessary nesting substrates would create risk of degrading the structure and increase the likelihood of falling debris from the bridge.

Table 7. Projects proposals met with barriers. This table illustrates projects that were stopped short of implementation due to barriers.

Proposed projects	**Barriers that prevented implementation**
Creating habitat for roseate tern on 7-mile bridge	Managing agency would not allow alterations to historic structure
Attempting to shade, control flow, and aeration to corals with a mechanical structure during high exposure events	Met with too much permitting red tape. Couldn't even test on a small research scale
Miami blue butterfly introductions to mainland	Were stopped but still being pursued. MOU took too long. Wanted to move to a state park but it would cause conflict with management and fear of taking on an endangered species. Mosquito control sued to stop re-introductions
Prescribed fire on No Name Key for Big Pine partridge pea	Prescribed fire has a lot of social opposition currently. Lack of current capacity to implement from the managing agency. Current lack of priority or interest from the managing agency.

Result Overview by Objective

Listed below are the project objectives and examples of results for each objective. For example, Objective 1 was to develop 5 adaptation strategies designed to address suites of species (coarse filter). While the project was able to generate far more than 5 coarse filter actions, only 5 are listed below as examples to the fulfillment of objectives. More results for each category can be found in Appendix II: Species Results.

1. **Develop 5 adaptation strategies designed to address suites of species (coarse filters)**
   I. Refine projections of habitat availability spatially
   II. Utilize SLAMM to inform reintroduction, and restoration efforts
   III. Acquire high ground sites throughout Keys
   IV. Prevent new development in tropical hardwood hammock and target it for conservation purchase
   V. Strategic retreat; Buy out private landowners, rolling easements

2. **Develop 8 species-specific strategies that are not addressed by coarse-filter strategies (fine filters)**
   I. For Tortugas; Prevent visitors from feeding gulls, which prey upon tern chicks and eggs
   II. For Florida Keys mole skink; Research ability to move with beach berms, and survival of storm impact
   III. For Stock Island tree snail; Reintroduce to Stock Island and Lower Keys where possible
   IV. For Schaus swallowtail; design and implement monitoring of adult butterflies
   V. For sooty tern and brown noddy; Create floating habitats or convert rooftops - would require substrate and small shrubby plant species
   VI. For roseate tern; Supplement rocky and sandy substrate on abandoned bridges and infrastructure
   VII. For Florida purplewing; Make crabwood more available for private planting
   VIII. For Florida tree snail; Eliminate New Guinea flatworm

3. **Identify 5 suite-specific and 8 species-specific trigger points that inform the implementation of adaptation strategies**
   I. 5 suite-specific trigger points
      i. Most actions would occur within 1 ft of sea level rise
      ii. Between 1-2 ft. of SLR, reassess status of habitat, and explore ex-situ actions
      iii. Post-storm population surveys, updated population surveys, and distribution as storm events may move up trigger points
      iv. Base data gap trigger points off updated population surveys
      v. Monitor for spatial distribution, exposure risk, sensitivity, or adaptability
   II. 8 species-specific trigger points
      i. Trigger point is now: Fill data gaps for the brown noddy and sooty tern – nesting success rates
      ii. For the brown noddy and sooty terns; If nesting success falls below a sustainable level (determined by data gaps), enact adaptation actions
      iii. For the magnificent frigate bird; Trigger points may have already been reached, research urgently needed
      iv. For magnificent frigate bird; Start nesting and habitat enhancement before 50% loss of nesting trees

v. For Wilson's plover; Trigger is low due to ground nesting – At or before 1ft. of SLR
vi. For the Florida brown and the Keys ringneck snake; 1-2 ft. of SLR, reassess status of habitat, and explore ex-situ actions
vii. For the peninsula ribbon snake; Trigger is now: Begin experimenting with artificial wetlands
viii. For the Florida tree snail; 1-2 ft. SLR. Lower and Middle Keys populations assisted migration – ex-situ

4. **Develop 6 monitoring programs to inform when triggers are reached**
   I. For all birds that occur outside of the Florida Keys; Revaluate each species on a global level- updated population surveys and risk analysis
   II. Annual monitoring of salinity in freshwater systems throughout the keys
   III. Monitor colony size of brown noddy and sooty tern annually
   IV. Monitor for nesting success rates in white-crowned pigeon
   V. Annual monitor the lower keys cotton rat
   VI. Annual monitoring already in process for many of the FL Keys reptiles. Continue to support this effort.

5. **Identify gaps in knowledge that are required for adaptation strategy development**
   I. For the magnificent frigate bird; Update population trends, nesting success, to determine how critical Florida is to species
   II. No current information on the Keys scaly cricket, Big Pine, and short winged conehead katydids. Utilize call recording devices to detect.
   III. Dingy Purplewing and Florida Purplewing data deficient
   IV. Currently no information for the Key silverside to inform management decisions
   V. Need to establish presence of absence of the cactoblastis moth in the FL Keys
   VI. Research the pollinators of the yellow wood, Bullsuckers, and Keys jumping cactus.
   VII. Genetics data gaps for the Palatka skipper will inform further decision making
   VIII. Nesting success rates of the brown noddy and the sooty tern

Discussion

Wilson's plover. Illustration by David Allen Sibley

With over 8,000 miles of coastline, Florida faces a significant threat from sea level rise. While all coastal regions will see impacts from the threat of sea level rise, the low-lying Florida Keys will be among the first locations to experience the loss of endemic species from this threat. Species that currently call the terrestrial habitats of the Tortugas, Marquesas, and Florida Keys home are losing ground and have little or no means of escape. The goal of this project was to determine the potential impacts of sea level rise on a range of state listed and SGCN Keys species, while also developing and prioritizing climate adaptation actions to address those impacts. Further we kept an eye towards the results remaining relevant for other Florida locations and beyond. To accomplish this, we employed a clear and simple methodology to address climate adaptation planning that resource managers could easily apply to multiple similar conservation targets.

Through a series of workshops and pointed meetings, we were able to accomplish our objectives and provide a clearer understanding of potential species losses due to sea level rise, and as well as develop methods to reduce or avoid those losses. Project results from SLAMM and input from species experts suggests that most losses will occur by, or prior to, 2 feet of sea level rise. This is driven by not only by loss of physical land to sea level rise, but also loss of freshwater resources due to saltwater intrusion. Participants also discussed the possibility that saltwater intrusion would likely kill off saltwater intolerant plants, making way for coastal tolerant assemblages (e.g. mangroves). With this in mind, participants felt that most adaptation actions needed to be enacted in the short term, or prior to 2 feet of sea level rise. As a result, most adaptation actions listed in Table 6 were prioritized under "current" sea levels or 1ft of sea level rise.

During our first workshop, participants determined which species are most at risk to impacts of sea level rise, and which may be seemingly less threatened. Where possible, participants estimated how much loss a species might endure at each interval of sea level rise. This also revealed that for some species the time for action is now. Spatial projections illustrated by SLAMM maps and current species range maps were instrumental in determining these impacts and provided participants a spatial context for impacts. Specifically, these results show a trend of loss occurring soonest in the Tortugas, Marquesas, and Lower Keys, followed by the Middle and Upper Keys. While we have no way of forecasting the exact changes to habitats, sophisticated models such as SLAMM provide the means to overcome planning paralysis. However, providing SLAMM outputs alone is not sufficient for the development adaptation actions when discussing individual species and the outputs from these models should not be viewed as certain. Nevertheless, they are informative and form the basis from which conversations can start.

The maps were especially useful when used in conjunction with species distribution maps. We provided participants with the best available distribution maps for each project species.


Roseate spoonbill. Illustration by David Allen Sibley

Comparing SLAMM outputs to species distribution maps is a very simple approach that provided our project participants with clear visualization of where each species may see impacts. Providing multiple intervals of sea level rise also provided insight into which areas of each species distribution will be impacted first, and which may be secure for longer.

Decoupling the element of time from the intervals of sea level rise allowed us to approach each discussion without participants worrying about whether higher intervals would be seen within their careers or lifetime. We have found in past scenario-planning efforts that participants are seemingly stymied by uncertainty to propose actions if models are generated for dates as far away as 2100. Removing this element seemingly reduces the mental restrictions that are implicit in long term planning and allows for the proposal of more forward-looking adaptation approaches. However, participants still seem to favor short term solutions that may buy a species more time but may not provide long term success.

Regardless of time or interval of sea level, participants found that data gaps in species distribution and life history were the biggest obstacle to planning. Those species with the largest data gaps (e.g. Keys silverside, Keys scaly cricket, and the conehead katydids) had almost no impacts that were identified, or adaptation actions that were generated for them due to uncertainties about their basic biology and distribution. Resolving these data gaps then becomes the immediate priority for these species before we can begin to determine what adaptation actions could best address their vulnerabilities.

One of the more important steps of this project was determining the applicability of each adaptation action to each species, regardless of which species that action was initially developed for. For example, the efficacy of actions developed for the Keys mole skink were judged on whether or not they may be applicable to one or more other state listed or SGCN. We also asked participants to review adaptation options generated not only within this project, but also those generated in previous work focused on federally endangered species. The goal of the exercise wasn't to further develop adaptation options for the federal species, but to determine if actions generated for federally endangered species could also benefit state listed or SGCN species. Not only did this expand the suite of adaptation actions to be considered for state listed and SGCN species, but it also highlighted areas of commonality and areas for potential state and federal collaboration. While common areas could be found, for the purposes of this project participants were asked to focus on applicability of actions for state listed and SGCN species.

Through this process we found that most adaptation actions had broader applicability than their original intent. However, this was inherently less true in actions that were deemed fine-filter actions. Many of these actions were tailored so specifically to individual species that there was little to no chance of broader applicability. For example, action 23 addressed the Keys tree cactus. The action called to collect germ plasm from other areas of Big Pine and introduce to Upper Big Pine Key. This action is highly specified to one species and one location. Prioritization therefore leaned toward fine-filter actions that could translate to several species. The top 3 priority actions for filter were actions 15, 19, and 36. Action 15 focused on reducing gull predation on shorebird chicks in the Tortugas, 19 focused on researching the Florida Keys moles skink's ability to move with shifting berm habitats and storm survival, and 19 focused on public education and outreach on species-specific impacts due to climate change. Each one of these actions was determined to be applicable for 5 or more project species. It is also worth noting that none of the three actions selected were directly aimed at combating loss to sea level rise. Even the 4th highest rank action focused on monitoring butterfly populations rather than taking any direct action. This seems to suggest that most of our project participants were not yet ready to implement counter measures to sea level rise impacts.

Mangrove cuckoo. Illustration by David Allen Sibley

Due to the inherently broad nature of coarse filter adaptation actions, a majority of these actions were found to have the high applicability to project species within the matrix. Most coarse-filter actions were noted as having the potential to help 10 or more project species; some would likely benefit all project species. For example, when considering action 7 (Need for annual monitoring of populations to assess next steps) the workshop participants felt that implementing annual monitoring with a focus on determining next steps for climate change adaptation would benefit all species. While the prioritization was very close for coarse-filter actions, the top three were actions 3, 8, and 23. Coarse filter action 3 focused on refining range maps and habitat availability, action 8 called for the use of SLAMM outputs to inform all reintroduction and restoration efforts, and 23 called for the acquisition of all available high ground sites in the Keys. Actions 8 and 23 focused directly on buying time for species losing ground to sea level rise by maximizing efforts toward climate-informed restoration and land acquisition.

Interestingly, more ex-situ adaptation actions were identified for federal species than state-listed or SGCN species. This may infer that federal managers and biologists are more accepting of ex-situ actions, while those charged with management of state listed or SGCN are less accepting. This may be due to a cultural difference between state level or federal level employees, differences in mandates between agencies, or due to the more immediate threat posed to those already federally listed. This also could be due to the amount of interest in, and money available to, the federal species. Many of the federally listed species are high profile whereas the State-listed species and SGCN are less well known. With interest and money come more research and consequently more information about those species.

The top three priority ex-situ adaptation actions (actions 9, 10, and 14) are similar in that they do not involve actually moving a species into a natural environment outside its range. These ex-situ actions received more than 2x the number of votes than any action that would be considered assisted migration Action 9 called for seed banking, action 10 called for gene banking, and action 14 called for the creation of new islands specifically for shorebird nesting. Actions 9 and 10 were seen as low risk and unlikely to face barriers in that they do not initially impact other wildlife populations, only the individual species providing the genetic material. However, subsequent actions taken with this genetic material or seeds may be higher risk and face more barriers to implementation. While likely cost prohibitive, creating new islands is another ex-situ action that doesn't require actively moving a species into the established range of another species.

Reddish egret. Illustration by David Allen Sibley

Several conclusions can be drawn from this outcome. First, this may suggest that a majority of project participants are not ready to consider actions that actively move a species outside of its historic range, at least in the current social and political environment.

Secondly, these actions are easy-to-implement and can be done now with little or no backlash. In fact, these approaches can be categorized as no-regret strategies that can be, and we argue should be, employed regardless of the species status.

It is also worth noting that while each adaptation action within each category was prioritized (i.e., coarse, fine, and ex-situ), this was done within categories and not across. Therefore, we cannot say definitively which type of adaptation action is the highest or lowest priority across all categories. However, many participants voiced their concerns and apprehension with most ex-situ actions while seeming more comfortable discussing coarse filter actions more thoroughly. A human dimensions study within FWC or expanded to partnering organizations may help us further understand what type of actions managers are comfortable with implementing now.

Many participants noted that they did not prioritize some adaptation actions (such as assisted migration) due to their perception that the public may not view those actions as permissible. While this may be true, currently no steps have been taken to understand the public's perception on climate change as it relates to wildlife management. Therefore, we recommend that the results of this project be included in human dimensions work to determine what actions the public perceives to be acceptable or unacceptable. We may find that assumptions are true, or we may find that public tolerance for unorthodox management is higher than that of natural resource managers and biologists. Public perception on inaction from government agencies on climate change should also be explored. Until we have a true understanding of the public's tolerance or intolerance of actions, we should avoid justification of action or inaction based upon said perceived public perspectives.

Even if public perception favors implementing adaptation actions, future wildlife conservation efforts will present increasingly difficult decisions that may have no ideal solutions. Whereas each of the project adaptation action is designed with the best intentions, we can't ignore that some actions could instead be maladaptive and have negative repercussions rather than help the species. Any planning effort must also incorporate discussions surrounding risks. The risks associated with these actions must then be weighed against the risks of inaction. In the case of the Florida Keys endemics, inaction will eventually result in complete loss of habitat and subsequent loss of the species.

Masked booby. Illustration by David Allen Sibley

Whereas our project focused directly on the impacts of sea level rise on state listed and SGCN, many participants felt that there were more pressing issues than climate change. Many of the small mammals, birds, and reptiles within this project are preyed upon by a non-native predator, feral cats. Therefore, many felt that the issues of feral and outdoor cats need to be address before or alongside sea level rise. Similarly, tern species are threatened by gull predation in the Tortugas. Recent human activity and food has attracted more gulls to the island, resulting in higher rates of nest predation. For the Florida tree snail, an invasive, predatory flat worm is a more immediate threat that could reduce its populations long before populations would be impacted by rising seas. While sea level rise was the focus of this project, these additional impacts require near term solutions.

At the time of this report, implementing adaptation actions remains rare and is where climate adaptation efforts fall short. While we have laid important groundwork for Keys state-listed and SGCN, adaptation efforts should not end with this report. We must continue the dialogue on currently uncomfortable and unorthodox methods of climate adaptation, as perceptions may change as conditions continue to change. We must understand if and when to abandon in-situ management of a species within its native range? If you do abandon it, how do you determine between untested ex-situ methods or allowing for extinction? When is extinction of species under our care permissible? Is it more acceptable for a species to become extinct if its known habitat disappears, or should we do everything within our power to prevent it? Is hybridization of a species on the verge of extinction with its more common relative a form of extinction, or a method of genetic conservation? Each of these questions requires that managers think differently and embrace the uncomfortable reality that conditions are changing, and that conservation will likely need to change along with it.

While the species represented in the project may be among the first in the US to feel the impacts of climate change, ultimately wildlife on national and global scale will face the impacts of climate change and face these same questions. Therefore, lessons learned from our efforts within the Keys may provide stepping stones for managers outside of this project's original intent. It is our hope that the process and results within this project may be applied throughout the U.S., and beyond, and that efforts to address some of the more vexing issues receive more attention.

Conclusions

While our conclusions are the result of this project, we believe that they will be similarly applicable to adaptation projects that are beyond the Florida Keys region.

Adaptation as it pertains to species management is by design an ongoing process requiring periodic revisiting and revising. The KeysMAP model for climate adaptation emphasizes continually revisiting goals, objectives, approaches, and strategies. Revisiting planning efforts and trigger points frequently to reduce the need to reiterate effort.

For most species there is already sufficient existing knowledge to develop and implement robust decisions. We found that a majority of the species that we examined already had sufficient life-history and distribution information available to develop and implement adaptation actions in the face of threats from sea level rise. There were only a small number of species for which there was insufficient knowledge to fully identify the consequences of climate change thus limiting the ability to develop effective adaptation actions. In the same spirit, we don't need to remake the wheel to address climate adaptation with wildlife. Existing management activities already exist which, although not explicitly climate-focused, may be adaptable with little or no changes to address a changing climate (e.g., prescribed fire regimes). By extension, climate adaptation actions that were developed for one species may be appropriate for other species, especially those that share similar life histories or vulnerabilities.

Some species may face more immediate risks from non-climate stressors than climate-based stressors. This is especially true in the case of predation from outdoor cats. While outdoor cat predation is an immediate threat, its interaction with climate change must also be considered. For example, suitable habitat for many at-risk species will likely contract under sea-level rise thus increasing interactions with cats. Beyond the issue of cats, it is important to consider other non-climate stressors when planning for climate change adaptation (e.g., pollution, human disturbance, invasive species, and loss of habitat from coastal development).

Tools for addressing uncertainty must be incorporated into adaption planning. Scenario planning is an important tool for addressing uncertainty by visualizing alternative futures. Without tools that address uncertainty, planning paralysis is inevitable. This project used scenarios in a way that was unique – identifying adaptation options along the trajectory of incremental sea level rise. Managers and other decision-makers without direct experience with climate change adaptation planning or climate change-based models (e.g. SLAMM) may require approaches that help them interpret possible alternative futures and how to contextualize impacts and generate adaptation solutions.

<u>We must focus more on what to do and less on when it will happen</u>. Traditional climate adaptation planning considers the time that events occur. For example, the IPCC AR5 models estimate SLR associated with the time from the present. Adding the element of time is often necessary because of planning horizons as required for example by land-use managers. We purposefully chose to remove the element of time from this project because we felt it reduced the distraction associated with the understandable focus on when specific changes will occur. In that respect, the intervals we selected could simultaneously be viewed as triggerpoints since those intervals represent when specific actions should be implemented.

<u>Barriers to implementing climate adaptation work must be identified and overcome</u>. When implementation of climate change adaptation has been attempted, it is often met with barriers that range from social to legal to economic to technical. Identifying, understanding, and overcoming these barriers will be an important step towards accomplishing climate change adaptation goals. Strategic approaches that identify and recognize barriers will be necessary to effectively overcome them in many cases.

<u>Agency missions, governance structures, and funding mechanisms need to be reviewed to ensure they are robust to changing conditions</u>. Agencies and their divisions need to review their missions to ensure that they are forward-looking rather than focused on resisting change. Effective adaptive management requires sufficient flexibility in governance structures. Rule-making and development of legislation must provide or support new and innovative approaches should conditions change. Additionally, adaptive management must be encouraged since current funding streams that are available for management are often one-time funds tied directly to specific goals and objectives with little flexibility should conditions change.

<u>Don't make assumptions about public tolerances for adaptation</u>. Without direct public input or human dimensions analyses, we should not assume what the public wants. Wildlife managers may have different perceptions and tolerances for adaptation actions than the public. Different stakeholders have different priorities, and these are often at odds with natural resource managers' priorities or understanding of other stakeholders' priorities. Therefore, we should not dismiss any action due to the assumption that the public will not approve or tolerate it.

<u>Effective adaptation implementation requires a comprehensive understanding of the motivations of people and adaptation approaches should seek to integrate these motivations</u>. Adaptation must be incorporated as components of managing the human landscape. For example, it is unlikely that the majority of society will place a higher value on wildlife than on human health; therefore, adaptation should consider integrating the priorities of multiple sectors into a holistic adaptation that benefits both wildlife and humans.

<u>Ethical considerations will play an important role in addressing vexing issues</u>. There are many tough ethical questions and decisions ahead: For example, when do you move a species outside of its historic range? When is extinction allowable? Is hybridization an acceptable outcome? When should assisted evolution be viewed as a viable adaptation approach? We must begin these difficult conversations now.

We must manage for change. Given the paradigm that recognizes that we have now entered the Anthropocene, we must manage our natural resources based in part upon the changes associated with that new epoch. Whereas maintaining or restoring conditions to previous states may be desirable, there must be a recognition that at some point, resistance is futile.

Project Team

Bob Glazer |Florida Fish and Wildlife Conservation Commission
Robert Glazer is a Research Scientist with the Florida Fish and Wildlife Conservation Commission where he serves as the Climate Change Research and Monitoring Workgroup leader. He also serves as the Chair of the Monroe County Climate Change Advisory Committee, a committee that is tasked with making recommendations to the Board of County Commissioners on adaptation options. He has served as co-PI with MIT for a project developing climate adaptation plans for species and habitats in the Florida Keys marine environment and served as PI on a number of marine climate adaptation planning projects. He participated in developing the National Fish, Wildlife and Plants Adaptation Strategy. In 1994 he received the first Florida Jaycees Outstanding Young Environmentalist Award, and in 2006 he received the Southeastern Association of Fish and Wildlife Agencies Fisheries Biologist of the Year award, both in recognition of his work to restore south Florida queen conch population. In 2016, he received an Honorable Mention for the Climate Adaptation Leadership Award sponsored by the National Fish, Wildlife, and Plant Climate Adaptation Strategy's Joint Implementation Working Group in the State/Local category. Since 2004, Bob has served as Executive Director of the non-profit Gulf and Caribbean Fisheries Institute.

Steve Traxler | U.S. Fish and Wildlife Service
Steve works for the US Fish and Wildlife Service as a Senior Fish and Wildlife Biologist. Steve has been working on Everglade's restoration since 1996. Since 2011, he has been coordinating science for the Peninsular Florida Landscape Conservation Cooperative. Steve's other projects include Everglades RECOVER (System wide evaluation, monitoring and adaptive management team) and climate change. Previously, he has worked on Everglade's restoration projects on the estuaries such as the Indian River Lagoon, Florida Bay, and Biscayne Bay. Steve also works with a local marine conservation non-profit focused on sea turtle research and education called Inwater Research Group, Inc. His degrees are from Florida Institute of Technology (Bachelors) and a Masters in fisheries from Texas A & M University. His main hobbies include fishing, scuba diving, canoeing, kayaking, and hiking.

Chris Bergh | The Nature Conservancy
Chris Bergh was raised in the Florida Keys and studied environmental conservation in Florida and Arizona prior to beginning a career that has run the gamut from nature preserve management to urban conservation strategy development. In 2005 he helped initiate the Florida Reef Resilience Program (FRRP), an interdisciplinary partnership among coral reef managers, scientists, other NGO's and businesses designed to help Florida's reefs and reef-dependent people cope with climate change impacts, and he has overseen the Conservancy's partnership-based coral reef restoration efforts. In 2013 he helped launch and now leads the Southeast Florida Regional Climate Change Compact's Shoreline Resilience Working Group which is focused on identifying opportunities for natural or nature-based coastal defenses for one of the United States' most vulnerable regions with respect to hurricanes and sea level rise. He led the Conservancy's early and ongoing work on sea level rise vulnerability analysis for the Florida Keys and is overseeing the development of on-line decision support tools that help people in the Keys and Southeast Florida's urban areas look beyond their vulnerability to the nature-based solutions for reducing that vulnerability. Chris serves on the Southeast Florida Regional Climate Change Compact's Staff Steering Committee.

Beth Stys | Florida Fish and Wildlife Conservation Commission
Beth Stys is a Research Administrator for the Florida Fish and Wildlife Conservation Commission. She has worked for the FWC for over 24 years. Her work with FWC has focused on landscape level, statewide conservation planning, imperiled species protection, terrestrial and freshwater aquatic conservation area identification and

prioritization, species habitat modeling, land cover mapping, and climate change. She is an instructor for the USFWS Climate Change Vulnerability Assessment and the Climate Smart Conservation classes. Beth is involved with all three Landscape Conservation Cooperatives in Florida, recently serving a 2-year term as Steering Committee Chair for the South Atlantic LCC and since August 2014, serving as co-Science Coordinator for the Peninsular Florida Landscape Conservation Cooperative.

Dr. Jason Evans | Stetson University
Dr. Jason M. Evans is Associate Professor of Environmental Science and Studies at Stetson University and Co-Editor-in-Chief for the Journal of Environmental Management. Trained as a landscape and systems ecologist, most of Evans's recent and current research focuses on sea-level rise and climate change adaptation in the southeast United States. He was the lead author for the Tybee Island Sea-Level Rise Adaptation Plan and the lead technical modeler for Monroe County's GreenKeys! Sustainability Action Plan, both of which have received national attention for innovation in climate change research, outreach, and policy development. Other communities in which he has advised on sea-level vulnerability and planning include Islamorada and Satellite Beach, FL; St. Marys, Glynn County, and Liberty County, GA; Beaufort, SC; and Nags Head and Hyde County, NC. Evans received his Ph.D. (2007) and M.S. (2002) in Interdisciplinary Ecology from the University of Florida. He also holds a B.A. (1998) in Philosophy from New College of Florida.

Logan Benedict | Florida Fish and Wildlife Conservation Commission
Logan is a climate adaptation biologist for the Florida Fish and Wildlife Conservation Commission, where his work has been focused on climate adaptation planning. Logan previously worked in Floodplain restoration ecology where he focused on long term shifts in species, and how they relate to environmental and biological stressors. His recent projects have focused on scenario planning related to managed lands and species in the northern gulf coast of Florida spanning from Hernando county to St. Marks county, and the terrestrial systems of the Florida Keys. Logan Benedict received his bachelor's degree in zoology at Southern Illinois University Carbondale, and his master's in biology at the University of Illinois Springfield.

Lily Swanbrow-Becker | Florida Fish and Wildlife Conservation Commission
Lily Swanbrow Becker joined the Florida Fish and Wildlife Conservation Commission as the Climate Adaptation Coordinator in December 2016. She enjoys her role of working with staff and a broad network of conservation partners in supporting climate research, communication, planning, and on-the-ground adaptation projects. Prior to joining Florida Fish and Wildlife, Lily worked in curriculum development at Florida State University where she developed educational texts, lesson plans and interactive tutorials focused on topics covering conservation ecology and climate change. She graduated from the University of Michigan with a degree in Environmental Science in 2005 and received her Master's in Conservation Biology from Texas State University in 2012.

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Additional Information:

A by-product resulting from this project is informational sheets on impacts of climate change to state listed or SGCN at each relevant interval of sea level rise. As a special bonus, David Allen Sibley of Sibley’s Guides is providing illustrations of each project bird for the purpose of raising awareness to climate-change impacts to birds. We hope that his illustrations and the project results will provide an esthetically pleasing and valuable informational tools.

We would also like to acknowledge that the least tern results from this project are currently being utilized to develop grant focused on the implementation of raised platforms in near coastal areas for nesting. These platforms were suggested during workshop 1 as a means to provide nesting availability above projected sea level rise, and to compensate for habitat lost due to human development and reduction of gravel rooftops that were currently being utilized as substitute nesting sites. Some of our stakeholder groups that participated in the workshops have also began to deploy this method of climate change adaptation within the Keys. It is our hope that more climate adaptation actions will be implemented as a result of the information generated in this project.

Appendices

APPENDIX I. WHAT CHANGES ARE YOU ALREADY SEEING?

- Shift in plant species composition in ecotone zones and hammock areas, even in salt tolerant species (N. Key Largo site) due to increased inundation – high tides
- Habitat loss, squeezing out
- Habitat shifts, beach loss – altered berm structure/habitat (long key)
- Shrinking berms and encroaching mangroves - in N. Key Largo
- Die-off of mangroves – hurricane damage/debris, storm surge, increased salinity
- Some mangroves areas damaged by storm are recruiting back to mangrove, damage will lead to younger stands of mangrove (loss of mature mangrove forests)
- Shifting sand (not sure how much or effects of shifts)
- Loss of sand (hurricane), other areas gained sand (accretion)
- Elliott Key (oceanside) – loss of wider sandy beaches, more mangroves (1980s – current)
- More mangroves now than in recent past
- Loggerhead (Louise Key – near Summerland) – berms shifted and increased in height – due to storms squeezing berms from both sides
- Buttonwood die-offs, reduced flushing – in ecotone areas (not storm related) (may have started in the 1990s due to previous mosquito ditching, but has continued)
- Thatch palms die-offs (lower keys) (not storm related)
- Joewood die-offs (very recently) salt water intrusion (lower keys and N. Key Largo)
- Loss of amphibian breeding habitat (Summerland and upper sugarloaf), wetland sites
- Data from 1980s, 90s, 2000s – shows changes in herbaceous species composition, also in tree species
- Disruption of hydrological flow (also due to human alterations)
- Sawgrass wetlands (FW) (Palatka skipper), buttonwood and other species showing up – may be due to lack of fire (change from past 5-7 years) (Big Pine and lower keys)
- Salt tolerant hardwood loss, shifting to mangrove (Chris Bergh's pine photo example) (over past 17 years)
- Spoonbill abandoning traditional sites, leaving keys, moving inland to nest, shifting timing - nesting later (due to altered wet season/dry season shifts) now nesting in S.C. (northern limit was historically Tampa/Merritt Island)
- Erosion leading to loss of Dry Tortugas island size, but some accretion has added back (Sooty tern, sea birds, Noddy, magnificent Frigatebird, masked booby, roseate tern)
- Shifts in plant phenology - plantation key, year-round reproduction rather than seasonal. could this be the plants "last gasp", putting all effort into reproduction?? (need monitoring?)
- White-crowned pigeon, could start moving north due to loss of habitat in keys due to storm damage, nesting on mangrove islands. (RZ)

APPENDIX II.SPECIES RESULTS

BIRDS

Bridled Tern

Breakout Exercise 1: Consequence Information

Currently only in the Dry Tortugas. 1st nesting occurred in Florida in 1988. Their former nesting ground was Pelican Shoal near Summerland, but it doesn't exist anymore. Attempted habitat enhancement in Dry Tortugas, hosted nesting for a few years. Nesting is currently spotty. Max was 8-12 nests. Currently not a management priority for FWC.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Not a management priority
- Could potentially enhance current habitat with "bird huts"

Breakout Exercise 3: Trigger Points and Monitoring

- No established trigger point now
- Observe global population trends, as they may be ok elsewhere
- Updated population surveys and trend analysis
- Determine sensitivity so sea level rise – how at risk are they? – Are FL populations areas "safest"?

Brown Noddy & Sooty Tern

Breakout Exercise 1: Consequence Information

Dry Tortugas show high coastal geomorphological dynamics. Require beach habitat

- 1 ft. Ocean beach habitat increases but may not be suitable for nesting. 2/3 loss of undeveloped dry land. Loss of nesting shrubs. While more habitat could be created elsewhere, increased SLR would impact that too.
- 2 ft. Only ~ 6 % of undeveloped dry land left.
- 3 ft. Habitat gone
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Building floating habitats with substrate and shrubby plant species for nesting
- Convert abandoned building rooftops for nesting with substrate and shrubby plant species
- Raise elevation of existing habitat to match rising seas
- Exotic rat control to remain a priority
- Prevent visitors to the Tortugas from feeding gulls. This has attracted more gulls, resulting in nest predation
- Closures to protect nesting grounds should continue
- Marine debris removal to continue

Breakout Exercise 3: Trigger Points and Monitoring

- Now: get data gaps filled – nesting success rates
- Most actions would occur within 1 ft of sea level rise
- If nesting success falls below a sustainable level (determined by data gaps), enact further actions
- Revaluate species on a global level- updated population surveys and risk analysis
- Use aerial imagery to track changes in islands
- There is current monitoring into colony size
- Study nesting success, recruitment rate, and sustainability

Great White Heron

Breakout Exercise 1: Consequence Information

Restricted to the Florida Keys. Controversy surrounding if it is the same spp. as Great Blue Heron. Nests on mangrove islands. Great blue herons nest all over Florida, but this subspecies/morph does not.

- 1 ft. 12% loss of mangroves in the Lower Keys. Some loss in habitat. Stable in the Upper Keys.
- 2 ft. More than 50% loss of mangroves in the Lower Keys. Significant loss of habitat. Some loss in Upper Keys. Foraging habitat may increase with more open water.
- 3 ft. Significant loss of mangroves, therefore nesting habitat. Unsure of response
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Plant more mangroves for nesting sites
- Ensure protection of shallow flats. Including future shallow flats, if any
- Seagrass restoration and protection would be beneficial to many species
- Plant seagrasses in newly inundated areas

Breakout Exercise 3: Trigger Points and Monitoring

- Trigger point unknown – will be tied to available foraging habitat as sea levels rise
- Re-establish surveys and nesting success studies
- Additional genetic data to determine if it is a color morph or a subspecies

Magnificent Frigatebird

Breakout Exercise 1: Consequence Information

The only nesting colony in Florida is on Long Key, Dry Tortugas. They need tress, and trees on islands are highly vulnerable to sea level rise. This species has capacity to fly long distances, but are only roosting in other counties, not nesting. This species has a high susceptibility to sea level rise.

- 1 ft. 2/3 loss of habitat
- 2 ft. Only ~ 6% of habitat left – potentially all trees lost
- 3 ft. All Dry Tortugas are gone
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Build artificial nesting trees in current nesting locations
- Build new islands and create artificial nesting habitat
- Reduce or prevent military overflight and human disturbance in the Marquesas
- Move rubble off mangroves that are hindering growth

Breakout Exercise 3: Trigger Points and Monitoring

- Start nesting and habitat enhancement before 50% loss of nesting trees
- Trigger points may have already been reached, research urgently needed
- Opportunistic surveys currently being performed
- Need updated population trends, nesting success, to determine how critical Florida is to species
- Research into why the left Marquesas & why attempts to lure them back are not successful

Mangrove Cuckoo

Breakout Exercise 1: Consequence Information

So long as mangroves are healthy, mangrove cuckoos should be ok

- 1 ft. Potentially ok
- 2 ft. Potentially ok
- 3 ft. This level may result in extensive loss of suitable habitat for mangrove cuckoos. Could potentially join the mainland populations of cuckoos on the peninsula
- 4 ft. Severely reduced

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Protecting existing and future mangrove areas
- Restore and plant mangroves

Breakout Exercise 3: Trigger Points and Monitoring

- Base trigger points off updated population surveys
- Triger point: reduction of mangrove cover is to too small of patch sizes
- More updated intensive population survey as part of mangrove land bird survey – determine population trends
- Determine mangrove patch size necessary for breeding and other habitat requirements for nesting

Masked Booby

Breakout Exercise 1: Consequence Information

Only one colony in Florida on Hospital Key in the Dry Tortugas. Requires sandy beach above the high tide line. Masked boobies are found elsewhere in the Caribbean and is adaptable. Could potentially leave and find suitable habitat elsewhere. However, Caribbean colonies are also subjected to SLR and would also see impacts. Would changes in habitat result in a net adverse impact on boobies?

- 1 ft. Increase in ocean beach habitat from 28.9 ac to 52.4 ac. Could be beneficial for boobies.
- 2 ft. Ocean beach is ~ same as 1 ft.
- 3 ft. All ocean beach is gone.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Enhance nesting habitat by adding substrate to a higher elevation
- Utilize bricks from Fort Jeff to increase elevation of Hospital Key
- Fill Garden Key with substrate – could be problematic given Sec. 106 of NHPA
- Build floating islands
- Consider translocation to new sites

Breakout Exercise 3: Trigger Points and Monitoring

- Trigger point may have already been reached
- Further trigger: 20% population reduction
- Opportunistic counts are performed currently
- Nesting success, breeding phenology, at Dry Tortugas is a research need
- Global population survey, population trends, to determine importance of FL populations – May require no action if secure in Caribbean

Reddish Egret & Roseate Spoonbill
Breakout Exercise 1: Consequence Information
Spoonbills have already started to move inland as a response to reduced foraging habitat, due to sea level rise. Group thinks reddish egret may move to higher elevations along coastal areas. They forage in mud flats • 1 ft. Potential for further radiation to mainland and higher elevation areas as sea levels rise. • 2 ft. “ • 3 ft. “ • 4 ft. “
Breakout Exercise 2: Adaptation Actions
Although birds might move, they may benefit from • May require no actions in the Keys, as they may radiate inland on their own
Breakout Exercise 3: Trigger Points and Monitoring
• Trigger points unknown – tied to available foraging habitat as sea levels rise • Need for updated distribution study, population counts, trends, nesting success

White-Crowned Pigeon

Breakout Exercise 1: Consequence Information

Other colonies in the Caribbean. May have higher adaptive capacity, and ability to radiate to new areas.

- 1 ft. Lower Keys nesting habitat significant loss. Pigeons may shift to other Keys, or north.
- 2 ft. Upper Keys nesting habitat reduced. Pigeons may shift to peninsula, where mangrove habitat is available. Everglades National Park possible.
- 3 ft. Most island nesting habitat gone. Birds will likely be relocated to Caribbean or peninsular Florida. Provided there is mangrove and proper forage habitat (poisonwood, etc.)
- 4 ft.

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Create nesting island with tropical hardwood hammock
- Restoration and creation of tropical hardwood hammock and habitat enhancement
- Remove Brazilian pepper and other exotics
- Prevent new development in tropical hardwood habitat and target it for conservation protections
- Maintain elevation of mangroves in large colonies of pigeons through added substrate

Breakout Exercise 3: Trigger Points and Monitoring

- 25% population loss in Florida should trigger adaptive management actions
- Need to look at global population trends
- Examine where in Florida they are foraging vs where they are nesting
- Further research to understand current distributions
- Examine if potential future areas optimal or suboptimal
- Long term monitoring of nesting success rates may help inform trigger points

Wilson's Plover

Breakout Exercise 1: Consequence Information

Already experiencing a downward population trend. Mostly found in transitional saltmarsh

- 1 ft. Habitat still there
- 2 ft. 2/3 loss of habitat
- 3 ft. Only ~ 7% of habitat left
- 4 ft. Potentially gone

Breakout Exercise 2: Adaptation Actions

Although birds might move, they may benefit from

- Can create nesting habitat by knocking down abandoned buildings in the Keys. Potential restoration site on Ocean Forest Estate.
- Reduce human disturbance at known nesting sites

Breakout Exercise 3: Trigger Points and Monitoring

- Trigger is low due to ground nesting – At or before 1ft. of SLR
- Updated population distribution, trends, and reproductive success
- Determine nesting threats and nesting habitat needs

Key Vaca and Key West Raccoon

Breakout Exercise 1: Consequence Information

Both are generalists with high adaptive capacity. If sea level rise pushes populations up the Keys, there will likely be genetic mixing. Low priority for management in face of sea level rise.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Low priority for management
- Could potentially benefit from actions taken for other species (e.g. Lower Keys cotton rat)
- Control of predators, such as pythons, would provide benefit to this and many other species
- If mangroves are protected, raccoons will likely be ok
- Will continue to benefit from human garbage, so long as humans occupy the Keys

Breakout Exercise 3: Trigger Points and Monitoring

- Will be determined by loss of mangrove- however, density of mangrove needed is unknown
- Track predators and rate of predation (i.e. pythons)
- 1ft. to 1.5 ft. of sea level rise would trigger need for action, if any
- Post -storm population survey, updated population surveys, distribution, and taxonomy work needed (Is it distinct from mainland)

Lower Keys Cotton Rat

Breakout Exercise 1: Consequence Information

Occupies pine rocklands and cattail marsh. This species depends on a healthy freshwater lens, and changes in hydrology would further impact this species

- 1 ft. Habitat reduced by 1/3. Already heavily impacted. Freshwater would likely increase in salinity with each interval.
- 2 ft. Almost all habitat impacted/submerged. Abandoned cats would pose a predatory threat.
- 3 ft. Only around 1/15th of undeveloped dry land and ~ 4% of freshwater wetland left.
- 4 ft. Natural habitat almost entirely gone. ~ 3% of undeveloped dry land, and 1% of freshwater wetlands.

Breakout Exercise 2: Adaptation Actions

- Translocation to mainland would cause hybridization, and therefore is not feasible/ideal
- Create or restore wetlands at higher elevations, using liners to prevent saltwater intrusion. Pumps for oxygenation. Could benefit many federal & state T&E species, and SGCN
- Captive breeding program
- Build uplands on elevated surfaces
- Improve upon existing hydrology and wetland plants. Such as, removing woody vegetation, exotic vegetation, and planting natives
- Acquire adjacent properties to current range
- Plug mosquito ditches
- Feral cat control

Breakout Exercise 3: Trigger Points and Monitoring

- Trigger at 1 to 1.5 ft. of SLR
- Population needs more monitoring
- Research into sensitivity to SLR and adaptive capacity
- Will shifting habitats make them more vulnerable to predation?

Pallas' Mastiff Bat

Breakout Exercise 1: Consequence Information

Recent colonist to the Florida Keys (Within the last 20 years). Exists in Caribbean and South America. For United States, only known to occur in the Keys thus far. All colonies seem to occupy structures and would not be directly impacted by SLR. Could be beneficial impacted by abandoned homes as sea levels rise.

Additional notes: Has a new common name, and potentially was introduced in 1929.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- No action needed

Breakout Exercise 3: Trigger Points and Monitoring

- Monitor for habitat use in FL Keys
- Monitor for spatial distribution, exposure risk, sensitivity, or adaptability

REPTILES

Overarching concept for REPTILES: Prioritize true endemic species for ex-situ adaptation actions. Address data gaps before populations are lost forever.

Florida Brown Snake & Keys Ringneck

Breakout Exercise 1: Consequence Information

Exists in non-mangrove uplands in the Lower Keys. Data deficient. Only one recent sighting of Florida brown snake on developed area on Big Pine Key. Ringneck like brown snake, but more sighting records. Needs freshwater.

Additional threats: New Guinea flatworm impacts snakes' prey. Cats may pose threat.

- 1 ft. Data deficient
- 2 ft. Major habitat reduction
- 3 ft. Further habitat reduction
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Acquire high ground sites for conservation
- Assisted migration to Upper Keys or Mainland possible
- Bring into captivity in zoos – husbandry may be difficult
- Manage existing habitat to increase resiliency (remove invasive species, predator control, prescribed fire)
- Smithsonian institution may be best for ex-situ. Captive populations could provide educational value and cultural heritage

Breakout Exercise 3: Trigger Points and Monitoring

- 1-2 ft. of SLR, reassess status of habitat, and explore ex-situ actions
- Now: Improve habitat and start tissue banking
- Need to continue monitoring

Florida Keys Mole Skink

Breakout Exercise 1: Consequence Information

Habitat on beach berms. Records exits for other habitats. Detection is difficult. Seemingly salt tolerant. Preliminary analysis supports that each island is a distinct population. Adapted to disturbance. Sea level rise and storm events may move or create new potential habitat. However, it is unclear if mole skinks will move with shifting habitat.

- 1 ft. Habitat impacted on Lower Keys. Upper Keys ok
- 2 ft. Further impact to Lower Keys habitat. Upper Keys ok
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Research is needed to address ability to move within beach berms & survival of storm impacts
- Berm re-nourishment
- Assisted berm habitat migration
- Ex-situ: Send live animals or genetic samples to the Smithsonian or other organization
- Strategic retreat: Buying out private landowners/rolling easements
- Enforcing existing land use regulations

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Buyouts and easements
- Storm events trigger berm actions
- Now: Research ability for skinks to move with berm
- Now: enforce current land use regulations

Peninsula Ribbon Snake

Breakout Exercise 1: Consequence Information

Associated with freshwater wetlands. Recently delisted by Florida Fish and Wildlife. More related to the panhandle species than the south Florida species.

- 1 ft. Would cause serious declines. Will persist a bit longer at central marsh on Big Pine.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Assisted migration to Upper Keys and mainland
- Captive populations possible, buy may not be practical
- Urgent need for restoration of freshwater resources
- Creation of artificial wetlands with liners

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Begin experimenting with artificial wetlands
- Determine sites for artificial wetlands
- Monitor salinity of freshwater wetlands

Red Rat Snake
Breakout Exercise 1: Consequence Information
Adaptable. Found across many habitats. Associated with people and altered landscapes. Morphologically like mainland populations. Poaching is a threat. Each interval of sea level will reduce habitat, but not eliminate. • 1 ft. • 2 ft. • 3 ft. • 4 ft.
Breakout Exercise 2: Adaptation Actions
• May not require action – will inhabit abandoned structures and human infrastructure • Continued predator control • Enforcement of current poaching laws
Breakout Exercise 3: Trigger Points and Monitoring
• No trigger points • No specific monitoring needs, as red rats are found as bycatch of other survey and research efforts

Rim Rock Crowned Snake

Breakout Exercise 1: Consequence Information

Like the Florida Brown Snake, except wider distribution. Includes Upper Keys and Mainland populations. Lower Keys population is data deficient, with very few surveys and records.

- 1 ft. Lower Keys population vulnerable
- 2 ft. Lower Keys population highly vulnerable
- 3 ft.
- 4 ft. Upper Keys population would likely persist

Breakout Exercise 2: Adaptation Actions

- Acquire high ground sites for conservation
- Assisted migration to Upper Keys or Mainland possible
- Bring into captivity in zoos – husbandry may be difficult
- Manage existing habitat to increase resiliency (remove invasive species, predator control, prescribed fire)
- Smithsonian institution may be best for ex-situ. Captive populations could provide educational value and cultural heritage

Breakout Exercise 3: Trigger Points and Monitoring

- 1-2 ft. of SLR, reassess status of habitat, and explore ex-situ actions
- Now: Improve habitat and start tissue banking
- Need to continue monitoring

Striped Mud Turtle

Breakout Exercise 1: Consequence Information

Freshwater dependent. Can tolerate a salinity of up to 6 parts per thousand. Lethal salinity = 17 parts per thousand.

- 1 ft. Most habitat eliminated
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Assisted migration to Upper Keys and mainland
- Captive populations possible, buy may not be practical
- Urgent need for restoration of freshwater resources
- Creation of artificial wetlands with liners

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Begin experimenting with artificial wetlands
- Determine sites for artificial wetlands
- Monitor salinity of freshwater wetlands

INVERTEBRATES

Big Pine and Short Winged Conehead Katydids

Breakout Exercise 1: Consequence Information

Very little is known. Only 3 Big Pine coneheads have been seen in recent decades. However, no surveys are being done. Likely dependent on uplands.

- 1 ft.
- 2 ft.
- 3 ft. Likely to greatly impact habitat
- 4 ft. Increased impact to habitat

Breakout Exercise 2: Adaptation Actions

- Address data deficiencies now
- Restoration and management of upland habitats

Breakout Exercise 3: Trigger Points and Monitoring

- Monitor for individuals using recording calls
- Now: address data gaps

Dingy Purplewing

Breakout Exercise 1: Consequence Information

Host plant is the gumbo limbo tree. Occupies hammocks in the Upper Keys. Threatened by mosquito spraying. Habitat will decrease at each interval, but will persist in some form up to 4 ft.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Promote planting of gumbo limbo tree
- Maintain genetic integrity of Keys plants
- Increase habitat resiliency of existing high hammocks – prioritize higher areas

Breakout Exercise 3: Trigger Points and Monitoring

- Now: fill data gaps – understand threats

Florida Purplewing

Breakout Exercise 1: Consequence Information

Host plant is crabwood. Known on Lingumvitae, Key Largo, and Windley Key. Habitat will reduce at each interval, but will persist in some form up to 4 ft. Threatened by mosquito spraying.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Make crabwood more available for private purchase
- Maintain genetic integrity of Keys plants
- Increase resiliency of existing high hammocks – prioritize higher areas
-

Breakout Exercise 3: Trigger Points and Monitoring

- Now: fill data gaps – understand threats

Florida Tree Snail

Breakout Exercise 1: Consequence Information

Hammocks in the Upper Keys will persist at 4 ft. of sea level rise. New Guinea flatworm is a major threat. Poaching remains a threat. Also threatened by mosquito spraying. RIFA

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft. Lower Keys hammocks gone

Breakout Exercise 2: Adaptation Actions

- Habitat management
- Predator control – eliminate the New Guinea flatworm
- Poaching needs to be addressed, as it remains an issue
- Potential re-listing due to new threats
- Create legislation to protect invertebrates that are not currently listed
- Propose listing for CITES

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Relist, prevent invertebrate sales, prevent take, and propose for CITES
- 1-2 ft. SLR. Lower and Middle Keys populations assisted migration – ex-situ
- Now: Research New Guinea flatworm
- Understanding reasons for color variations

Keys Scaly Cricket
Breakout Exercise 1: Consequence Information
Associated with wiregrass. Little is known about this species. • 1 ft. • 2 ft. Drastic decrease in habitat. • 3 ft. • 4 ft.
Breakout Exercise 2: Adaptation Actions
• Address data deficiencies now • Restoration and management of upland habitats
Breakout Exercise 3: Trigger Points and Monitoring
• Monitor for individuals using recording calls • Now: address data gaps

Palatka Skipper

Breakout Exercise 1: Consequence Information

Freshwater dependent. Larval host plant is sawgrass. Woody vegetation is encroaching on habitat. Threatened by mosquito spraying.

- 1 ft. Habitat potentially eliminated
- 2 ft. Habitat eliminated.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Create artificial freshwater wetlands with sawgrass planted. Factor in dynamic elevation (i.e. generate artificial wetlands on a slope
- Work with Monroe County to develop smaller wetlands
- Experiment with small scale wetland creation
- Acquire land on Boot Key and Big Torch
- Bank genetic material
- Address data gaps to better understand genetics

Breakout Exercise 3: Trigger Points and Monitoring

- Establish monitoring program for existing wetland projects
- Now: Explore artificial wetlands
- Now: Mechanical clearing of woody vegetation – follow with fire
- Collect genetic material

FISH

Key Silverside

Breakout Exercise 1: Consequence Information

Restricted to shallow salt ponds. Sea level rise could potentially increase habitat.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Natural migration within range is likely

Breakout Exercise 3: Trigger Points and Monitoring

- None

PLANTS

Bullsuckers

Breakout Exercise 1: Consequence Information

Two populations. Big Munsen and Big Pine Key. Threats of exotic plants and cactoblastis moth. Is a hybrid

- 1 ft. Serious impact
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Seed banking
- Ex-situ populations need to expand
- Address data gaps for pollinators – currently unknown
- Exclude Key deer from individuals
- Encourage public to plant on private lands

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Create ex-situ collections
- Clear hardwood at Long Key site
- Now: Research and monitor for cactoblastis moth – and pollinators

Keys Jumping Cactus

Breakout Exercise 1: Consequence Information

Endemic to Keys only. Long – Big Pine Key. Exists on coastal rock barrens. Persisted on Long Key after weeks long inundation. One population on Long Key is impacted by hydrological development. Crawl Key population is likely already lost. Threatened by exotic plants and cactoblastis moth.

- 1 ft. Impact on Big Pine Key population.
- 2 ft. Impact on Long Key population. Increased impact to Big Pine Key population.
- 3 ft. Increased impact on Long Key population
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Recommend for federal listing due to endemic status to the Keys
- Seed banking
- Ex-situ population need expanding
- Address pollinator data gaps – currently unknown
- Add to initiative for several other FL Keys cacti
- Encourage public to plant on private lands

Breakout Exercise 3: Trigger Points and Monitoring

-
- Now: Create ex-situ collections
- Now: List jumping cactus
- Clear hardwood at Long Key site
- Now: Research and monitor for cactoblastis moth – and pollinators

Yellow wood

Breakout Exercise 1: Consequence Information

Two populations (Bahia Honda and Marquesas). Also found in Caribbean Historically was found throughout the Lower Keys. 11 individuals remaining at Bahia Honda – post Hurricane Irma. Approximately 45 individuals on Marquesas, pre- Hurricane Wilma.

- 1 ft.
- 2 ft.
- 3 ft.
- 4 ft.

Breakout Exercise 2: Adaptation Actions

- Target coastal berms for planting in the Lower Keys
- Plant as a landscape plant
- Address pollinator data gaps

Breakout Exercise 3: Trigger Points and Monitoring

- Now: Protect current populations
- Explore federal listing
- Now: Research to understand pollinators
- Identify additional institutions other than Fairchild to work with yellow wood

APPENDIX III. WORKSHOP AGENDAS

Keys Terrestrial Climate Adaption Workshop 1

'Addressing Consequences and Determining Adaptation Actions for Threatened and Endangered Species in the Florida Keys'

State of Florida Office Building, Marathon, Florida

February 28th & March 1st, 2017

DRAFT AGENDA

Workshop Leader: Logan Benedict

Project Team: Bob Glazer, Steve Traxler, Chris Bergh, Jason Evans, & Beth Stys

Sponsors: US Fish and Wildlife Service, Florida Fish & Wildlife Conversation Commission, & The Nature Conservancy

Workshop Goal:

1. Using scenarios and other best available science, develop climate change adaptation strategies and actions for the terrestrial federally threatened and endangered species throughout the Florida Keys for agencies and other conservation interests to consider in their immediate and long-range planning efforts.

Workshop Objectives:

1. Determine area specific species impacts
2. Generate area specific potential adaptation actions

Items to review prior to meeting:

1. Agenda and definitions
2. Webinar PowerPoints
3. Species range maps

Tuesday February 28th, 2017

Arrive in time to be ready to start at 12:30 PM

Time	Agenda Topic	Process	Desired results
12:30	Welcome and Opening Statements	• Welcome • Introductions • Overall Projects Goals • Workshop Goals & Objectives • Meeting format and agenda review • Ground rules	Participants have been introduced and understand the meeting purpose and objectives. Participants have been informed about the overarching goals of the project.
1:00	Current State of Knowledge	• Climate research in the Keys	Participants up to speed on current information for climate change research in the Keys, and its future implications
1:20	What Changes Are You Seeing?	• Outline consequences of climate change in the Florida Keys (already observed)	Participants contribute their perspectives and experiences about changes on the landscape.
2:10	Climate Change Thresholds	• Review sea level thresholds • Present SLAMM maps • Present species distribution maps • Outline breakout groups	Participants knowledgeable on the sea level rise thresholds, and supportive

Time	Agenda Topic	Process	Desired results
			materials that will be used for exercises
2:30	Break		
2:40	Breakout Groups: Brainstorming Impacts to T&E Species & their habitats (2 groups: Vertebrates & Invertebrates/Plants)	• Determine impacts spatially • Determine Impacts at each SLR interval	Participants have outlined expected impacts to T&E species and habitats. Participants have outlined what impacts are expected to occur at each interval of SLR, and where they are expected to occur.
4:20	Exercise Report out	• Participants briefly share their current results • Questions	Groups have shared their results and any questions have been answered

Time	Agenda Topic	Process	Desired results
4:40	Wrap up and Day 2 preview	• Overview of day one • Preview day two • Housekeeping • Dinner plans	Any issues clarified, and participants prepped for following day.
5:00	Adjourn		

Wednesday March 1st, 2017

Time	Agenda Topic	Process	Desired results
8:30	Opening remarks and day 2 framework	• Welcome Back • Quick recap of day one • Day two objectives	Previous day reviewed. Participants are informed on activities for day two.
8:40	Breakout Groups: Brainstorming Impacts to T&E Species & their habitats (same 2 groups)	Resume exercise from previous evening • Determine impacts spatially • Determine Impacts at each SLR interval	Participants have reviewed their impact outputs and have added any additional thoughts

Time	Agenda Topic	Process	Desired results
9:10	Exercise Report Out	• Participants briefly share any changes or additions to their results from the day before • Questions	Groups have shared their results and any questions have been answered
9:30	Climate Adaptation	• Brief perspective on climate adaptation	Groups understand the importance of climate adaptation
9:30	Break Out Groups: Brainstorming Adaptation Actions	• Participants generate adaptation actions for each species, given the impacts outlined the day before.	Participants have generated adaptation actions for all T&E species, to account for all expected impacts at each sea level rise interval.
10:40	Break		
10:50	Break Out Groups: Brainstorming Adaptation Actions (Continued)	• Groups come back together and resume 9:30 exercise.	Participants have reviewed their actions, and have added any additional thoughts

Time	**Agenda Topic**	**Process**	**Desired results**
11:30	Exercise Report Out	• Participants briefly share results • Questions	Groups have shared their results and any questions have been answered
11:50	Wrap up & break for lunch		All participants back by 12:50 and ready to start by 1:00 pm
1:00	Break Out Groups: Brainstorming Trigger Points & Critical Monitoring	• Groups determine when the need to execute adaptation actions would be reached, & what information is needed to make decisions	Trigger points & monitoring outlined for all T&E species. Participants agree on what trigger points will be.
2:00	Break		
2:10	Break Out Groups: Brainstorming Trigger Points	• Groups come back together and resume 1:00 exercise	Participants have reviewed their trigger points & monitoring, and have added any additional thoughts

Time	Agenda Topic	Process	Desired results
2:50	Exercise Report Out	• Groups share their results • Questions	Groups have shared their results and any questions have been answered
3:10	Wrap up and Feedback	• Overview of workshop • Next steps • Next workshop time and focus • Feedback • Q&A	Decisions clarified, and participants informed about next steps. Workshop +/deltas captured
3:30	Adjourn		

Key Definitions:

Adaptation: Adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation.

Climate Change Consequence: Expected effects on natural or anthropogenic systems as a result of measurable climatic shifts.

Projection: In general usage, a projection can be regarded as any description of a variable at a given time in the future and the pathway leading to it.

Uncertainty: A lack of certainty or knowledge; a condition caused by having limited knowledge where it is impossible to exactly predict the value of a given variable.

Keys Terrestrial Climate Adaption Workshop 2

‘Moving Forward with Adaptation for State Listed and SGCN Species in the Florida Keys’

State of Florida Office Building, Marathon, Florida

May 1st, and 2nd, 2018

Project Goal:

To develop climate change adaptation strategies and actions for SGCN and their habitats threatened by climate change in the Florida Keys for agencies and NGOs to incorporate into their immediate and long-range planning and implementation efforts.

Workshop Objectives:

1. Determine which adaptation actions are priority
2. Discuss persistence management vs managing for change
3. Determine risks of area specific adaptation actions and inaction

4. Determine current barriers to implementing priority adaptation actions

Tuesday May 1st, 2018

Arrive in time to be ready to start at 12:30 PM

Time	Agenda Topic	Process	Desired results
12:30	Welcome and Opening Statements	• Welcome • Introductions • Overall Projects Goals • Workshop Goals & Objectives • Meeting format and agenda review • Ground rules	Participants have been informed of workshop purpose and objectives. Participants have been informed about the overarching goals of the project.
1:00	Climate Adaptation Planning Cycles	• Climate adaptation planning cycles, and how they apply to this project	Participants up to speed on climate adaptation planning cycles, and what part they will be executing

Time	Agenda Topic	Process	Desired results
1:20	Reviewing State Workshop 1, and Federal Project Results	• Species distribution maps • Results on sea level rise consequences, actions, trigger points, & monitoring needs • Review and ask questions of project team as needed	Participants knowledgeable on supportive materials that will be used for exercises
1:40	Breakout Groups: Determining Priority Actions for Project Species & Habitats (2-3 groups)	Participants will: • Outline species that would benefit from suite actions • Determine what actions need to be implemented now • Determine what are you doing already that needs small adjustments or augmentation	Participants have determined which actions need to be taken first for SGCN and state listed species and their habitats.
2:50	Break		
3:05	Breakout Groups: Determining priority actions for T&E Species & their habitats (2-3 groups)	• Resume 1:50 exercise	Participants have determined which actions need to be taken first for SGCN and state listed species and their habitats.
4:20	Exercise Report out	• Participants briefly share their current results • Questions	

Time	Agenda Topic	Process	Desired results
			Groups have shared their results and any questions have been answered
4:40	Wrap up and Day 2 preview	• Overview of day one • Preview day two • Housekeeping	Any issues clarified, and participants prepped for following day
5:00	Adjourn		

Wednesday May 2nd, 2018

Time	Agenda Topic	Process	Desired results
8:30	Opening remarks and day 2 framework	• Welcome Back • Quick recap of day one • Day two objectives	Previous day reviewed, and participants are informed on activities for day two.
8:35	Full Group: Managing for change vs Persistence	• Group discusses managing for change in habitats within the Florida Keys vs persistence o When do you switch from persistence to change?	Participants have outlined managing for change in the Florida Keys vs persistence, and some potential impacts of each style
10:00	Break		
10:15	Break Out Groups: Assessing Risk discussion	• Review actions evaluated for risk in federal project workshop 2 • Determine risks & costs of adaptation actions or inaction for state species • Which actions have highest potential payoff, and which are associated with the most risk?	Participants have outlined risks of action and inaction, highest risk and lowest risk actions, and the species who may be impacted.
11:30	Exercise Report Out	• Participants briefly share results • Questions	Groups have shared their results and any questions have been answered
11:50	Lunch Break		

Time	Agenda Topic	Process	Desired results
1:00	Full Group: Perceived Barriers to Implementing Climate Adaptation	• Group discusses what obstacles must be overcome to implement these priority actions	Participants have outlined their perceived barriers to implementation
2:30	Wrap up and Feedback	• Overview of workshop • Next steps • Next workshop time and focus • Feedback • Q&A	Decisions clarified, and participants informed about next steps. Workshop +/deltas captured
3:00	Adjourn		