Final Report Summary and Synthesis

Environmental Stressors and Priority Plant Communities on Jekyll Island, Georgia: Interacting Effects, Stakeholder Values, and Structured Decision Modeling

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TABLE OF CONTENTS

Summary and Synthesis Report

Table of Contents 1

About this Synthesis Report 2

Executive Summary 2

Key Concepts and Guiding Principles 3

Context and purpose of research program 3

Herbivores and forest regeneration 4

Our approach to generating management-relevant knowledge 5

Uncertainty, adaptive management and restoration 6

Leveraging Jekyll Island Authority support 7

Research contributors and collaborators 7

Research Highlights and Recommendations 9

Final Public Reports

Report 1: Spatial Study: Live Oaks, Laurel Oaks, and Environmental Stressors

Report 2: Exclosure Experiment: Effects Of Herbivory on Naturally Occurring Oak Seedlings, Planted Live Oak Seedlings, and Understory Vegetation

Report 3: Camera Trap Study: Wildlife activity and Protecting Newly Planted Live Oaks

Report 4: Camphor Study: Deer Herbivory and Exotic Camphor Trees

Report 5: Maritime Forest Workshop: Co-Producing Knowledge of Forest Ecology, Concerns, and Research Needs

Report 6: Structured Decision-Making: Participatory Maritime Live Oak Forest Restoration Planning

Report 7: Social Values Study: Social Values of Live Oaks on Jekyll Island

ABOUT THIS SYNTHESIS REPORT:

This synthesis report summarizes and synthesizes the rationale, findings, and recommendations from our research program. It has three parts.

- Section 1 is an executive summary of the research program.
- Section 2, "Key Concepts and Guiding Principles" explains the context and approaches that we took in our research. *We highly recommend reading it as a preface to the individual public final reports for each research study.*
- Section 3 contains brief highlights from each component study, with a synthesis of the management implications and recommendations.

1. EXECUTIVE SUMMARY:

MOTIVATION

This research program was undertaken to expand our knowledge regarding Jekyll Island's treasured Maritime Live Oak (MLO) forests. The MLO forests on Jekyll are unique, rare ecosystems, and they are valued dearly for their biodiversity and their aesthetic beauty alike. Their continued presence and health are a management priority, yet there is surprisingly little scientific information to help guide their conservation and restoration. Our aim was to supplement available knowledge to support forest stewardship.

SCOPE

As per our original proposal, the focal subject of our research was the status of tree populations and forest vegetation. To gain a more holistic perspective on forest dynamics, we conducted seven studies that investigated environmental stressors and ecological processes that shape these forests, and implications for forest stewardship decision-making (Figure 1). ***Our conclusions and recommendations focus on managing and restoring vegetation*** in light of multiple environmental stressors and visitor/resident perceptions. While wildlife herbivory and was studied as a potential stressor on vegetation, ***that perspective on wildlife is very one-dimensional, thus the findings on their own are insufficient to fully inform the management of deer or other wildlife***.

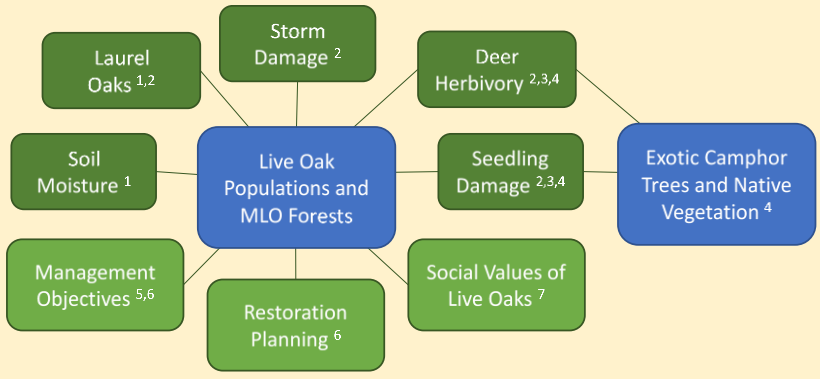

Figure 1: Scope of research program. Blue boxes are focal species and ecosystems studied. Dark green boxes are ecological factors; light green boxes are social-ecological factors. Superscript numbers refer to component studies that address each factor.

KEY FINDINGS AND RECOMMENDATIONS

***Conserving MLO Forests**:* Our studies found that there are currently very few live oak seedling and saplings, but a plethora of young laurel oaks in the MLO forest on the north end of Jekyll. It remains unclear whether, and to what extent, deer are contributing to that low abundance. Regardless of cause, this raises concern that laurel oaks, not live oaks, will ascend to the canopy in current and future light gaps, thereby changing forest composition. We do not know for certain that current conditions would result in such a long-term change, but as a proactive measure, we recommend planting young live oaks to ensure that there are young trees in forests to replace mature trees over time.

Proactive restoration planning: Jekyll Island Authority's conservation objectives include the maintenance of live oaks as dominant overstory trees in MLO forests. Proactive restoration via planting live oak seedlings is an appropriate strategy to meet that objective. Planted seedlings should be protected from small and large mammal herbivores to increase their survival probability. The costs and benefits of other possible manipulations, including clearing surrounding vegetation, are being explored through a decision support tool.

Invasive camphor: In a mixed hardwood forest with invasive camphor, the exclusion of deer appears to benefit native understory vegetation as well as camphor seedling growth. The study was only two years long, so our conclusions are tentative. But it appears that deer exclusion alone may not control camphor proliferation.

***Social values**:* In studying residents' and visitors' social values associated with live oaks, we found that actively engaging in tree stewardship, and enhancing opportunities to learn about and admire live oak trees, would reinforce existing social values and likely build public support for forest conservation and restoration initiatives.

2. KEY CONCEPTS AND GUIDING PRINCIPLES

Context and purpose of research program

Maritime forests on Jekyll Island, like many of Coastal Georgia's ecosystems, are facing a multitude of environmental stresses. Sea level rise, climate change, altered hydrology, fire suppression, invasive species, and altered wildlife abundances can all affect the dynamics of vegetation communities. Jekyll Island's maritime forest communities are globally rare, unique to barrier islands, foundational to the island's ecological health, and cherished for their aesthetic and recreational values. This creates a strong impetus for conserving the integrity of these forests.

Yet, there is surprisingly little scientific information on the functioning of these ecosystems, which can be used to inform conservation. Jekyll Island Authority recognized the need for scientific research, and offered a competitive grant to sponsor research to

investigate the effects of environmental stressors, including deer herbivory, on the island's ecosystems.

As recipients of the research grant, our four-year research program addressed a number of key ecological and management concerns regarding the present and future status of the island's prized maritime forests. The value and implications of this research extend far beyond Jekyll, and are highly relevant for conserving natural areas all along Georgia's coast. We were able to leverage Jekyll Island's forward-thinking funding initiative to secure additional grants, which we used to extend studies on three other barrier islands, and to engage a broader community of land stewards and stakeholders to assess research priorities, management objectives and strategies.

Herbivores and forest regeneration

On Jekyll Island, managers have noticed very few naturally occurring live oak seedlings or saplings in the island's iconic Maritime Live Oak (MLO) forests. The implications of this trend for the future of MLO forests is a key conservation and management concern, not only on Jekyll, but on other Georgia barrier islands that have also observed very few juvenile live oaks. .

In forest ecology, ***regeneration*** occurs when young trees establish, survive and grow, then reach the canopy to replace mature trees that are lost from the canopy.

It is widely recognized that herbivory by white-tailed deer (*Odocoileus virginianus*) can influence recruitment – i.e., the establishment, growth, and survival of young oak trees – by consuming acorns or by browsing on seedlings and saplings. And Jekyll Island's large deer population is almost as iconic as its magnificent live oaks. This naturally leads one to wonder: Are deer contributing to the observed scarcity of young live oaks? This question, however, is only one part of the puzzle that ecologists and land stewards ultimately seek to solve. **The ultimate questions of concern are not just whether deer eat live oaks, but are instead**:

- What are the longer-term consequences of herbivory on the live oak tree populations, and on the composition of the forest ecosystem?
- Are the levels of deer herbivory expected to impede the process of MLO forest regeneration?
- What other environmental factors may be limiting live oak recruitment and regeneration?
- How important are the effects of deer herbivory relative to other factors?
- Based on our emerging knowledge and remaining uncertainties, what are the likely outcomes of different forest management actions?

The challenge is to scale up from the specific effects of herbivores on individual trees to understand their cumulative consequences alongside other limiting factors. These ecological relationships are highly complex. For example, the impact of one factor, like

deer browsing pressure, will often depend on other factors, like light availability and competition with other plants. As naturalist John Muir wrote, "*When we try to pick out anything by itself, we find it hitched to everything else in the Universe*." It requires multiple research questions and methodologies to follow and understand the many threads of these intertwined relationships. Because interactions occur on many timescales, from days to decades, and they cannot be readily understood in a short period of time. The portfolio of projects described in the following reports represent our team's ongoing efforts to begin disentangling these threads.

Our approach to generating management-relevant knowledge

Quite surprisingly, there was very little existing research on MLO forest dynamics for us to build upon. Therefore we have worked closely with the Jekyll Island Authority (JIA) Conservation Program staff in choosing research questions to address, and we have sought insights from forest managers and stewards all along the Georgia coast to target our studies in response to management-driven questions and information needs. While we have sought to address management-relevant research questions, our team has derived its scientific findings and conclusions independently. This is important not only for scientific legitimacy, but also because the knowledge generated will be useful and relevant for MLO forest management beyond Jekyll Island, where different land stewards have different management priorities and visions. They need to be able to use our findings to help them work toward their own management and conservation goals. We have not interpreted or filtered our scientific findings in order to lend support to any stakeholder's management preferences or conservation goals.

In our research team's approach to generating management-relevant knowledge about forests, the first aim is to use research to understand ecological processes, i.e., what is happening, and what is likely to happen. The second aim is to share our findings with stakeholders, so that they can appreciate how different actions will likely lead to different outcomes. The third aim is to understand stakeholders' objectives – the things they want to happen – so that we can help them evaluate the extent to which different management decisions are likely to lead to the outcomes they wish to achieve. This process is generally referred to as "decision support." It means that scientists help stakeholders and decision-makers evaluate their options, whatever their objectives may be. Management objectives reflect people's values and priorities. When there are multiple stakeholders with different objectives, there may be no single plan of action that will fully satisfy all objectives. Decision support helps stakeholders and decision-makers understand the inherent tradeoffs. Decision support does not mean that we help stakeholders justify their objectives, or that we judge which objectives are more important than others.

It is also important to recognize that the scope of management implications from our work is not all-encompassing. ***The primary subject of our work is the status of tree populations and vegetation communities in maritime forests***. We evaluate ecological dynamics, multiple management objectives, and stakeholder values as they relate to

outcomes for the plant communities themselves. In doing so, we explore the drivers that affect plant communities, such as effects of herbivores or groundwater availability. However, we *did not* attempt to evaluate all the ecology, objectives, and values surrounding those driving factors. For example, we evaluated wildlife and hydrology drivers, and different stakeholders' values, as they relate to trees and forest communities. But we did not explore a fuller range of ecological dynamics or values around wildlife management or hydrological changes. The findings from our work provide multi-faced information to help achieve forest management objectives. But because of our vegetation-focused scope, ***the findings, taken on their own, are not intended to provide multi-faceted decision support on wildlife, hydrological, or other management issues***.

Uncertainty, adaptive management, and restoration

Even as we draw conclusions from the research conducted thus far, there is still considerable uncertainty that must be acknowledged as we interpret the management implications of our findings in light of JIA's ecological management objectives. We have observed that the JIA Conservation Program has two key strengths for the navigating the challenge of ecological management in the face of large uncertainties.

First, their emphasis on research and extensive ecological monitoring gives them great capacity for adaptive management. Adaptive management is a cyclical, research-like approach to managing and conserving natural resources. Actions are taken based on hypotheses regarding outcomes. Often, different actions are taken simultaneously and compared as a real-time experiment to better understand the how the ecosystem works. The outcomes are monitored and data analyzed to test hypotheses and update knowledge about how the ecosystem responds to management. Management practices are also updated according to new knowledge. Working with MLO forests, this is an invaluable approach to both building knowledge, improving outcomes, and to avoid persisting with an ineffective management plan – all of which are very important when managing systems with largely unknown ecological dynamics.

Second, the Conservation Program's approach toward MLO forest conservation tends to reflect the "Precautionary Principle" concept from the field of conservation biology, which is advocated in many international conservation agreements today. Often, we lack the detailed ecological knowledge necessary to know just how endangered a species or an ecosystem may be. But if we wait until enough knowledge is available, it may be too late or much more expensive to take appropriate action. In such cases, forward-looking proactive conservation measures are therefore favored as a bet-hedging strategy against irreversible or very expensive losses that might occur if no action is taken presently. Given that there is still much uncertainty regarding the future implications of low live oak recruitment, the Precautionary Principle is a reasonable approach for MLO forest management, in pursuit of the JIA Conservation Strategy's mission to "p*reserve, maintain, manage, and restore Jekyll Island's natural communities and species diversity while providing nature-based educational and recreational opportunities for the general public" (JIA Conservation Plan, 2011).* We do know that the canopy trees cannot be replaced in

the short-term future if there are no seedlings or saplings in the understory. Thus the Precautionary Principle favors restoration actions to establish some seedlings and saplings in existing MLO forests. JIA Conservation managers have expressed interest in evaluating management alternatives for doing so.

In the face of uncertain ecological dynamics and uncertain future environmental conditions, Precautionary Principle management coupled with adaptive management are considered best practices for the objectives of reducing risks and sustainably conserving biodiversity. The JIA Conservation Program is well-positioned to implement this approach. Thus, we have directed several research activities toward generating knowledge about live oak restoration options, which can be incorporated into adaptive management.

Leveraging Jekyll Island Authority support

Our research aims not only to provide management relevant information to Jekyll Island, but also to make broader impacts in Georgia coastal ecosystem management, conservation, and decision science. To extend the impact and scope of the JIA sponsored research, we secured additional funding from a NOAA/Georgia DNR Coastal Incentive Grant (CIG) to conduct parallel studies of multiple stressors in MLO forests on three other Georgia barrier islands, and to extend the studies of multiple stakeholder perspectives to a broader range of coastal stewards, and to generate a decision-support tool with applicability to Jekyll Island and beyond. Sponsorship of this work positions Jekyll Island at the frontier of innovation in decision science, which we continue to showcase at regional, national, and international scientific conferences.

Research contributors and collaborators

The original proposal sought to support a single PhD student to collaborate with the Principal Investigators, and proposed a significantly narrower research program. By leveraging additional sources of support through the Warnell School at UGA and the above-mentioned CIG grant, we were able to engage a larger team of collaborators to conduct a broader suite of studies. The grant from JIA helped support three doctoral students, one undergraduate student, and two employees, whose contributions (and sources of guidance) we outline below.

Hannah Morris is a doctoral candidate in Warnell and the Integrative Conservation PhD program, advised by Dr. Elizabeth King (UGA Faculty). She was chiefly responsible for the deer Exclosure Experiment in the MLO forest – in charge of fence construction, vegetation monitoring, the planting of hundreds of live oak seedlings, and recruiting and overseeing numerous teams of volunteers to assist with research activities. She also co-wrote the CIG grant, and was in charge of replicating the Exclosure Experiment on three other islands, which greatly enhances the broader importance of the knowledge we generate at Jekyll. Hannah was instrumental in conceptualizing, organizing, and facilitating the

Maritime Forest Workshop. She also undertook a substantial portion of the analysis of the Spatial Study data, with guidance from Dr. Nate Nibbelink (UGA Faculty).

Figure 2: UGA students who have been key contributors, with primary responsibility for different facets of the research program.

Dessa Dunn is a doctoral student in the Odum School of Ecology, advised by King (UGA Faculty). Dessa was responsible for the Camphor Study, including exclosure installation, all tracking of camphor seedlings and vegetation monitoring, recruitment and supervision of volunteers, and data analysis. Dessa is also leading the data synthesis, interviews to elicit expert knowledge, and model construction for the Structured Decision-Making Study, with guidance from Dr. Clint Moore (UGA Faculty). Additionally, she conducted vegetation monitoring for the Exclosure Experiment.

Kentrell Richardson is an undergraduate wildlife major in Warnell, who was responsible for the Camera Trap Study. He helped design the study, install the wildlife cameras, and analyzed the data with guidance from Nibbelink (UGA faculty) and Joseph Colbert (JIA Conservation Program).

Sarah Horsley is a doctoral candidate in Warnell and the Integrative Conservation PhD program, advised by Dr. Gary Green (UGA Faculty). She conducted the Social Values Study, bringing a stakeholder-focused perspective to the research program and generating new insights into social dimensions of live oak stewardship. This was one component of her dissertation, which examines sea turtles and live oaks as iconic species on Jekyll Island.

Ruth Cumberland worked as our research coordinator, managing and conducting a vast amount of fieldwork, data entry, and data management for Jekyll Island as well as the other islands covered by the CIG grant. **Emily Laske** also contributed as a research technician to fieldwork, GIS analysis, and data management. Both brought considerable prior experience with large-scale vegetation monitoring projects to improve data quality, efficiency, and our team's overall data handling and analyses.

Ben Carswell, **Joseph Colbert**, and **Yank Moore**, of the JIA Conservation Program, were invaluable collaborators throughout the study. They facilitated project logistics, provided site access, and helped us recruit volunteers for numerous data collection episodes.

Dozens of land managers, researchers, and concerned stakeholders helped to establish the context, starting knowledge, and salient research questions through individual conversations, interviews and workshops. See Report 5: Maritime Forest Workshop for list of collaborators and the outcomes of their insightful inputs.

3. RESEARCH HIGHLIGHTS AND RECOMMENDATIONS

Our research activities are summarized in seven public final reports, which follow this summary and synthesis. Below, we give a brief snapshot of each study's findings.

1. Spatial Study: Live Oaks, Laurel Oaks, and Environmental Stressors

- Elevation gradients affect the distribution of mature live oaks and laurel oaks.
  - Live oaks dominate lower, wetter sites
  - Both species are co-dominant at higher sites.
  - This is thought to be a response to differences in soil moisture
- Live oak seedlings were very rare.
- Laurel oak seedlings were common, and were present in low elevation zones.
- Without young live oak, laurel oaks could become more dominant over time.
- We do not know whether they would be able to dominate low elevations.

❖ **Given the trends, we recommend proactive management: planting seedlings of live oaks in MLO forests that lack young trees.**

2. Exclosure Experiment: Effects Of Herbivory on Naturally Occurring Oak Seedlings, Planted Live Oak Seedlings, and Understory Vegetation

- During the study period, understory vegetation varied dramatically with time.
  - Major storms altered the canopy and light conditions.
  - Vegetation fluctuations were probably responses to light.
- Against the background of substantial variability, we were unable to detect effects of deer exclusion on understory vegetation or naturally-occurring seedlings.
  - This doesn't mean that deer have no effects. It only means we weren't able to detect them under the conditions of the experiment.
  - The question of the whether deer have an influence on forest composition remains unanswered.
- Planted live oak seedlings were unexpectedly killed by small mammals.
  - We learned that small mammals may be a problem in restoration.
  - Other islands, with sparser and less variable vegetation, did detect deer effects on planted seedlings.

❖ **Given the high variability in time and space, quantifying deer impacts on Jekyll may take much longer than four years.**

❖ **Storm damage and light gaps may create windows of opportunity to steer forest regeneration through adaptive management.**

3. Camera Trap Study: Wildlife activity and Protecting Newly Planted Live Oaks

- We used wildlife cameras ("camera traps") in a two-phase study to determine that squirrels were destroying planted live oak seedlings.
- Squirrels consume the swollen bulb on the roots of acorn-grown seedlings.
- Wire cages were effective in preventing squirrel damage.
- **Protection from small mammals is recommended if seedlings are planted for restoration work.**

4. Camphor Study: Deer Herbivory and Exotic Camphor Trees

- The exotic camphor tree is becoming more invasive in forests near the center of Jekyll Island.
- We used deer exclosures to examine whether deer influenced camphor seedlings and other understory vegetation.
- Excluding deer benefitted native understory vegetation, but it also benefitted camphor seedlings.
- **Because the study was very short-term, we do not know whether deer exclusion would be effective to help control camphor proliferation in the long run.**

5. Maritime Forest Workshop: Co-Producing Knowledge of Forest Ecology, Concerns, and Research Needs

- Each barrier island, including Jekyll, has different visions, concerns, and management objectives for maritime forests.
- Jekyll's objectives favor active management and live oak restoration in the face of uncertainty about forest regeneration
- **Adaptive management and structured decision-making are recommended to effectively navigate uncertainty and multiple management objectives.**
- **Jekyll's concerns regarding fire present key knowledge gaps and priorities for future research.**

6. Structured Decision-Making: Participatory Maritime Live Oak Forest Restoration Planning

- Herbivory, light availability, and competition are key conditions affecting seedling growth and survival when planting live oaks for restoration.
- These conditions can be manipulated in restoration planting strategies.
- We are building a transition matrix model to simulate their combined effects so that restoration success rates can be projected.
- Incorporating the time and labor costs of alternative planting strategies will allow the model to be used to identify optimal strategies for a given budget or success criterion.
- **We will work through model simulations with JIA Conservation personnel to support restoration decision-making.**

7. Social Values Study: Social Values of Live Oaks on Jekyll Island

- Jekyll Island residents and visitors identified live oak trees as the island's 2nd most iconic species, after sea turtles.
- As iconic species, live oaks represent a source of psychological and social empowerment for residents.
- Live oak trees were not key reasons why tourists visited Jekyll Island, but they did influence decisions to return and recommend Jekyll to others.
- **To reinforce residents' affinities for live oaks, we recommend creating opportunities to participate in stewardship and ensuring that development is sensitive to preserving live oaks.**
- **To enhance visitors' positive experiences with live oaks, we recommend greater use of live oaks in marketing and promoting access to view and admire trees in forested settings.**