ANNUAL REPORT 2016-2017

Environmental Stressors and Priority Plant Communities on Jekyll Island, Georgia:

Interacting Effects, Stakeholder Values, and Structured Decision Modeling

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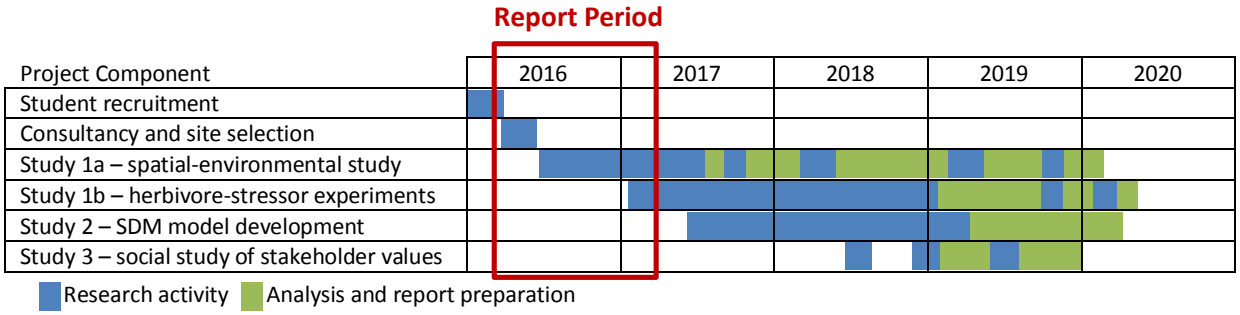
SUMMARY

Natural areas 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, and highly regarded for their aesthetic and recreational values. This creates a strong impetus for conserving the integrity of these forests. Our four-year study investigates the effects of multiple stressors on the dynamics of Jekyll Island's maritime forests.

The overall research plan includes three suites of Research Studies:

1) Investigate the effects of multiple stressors on vegetation structure and dynamics using (a) tree spatial-environmental correlations, and (b) experimental manipulations of herbivores and stressors;
2) Integrate field and existing data on expected management outcomes into a decision support framework; and
3) Evaluate stakeholder attitudes toward management options.



According to the project timeline, Year 1 activities (April 2016-March 2017) are focused on Project Initiation and Implementation of Research Study 1. We are on schedule with the proposed activities. Below are key progress elements. The subsequent sections of the report elaborate on each element.

Project Initiation

- **Site selection**: We conducted repeated field visits and selected two appropriate research sites: one in the maritime live oak forest on the north end of the island, and one in a live oak-sand live oak hammock on the south end of the island.
- **Scientific advisory committee** for the project was formed, and held an initial meeting to get input and guidance on research plans.
- **Student recruitment**: 1 PhD student and 2 Masters students, who will all contribute to the research.
- **Full-time technician** hired to accelerate the pace and extent of data collection.

Implementation of Research Study 1

- **Study 1a: the spatial-environmental study**. We designed the study and measurement protocol for the northern site, and data collection is currently underway. Adaptation of the research protocol for the southern site is currently in the planning and trial measurement phase.
- **Study 1b: the deer-stressor experiments**. We designed the experiment, and have set up 16 deer exclosures, and 16 non-fenced comparison plots, in the northern field site. Initial vegetation monitoring and application of experimental treatments is underway.
- **We applied for 3 additional grants** to leverage JIA's investment in interdisciplinary coastal conservation research, which would extend the study to 3 other Georgia barrier islands.

PROJECT INITIATION

♦ RESEARCH SITE SELECTION

Maritime live oak forest on Jekyll Island

In our initial proposal, we outlined a flexible research plan that could be implemented in freshwater wetland forests, upland forests, or both. In Summer 2016, we recognized that time, budget, and labor constraints would only allow us to do thorough, meaningful research in one study ecosystem. ***The research is focused on live oak maritime forests***: the most iconic and dominant forest type on Jekyll Island, a globally rare ecosystem, and a system that faces multiple environmental stressors that may threaten its future persistence. Oak regeneration failure is a major concern not only in maritime forests, but has been a challenge in numerous oak woodlands and forests around the world. Understanding the role of multiple stressors in shaping the future of these forests is a topic of very broad significance in environmental conservation and sustainability.

♦ SCIENTIFIC ADVISORY COMMITTEE

We assembled a scientific advisory committee for the project, with two main roles: to provide useful insights and guidance during the development of the research design during the initiation phase, and to participate in the process of developing the ecological foundations and key relationships that will be used in the decision-making framework. The advisory committee will be reconvened in Fall 2017 to review progress to date and plan ahead for Research Studies 2 and 3.

The panel includes:

Dr. Keith Bradley, Botanist
Ben Carswell, Conservation Director, Jekyll Island Authority
Dr. Gino D'Angelo, Deer Management, Assistant Professor at UGA Warnell
Christa Hayes, Coastal Ecologist
Dr. David Kaplan, Ecohydrologist, Associate Professor at University of Florida
Eamonn Leonard, Biologist, GA DNR
Jacob Thompson, Biologist, GA DNR

♦ STUDENT RECRUITMENT

Our initial proposal was to recruit a student through UGA's Integrative Conservation (ICON) PhD program to conduct the majority of the research. We did recruit a highly-qualified, competent student, who started in August 2016. However, by December 2016 it had become clear that his interests and

commitment were not aligned with the project, and he left the PhD program. Despite careful screening, in-person interviews, and convincing credentials, such regrettable circumstances do occur. But fortuitously, this initial setback has actually led to a strengthening of the research team, and also a shift in research focus that we believe will increase our work's applicability to Jekyll Island and to barrier island habitat conservation more broadly.

There is now one PhD student and one MS student actively working on the project, and another MS student recruited to begin in Fall 2017.

- *Hannah Morris, Warnell-ICON PhD student*. Hannah is in her second year of study, under PI King's advisement, and has been working on very similar research questions regarding herbivory, multiple stressors, and past, present, and future forest composition on St. Catherines Island. Hannah seized the opportunity of the previous student's departure to engage with the Jekyll Island project, and has taken a strong leadership role since January 2017. She will conduct parallel research (Research Study 1) on both Jekyll and St. Catherines as the basis of her PhD in coastal forest conservation and restoration. She will also be the lead student on Research Study 3, evaluating stakeholder perceptions and narratives regarding forest conditions.

- *Joseph Hansen, Warnell MS Student*. Joseph was recruited by PI King in January 2017. He brings an impressive background and aptitude in the field of forest restoration. He is collaborating on Research Question 1, particularly addressing stressors on forest regeneration that are associated with fire suppression. He will also perform studies regarding the ecology of fuel loads in maritime forests that are additional to, and complementary to, the original scope of research proposed.

- *Dessa Dunn, Ecology MS Student*. Dessa will begin in Fall 2017. Her interest is in forest restoration from the perspective of ecosystem services. Her work will be based on Jekyll Island and also in Athens, GA. She will contribute to the Jekyll stressors project by considering how different management and restoration strategies generate different portfolios of ecosystem services – the benefits that maritime forest structure and function provide to humans and to their own sustainability. This is also an addition to the original scope of the proposed research, and will help contextualize and generalize the findings of our ecological research and our social science research components.

♦ FIELD TECHNICIAN

We have also hired an experienced, full-time technician, Ruth Cumberland, to help execute the research plan, engage with JIA staff, and help recruit and manage volunteer and outreach activities. Ruth has an excellent background in forest ecology monitoring research and outreach. Not only is she contributing to the execution of the research plans, she is contributing intellectually to the project by helping refine and expand the research protocols. This experience will prepare her well for embarking on a MS in Forestry at Mississippi State University in Fall 2017.

IMPLEMENTATION OF RESEARCH STUDY 1

♦ STUDY 1A: SPATIAL-ENVIRONMENTAL STUDY OF FOREST COMMUNITIES

The first research activity we began is a **spatial-environmental study of plant community response to stressors**. The basic idea is to look at the spatial patterns of environmental conditions, then map the locations of (a) all individual mature trees, and (b) the density of seedlings and saplings, of different tree species. We can then determine whether seedlings are occurring in the same or different locations relative to the parental generation of trees, and the environmental conditions associated with observed distributions. The goal of Study 1a is to use a suite of spatio-temporal analyses to generate correlative trends of plant species distributions and environmental variables, from which we can infer the relative contributions of different underlying drivers and regulators that affect oak regeneration and forest composition.

Experimental Design

The northern field site is in the maritime forest between Horton House and Horton Pond. In January 2017, we established two large "macro-plots," each 100x200m, at the site. Both macro-plots span an elevation gradient and have variable densities of canopy tree species. The experimental protocol is to measure all individual oaks taller than 1.5m, and all other tree species that are larger than 10cm in diameter. The next step is to quantify seedling densities for all species of oaks throughout the macro-plots. Since there are too many seedlings (almost all laurel oak) to count individually, we will use a stratified subsampling strategy for seedling quantification. Additionally, we will map canopy closure and soil moisture throughout the macro-plots, using hemispherical photography and EMI soil conductivity measurements, respectively.

Figure 1: Macro-plot locations in the northern study site. Plot numbers refer to pairs of fenced and unfenced 10x10m herbivore plots.

Data Collection

Tree and seedling mapping began in mid-March 2017, and is expected to be completed by late-May. We have also begun trials of the canopy closure protocol. The upward-oriented hemispherical photographs require analysis with special software to calculate canopy gap fraction. Analysis of our trial data collections will inform the final choice of spacing pattern of photo points for the full study. We are consulting with two other scientists to gain more information about the special concerns for conducting EMI soil moisture surveys in this kind of environment, and will continue to work on establishing a feasible and robust protocol for that work.

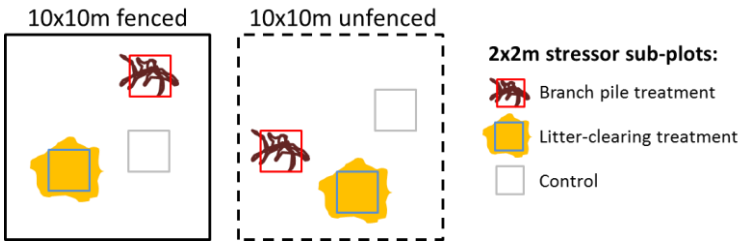
In March 2017, we also conducted preliminary assessment of tree species distributions at the southern island site, which is just north of the soccer field complex. We are in the process of developing a modification of our spatial-

environment measurement protocol to suit the distinctive landscape patterning at that site. The field measurements will be conducted during June and July 2017.

♦ STUDY 1B: DEER-STRESSOR EXPERIMENTAL STUDY

The second research activity we began is the **deer-stressor experimental study**. The basic idea here is to experimentally manipulate environmental conditions to cause or simulate three different stressor factors: deer herbivory, storm damage, and litter density. These factors can affect acorn survival, seedling survival, and seedling growth. Furthermore, because different oak species have different environmental tolerances and ecological interactions, response to factors may differ by oak species.

Figure 2: Schematic of 10x10m herbivore plot pair with 2x2m stressor sub-plot treatments.



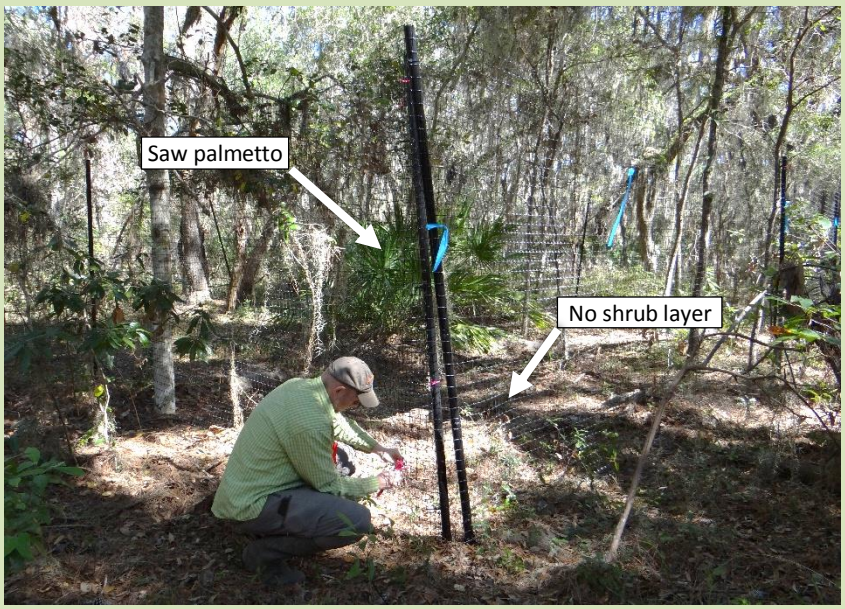
Experimental Design

Within the macro-plots, we established 16 deer exclosures (8 per macro-plot), which are 10x10m in area, and 2.4m tall. Each exclosure is paired with an un-fenced plot of the same area. These ***10x10m herbivory plots*** will allow us to compare the consequences of deer herbivory on a number of response variables, including acorn survival, oak seedling success, and understory vegetation dynamics. We used a random design to determine the locations of plots, but stratified the distribution of plots to ensure they evenly captured the elevation gradient within each macro-plot. The plots also occur under a wide variety of canopy densities, allowing us to incorporate canopy density as a factor in our analyses.

Figure 3: Fallen branch from Hurricane Matthew, creating cage-like structure that could protect seedlings from large mammal herbivory. Branches from the site will be placed over sub-plots.

Within each 10x10m herbivory plot, we will establish three ***2x2m stressor sub-plots***, each of which will receive a different ***stressor treatment***. The first will have ***branch piles*** to simulate the conditions created by fallen limbs as a result of severe storm damage to the canopy. We will utilize some of the abundant branches that fell at the site during Hurricane Matthew, selecting ones similar to the photo below and placing them over the assigned 2x2m sub-plot. The second will be subjected to ***litter-clearing***, by removing all the surface leaf litter in the sub-plot. This is not a direct simulation of fire, but one important role of fire is to reduce litter, which is known to influence acorn and seedling success. The third sub-plot will be a ***control***, and will not be manipulated.

Figure 4: Fenced 10x10m herbivore plot, with finer-scale variation in plant community and shade conditions inside.



Sub-plot screening

Determining the location of the three stressor sub-plots is an important and complex challenge: we wanted to limit the pre-existing variability between the sub-plots because large differences in conditions that affect oak seedling performance could confound the effects of the applied experimental treatments. Based on visual observations and natural history knowledge, we were particularly concerned that large differences in vegetation composition would exert different competitive effects on seedlings; large differences in density in the herbaceous/shrub layer would create different shading effects; and dense pine litter can cause seedling suppression. These conditions often varied within a 10x10m plot, as illustrated in Figure 4: the presence of a saw palmetto in the middle of the fenced plot creates much denser shade and may also exert different competitive effects on seedlings as compared to the more open area in the foreground of the photo. We therefore wanted to devise an efficient way to quantify and classify the finer scale variation in each plot according to these potentially confounding conditions. This would allow us to select and assign the 2x2m sub-plot treatments more objectively, so as to avoid subjective bias from visually selecting areas that appeared most homogenous.

We experimented with several different possible screening measurements, evaluating them for both their ability to capture our subjective natural history observations regarding seedling performance, and the ease and speed of measurement. We found that the above potentially confounding differences in sub-plots can be reasonably captured using only three measurements: light availability at 1.2m above the ground, light availability at 0.15m above the ground, and the density of laurel oak seedlings. We will survey all of the herbivory plots to quantify those three variables at a 1m scale of resolution, then use a hierarchical clustering statistical technique to find sets of 2x2m sub-plots that are most similar with regards to those three measurements. The 3 stressor treatments will then be randomly applied to selected 2x2m sub-plots.

Data collection

All 32 10x10m herbivore plots (16 fenced, 16 unfenced) have been established. We have also mapped the trees within all the plots. We developed and piloted the sub-plot selection protocol. We are recruiting a large team of volunteers to assist with the sub-plot screening, as well as the baseline measurements, scheduled for April 7-10. The screening data will be entered and analyzed as we go, so that sub-plots can be laid out and baseline measurements taken immediately. Before applying the stressor treatments (branch piles and litter-clearing) to sub-plots, all sub-plots will be surveyed to determine light environment, soil moisture, vegetation composition, and the size of existing oak

seedlings within the sub-plots. These measurements will serve as the baseline for Study 1b. In mid-April we will perform the manipulations – creating branch piles and clearing litter. The deer-stressor experiment will at that point be left to evolve until the first round of post-treatment measurements, which will quantify the effects of the treatments on soil moisture, oak seedlings, and vegetation dynamics. We will re-survey the sub-plots in late summer 2017 and at least twice a year in subsequent years of the study, and analyze the patterns of change that are associated with each treatment: herbivory, branch piles, and litter clearing. During and between surveys, plots and sub-plots will be inspected for damage or unexpected disturbances. Sub-plot branch treatments will be allowed to decay naturally, but pending additional funding to purchase and plant oak seedlings into the experimental plots, we will re-create branch piles. Litter-clearing will be reapplied each April and December of the experiment.

Data Analysis, Modeling, and Application

The data from Study 1a, the spatial-environmental study, will be analyzed to determine how current mature tree species distributions and seedling/sapling distributions are related to environmental variables. Since seedlings and saplings are the "future of the forest," this comparison will help us predict how changing environmental conditions may shift the composition and structure of forests. The herbivore-stressor interaction experiments will help us determine the relative impacts of herbivory and other types of environmental stressors on tree seedling emergence, survival, and growth. This is essential for identifying conditions that limit or promote oak regeneration. We will combine our data from Study 1a and 1b with life table parameters from the literature to construct a partial demographic model to predict future forest dynamics of each oak species. While the study will only provide a few years of survivorship and growth data, these are typically the most limiting and often the most sensitive life history stages for tree population dynamics. The purpose of the model is to help determine whether observed rates of acorn and seedling success are likely sufficient to sustain forest composition, and how stressors affect forest sustainability. Ultimately, the model will help understand the possible future trajectories of maritime forest composition and the potential effects of different management and restoration strategies.

♦ ADDITIONAL GRANT APPLICATIONS

The commitment that JIA has made to understanding the potential threats of environmental stressors on the regeneration and future condition of coastal maritime forests is a profound contribution to the larger endeavor of coastal conservation in Georgia and beyond. This study will provide management-relevant information for managing the maritime forests on Jekyll Island, but has the potential to contribute much more broadly if the research approach is replicated on other barrier islands. Each island has its own history of land use, management strategies, and environmental stressors. By extending the study, we can start to build more robust generalizations about the conditions under which forest regeneration is threatened, and by what specific stressors.

To pursue that goal, we have applied for three additional grants that would fund the replication of this study on Ossabaw, St. Catherines, and Sapelo Island. Our pre-proposal to the Coastal Incentives Grant program was favorably reviewed, and we were invited to submit a full proposal. We also submitted a pre-proposal to SeaGrant, and are awaiting review. Lastly, PI King applied for funding through the University of Georgia, through a program that is geared to supporting junior faculty to establish robust research programs. These grants are primarily to replicate the Jekyll study on other islands, but they also include provisions to enhance the work on Jekyll. Specifically they would fund a professional native

oak nurseryman to collect acorns from parental trees on the Georgia coast, which we would use in acorn survival studies, and which he would also germinate, grow for a year, and provide the seedlings to us to use in seedling survival studies.

Given that over 10 Georgia coastal managers and biologists have enthusiastically supported our plans, we are hopeful that the granting agencies will agree that this is a pressing, timely, and scientifically strong plan to strengthen our management of these rare treasures. In each proposal, we acknowledged JIA's critical role in instigating this important research avenue. By leveraging the JIA Research Grant to seek additional funding, we hope our efforts will further strengthen Jekyll Island's well-deserved reputation as a leader and innovator in coastal environmental conservation and education.

SIGNIFICANCE OF RESEARCH

As human-driven environmental changes pose increasingly complex conservation and management challenges, there is growing recognition that considering each driver individually cannot provide nuanced, robust, management-relevant understandings of the changes afoot or their consequences. Yet surprisingly little research to date has addressed the effects of multiple stressors on forest ecosystems. Within the last two years, the literature reveals an uncommon confluence of scholarship by disturbance ecologists, climate change biologists, restoration ecologists, and forest managers -- all arguing for the importance of integrating research on the complexity of stressor and disturbance regimes with ecological models to help us understand the behavior and future condition of forest ecosystems. There is also increasing demand for decision-making tools and strategies that can help managers guide ecosystems toward desirable, resilient future trajectories. Georgia’s barrier island maritime forests are rare, vulnerable, and valuable ecological and cultural resources, and present a prime context for pursuing this much-needed scientific advancement.