PROJECT INFORMATION

Project Director's Name*	Micheal S. Allen
Organization*	University of Florida
Project Title*	Ecological and Economic Impacts of Land Use and Climate Change on Coastal Food Webs and Fisheries
Reporting Period*	Final Report Due April 30, 2024

Note to Grantees: In sections 1 to 5, we ask you to highlight your accomplishments (including outputs and outcomes) through this grant award. These sections of the final grant report will be made available to the public.

1. GOALS AND ACCOMPLISHMENTS

1.1 Please restate the goals and objectives of your project.*

The interactions among human land and water use, freshwater delivery to estuaries, and associated changes in habitat quality and quantity present distinct examples of coupled human-natural systems present throughout the Gulf of Mexico. Increasing human activities (land use change, commercial fishing, and habitat modifications) and climate change (sea level rise and changes in temperature/precipitation patterns) present serious challenges for sustaining coastal resources and coastal economies. Some of the most dramatic influences of these stressors include changes in the quantity and quality of freshwater delivered to estuarine systems, with major impacts on salinity regimes and nutrient loading. Threats to estuary health include both reductions in freshwater inputs due to drought and land-use patterns that withdraw surface and groundwater resources for municipal and agricultural purposes. These same land uses are associated with increases in nutrient loading from fertilizer application and wastewater disposal. Overall, changes in freshwater quantity and quality can affect estuarine productivity and cascade through food webs to influence benthic invertebrates, forage fishes, and ultimately fisheries and protected species.

Landscape alterations that impact the timing and volume of freshwater inflow are common stressors to coastal systems in the Gulf of Mexico. Although agriculture and urban intensification generate economic benefits inland, they impact the coast by influencing both freshwater flows and nutrient loading to estuaries. This project assessed how changes in climate and watershed land/water use are expected to influence food webs, fisheries, aquaculture, and the nature-linked economic drivers of a tourism economy. The project explored the implications of a range of future climate and land/water use scenarios that are expected to influence coastal food webs and fisheries in a Gulf of Mexico estuary, focusing on the Suwannee River estuary.

The Suwannee River originates in the Okefenokee Swamp in Georgia and flows over 400 km before discharging into the Gulf of Mexico just north of Cedar Key, Florida. The Suwannee River is one of the largest remaining undammed rivers in the eastern USA, and at its mouth lies the Cedar Keys National Wildlife Refuge and Big Bend Seagrass Aquatic Preserve. This area of Florida, known as the Nature Coast, has been recognized for its “exceptional biological, aesthetic, and scientific value”, and has been identified by state and federal agencies as a high priority site for conservation.

The Gulf Coast around the Suwannee River has a very gradual elevation gradient and is thus exceptionally vulnerable to sea level rise and other climate change related phenomena. The region has already seen substantial impacts from changes in rainfall patterns and water withdrawals for agricultural use. Variability in precipitation patterns, possibly owing to climate change, has increased the frequency of low flow events, with four of the six most extreme low flow events occurring in the past 100 years since 2003. In addition, average river discharge per centimeter of rainfall has declined, which indicates an interaction between climate and anthropogenic influences on both groundwater and river flows (Seavey et al. 2011). The region is undergoing rapid urban development,

bringing increased water use and nutrient considerations from urban activities. Thus, understanding the impacts of climate and land use change on the Suwannee River estuary is a high priority for conservation and management.

This project explored how changes in land/water use and climate are expected to influence hydrology, ecosystems, economic activity dependent on these ecosystems (e.g., agriculture, fisheries, aquaculture, and tourism), and ecosystem services in the Suwannee River Basin. The objectives of this project were to (1) Develop a watershed-scale hydrological model to predict freshwater and nutrient inputs from the Suwannee River to the coast under alternative land use and climate scenarios (Figure 1). Objective 2 developed a spatially explicit trophic dynamic ecosystem model to predict how changes in freshwater quality, quantity, and species range changes will impact estuarine food webs. Specifically, we assessed how changes in estuarine conditions due to altered flow will influence populations of exploited fisheries species (e.g., Red Drum Sciaenops oscellatus, Spotted Seatrout Cynoscion nebulosus, and eastern oyster Crassostrea virginica), as well as shellfish aquaculture (e.g., hard clam). Where appropriate, results from the watershed and food web models were translated into estimates of changes in economic activity in Objective 3, to evaluate the economic impacts of a range of land use and climate scenarios on fisheries, aquaculture and tourism. Combined with surveys conducted and the bioeconomic model developed, Objective 3 provides data and insights on potential economic tradeoffs and changes in behavior that might result across scenarios. Finally, the project included direct input of community leaders through focus groups, public webinars, and a final public workshop (Objective 4) to present scenarios and explore management options (Figure 1).

1.2 Describe the accomplishments of your project. You should include both the anticipated accomplishments that you outlined in your project proposal as well as any *unanticipated* accomplishments that have since occurred. Describe any activities you have conducted, programmatic progress made, or project benchmarks and milestones met.*

Project Summary – Key Findings

• This project demonstrated that land use in the Suwannee Basin will influence downstream natural resources including both fisheries and aquaculture. The hydrological (Objective 1) and ecological (Objective 2) models were effective at predicting both river discharge to the estuary and estuarine food web composition relative to historical data in the watershed and estuary.
• Both land-use and climate scenarios were predicted to influence the estuarine food web and the natural resources (e.g., fisheries and aquaculture) it supports.
• Nutrient loading was driven largely by land use in the future scenarios, with the agricultural expansion scenario delivering the most nutrients to the estuary and complete restoration forestry the least.
• Overall, climate factors influencing precipitation patterns had a stronger effect on the estuary natural resources than land use, but both land use and climate were important drivers of natural resources in the estuary. Extreme land use changes (complete agricultural expansion or restored forests) were predicted to have substantial impacts.
• Land-use scenarios that substantially increased agriculture in the basin were predicted to increase nutrient loading, which caused predicted bottom-up increases in production of several fish species. However, negative impacts of increased algae production were predicted to harm seagrasses and thus negatively influence species that support important fisheries.
• This infers tradeoffs where any increases in production in estuarine resources would be at least partially offset by risks of habitat loss (e.g., seagrass coverage) that would affect upper trophic levels.
• Average shellfish aquaculture yields were predicted to increase in the agricultural expansion scenarios, due to bottom-up processes of increased nutrients and primary production. However, there remains high uncertainty in the degree to which increased nutrients would increase the occurrence of harmful algal blooms, which were not simulated in this food web model.
• Risks of higher temperature and lower salinity due to increased precipitation were expected to increase risk of periodic economic losses in the shellfish industry, particularly in Franklin and Levy counties. Thus, although average yields could increase due to higher productivity, higher temperatures, and nutrient loading, climate and land use impacts were expected to increase the risk of periodic crop losses for shellfish aquaculture.
• Total value added and employment levels in the Suwannee River Basin were strongly linked to agriculture, timber, and aquaculture operations, where land-use scenarios that reduced these activities generally reduced both value added and employment. However, modest changes in land use relative to current conditions exhibited decreases in value added and employment that were not offset by minor increases in these variables within some agriculture, forestry, and fishing related sectors.

• Angler surveys showed that anglers were willing to pay increased rates to prevent declines in seagrass abundance and populations of certain fish species. The willingness to pay to prevent declines in fish abundance was highest for Snook, followed by Spotted Seatrout and Red Drum. Survey respondents were only willing to pay more for environmental programs leading to increases in Spotted Seatrout and seagrass abundance.
• The community and science advisory committee for the project was heavily engaged and had an active role in selecting the future scenarios considered, which lays the groundwork for future use of this study for management and policy.
• This project included a significant amount of data synthesis, analysis, and future scenario development that can be used as a baseline for future investigations of management options at local levels, as well as future data collection to improve these models for future policy option explorations.

2. Outputs

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

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2. OUTPUTS

Outputs are tangible or measurable deliverables, products, data, or publications produced during the project period.

2.1. Please indicate the number of students (K-12, undergraduate, or graduate), postdoctoral scholars, citizen scientists, or other trainees involved in the project. *

Please enter 0 if none were involved.

K-12 students	75
Undergraduate students	45
Graduate students	10
Postdoctoral scholars	6
Citizen Scientists	6
Other Trainees	0

2.2. Has your project generated any data and/or information products? *

Generation of data includes transformations of existing data sets and generation of data from existing resources (e.g., maps and images). Information products include publications, models, software, code, curricula, and digital resources.

(Check all that apply.)

Responses Selected:

Data
Information Products

2.3. Briefly describe how you fulfilled the approved Data Management Plan and, if applicable, any changes from the approved plan. *

All datasets have been identified and preliminarily described in the publicly accessible Gulf Science Data Repository GRIIDC (www.griidc.org/), where they will be made publicly available and have DOIs assigned once the metadata and datasets are prepared, and curation is complete.

The team is in the process of documenting and preparing the metadata to accompany the submission of the datasets to the repository in accordance with best practices and the data management plan.

The objective 1 datasets will contain the necessary information, including inputs, outputs, calibration details and parameters for the Suwannee River Basin (SRB) SWAT-MODFLOW model and the Suwannee River Estuary Linkage Model (ELM) developed. Inputs for the setup, calibration and validation of the SRB SWAT-MODFLOW model included a large set of publicly available datasets that were collected and synthesized from USDA, USGS among other sources; these will be linked to from the repository. The observational data used for comparison during the calibration and validation periods will be provided or if in a repository, linked to. Model outputs include time series for each land-use and climate scenario, and annual average agricultural and silviculture yields.

A second model, the Suwannee River Linkage Model, used as the spatially explicit water quality maps developed from the SWAT-MODFLOW time series data as its inputs, in addition to other modeled or measured hydrological variables and meteorological conditions. These data, along with other historical observational data used in model development will be uploaded as part of the dataset or linked to from the repository as appropriate. This model was not one of the original tasks, however it was determined such a model was necessary due to output-input incompatibilities of SWAT-MODFLOW and the new Ecospace SREM. The outputs of this model were predictions of the spatial configuration of freshwater in the estuary, given changes in land use and climate from all the scenarios, which will be made available through the repository.

The objective 2 datasets will contain the necessary information, including inputs, outputs, and parameters, for the replication of the base run of the Suwannee River Estuary Model (SREM) using the publicly available Ecopath with Ecosim (EwE) ecosystem modeling software. The inputs were derived from a variety of locally collected data on fish and invertebrates, habitat, and water quality, much of which was publicly available data from the Florida Fish and Wildlife Conservation Commission. When local data were not available, inputs were derived from literature values or borrowed from other models of nearby or similar systems. The outputs are comprised of the model output from the base run, including the historical calibration period of 1997-2020 and future projections under three different climate/land-use scenarios. Model simulated time series and spatial maps of biomass, landings/discards, mortality, and ecological indicators (e.g. species diversity, richness) will also be provided.

The three datasets associated with objective 3 will be submitted to the repository. One objective 3 dataset will contain the survey instrument, de-identified responses, and related analyses of the online willingness to pay (WTP) choice experiment survey conducted between April and May 2022. Outputs from this survey include the following: household trip frequency to the Nature Coast, previously engaged coastal activities, attitudes towards water quantity/quality, climate change, and downstream impacts, and willingness to pay (WTP) to reduce alterations in ecosystem services provided by the Nature Coast. A second objective 3 dataset will contain the survey instrument, reference materials provided to the respondents, de-identified responses, and the analyses of the saltwater angler survey conducted in-person and online during the summer and fall of 2022, respectively. A recreational demand model for the Suwannee River estuary was also developed, differences in consumer surplus stemming from changes in recreationally-targeted fish species populations were estimated, and will be made available. The third objective 3 dataset will contain the input parameters used and results from the economic impact analyses conducted with customized IMPLAN models that reflect scenarios developed for the functional economic region that best approximates the Suwannee River Basin. Proprietary data and associated modeling code available to the project team through a paid IMPLAN license will not be provided, as approved during the initial data identification and description process related to this dataset.

The objective 4 datasets will contain the materials and analyses related to conducting the focus groups of community leaders in areas along Florida's Gulf Coast and from the facilitated discussions with the advisory committee. The data obtained from the focus groups and the analyses using qualitative methods to identify themes regarding community leaders' perceptions and knowledge of land use on estuaries will be included in the dataset submitted. Outreach materials, key messages and a communication toolkit are in development, which will be uploaded as appropriate to the repository. GRIIDC and NASEM will both be notified as required of these and any dissemination activities within the next year.

If your project has generated data, please download the Excel worksheet entitled GRP Data Management Reporting. Use the "Data Report" tab in the worksheet to create an inventory of data sets that you produced and to verify deposit in a curation facility. Upon completion, please upload the worksheet to your task list. If you need guidance on how to complete the Data Report, please e-mail gulfgrants@nas.edu. A member of GRP's data management staff will reach out to you.

If your project has produced publications, websites or data portals, GIS applications, models or simulations, software packages or digital tools, code, curricula, or other interactive media, please download the Excel worksheet entitled GRP Information Management Reporting. Use the "Information Products Report" tab in the worksheet to create an inventory of these products and to verify deposit in a curation facility. Upon completion, please upload the worksheet to your task list. If you need guidance on how to complete the Information Products Report, please e-mail gulfgrants@nas.edu. A member of GRP's data management staff will reach out to you.

2.4. Aside from data and information products, what other tangible or measurable deliverables or products (e.g., workshops, trainings, and outreach events) were produced during the project period? *

Upon completion of this form, you may upload supplemental material that represent the tangible or measurable deliverables or products to complement this narrative report.

Engagements & Communication Outputs

Advisory committee meetings:
• April 2021 – Project introduction; one-hour focus group session to understand community perceptions of environmental, social, and economic issues in the region.
• November 2021 – Overview of scenario development process; one-hour focus group session to gain input on attributes to address in scenarios.
• December 2022 – Project updates and presentation of example scenario; facilitated discussion on hydrological, ecosystem, and economic models.
• August 2023 – Interactive workshop to refine existing scenarios and identify additional factors to consider.
• June 2024 – Presentation of results; discussion on key messages, communication/ outreach strategy, and next steps.

Currently submitted manuscript:

Botta, R., Koeneke, R, Hilsenroth, J., Grogan, K., Harris, H. E., Court, C.D.
Valuing Coastal Fisheries and Seagrasses: A Case Study of Estuarine Resources on Florida's Nature Coast.
Submitted December 2023, Ecological Economics

Presentations from the project are listed below.

Hilsenroth, J. (2022, July 31). Willingness to pay for improvements in recreational fish and seagrass abundance in Florida's Nature Coast [Poster Presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Anaheim, CA.

Harris, H. (2023, March 9). Modeling the Impacts of Climate and Land Use Changes on Coastal Foodwebs and Fisheries [Poster Presentation]. Gulf and Caribbean Fisheries Institute, Fort Walton Beach, FL.

Reaver, N. (2023, March 14). Predicting estuarine water quality response to changes in upstream land use, management, and climate using data-driven modeling [Paper presentation]. North Florida Marine Science Symposium, St. Augustine, FL.

Koeneke, R. (2023, March 31). Evaluating the Economic Contributions of Saltwater Recreational Fishing in Florida's Nature Coast [Paper presentation]. Southern Regional Science Association, Savannah, GA.

Chagaris, D. (2023, June 1). Ecological and economic impacts of land use and climate change on the coastal food web and fisheries in the Suwannee River estuary [Poster Presentation]. FWC Landscape Conservation Summit, Fort Meyers, FL.

Reaver, N. (2023, June 6). Data-driven modeling for predicting estuarine water quality response to changes in upstream land use, management, and climate [Paper presentation]. American Ecological Engineering Society Annual Meeting, Tampa, FL.

Lindsey, A. (2023, June 28). Applying an interdisciplinary initiative to develop resilient communities, preserve industries, and protect the future of the Suwannee River Basin. [Paper presentation]. Development Studies Association Conference, Reading, UK.

Koeneke, R. (2023, July 24). Valuing Recreational Saltwater Fishing in Florida’s Nature Coast Using a Travel Cost Method [Poster Presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Washington, DC.

Marcillo, E. (2023, July 25). How do Climate and Environmental Risk Affect the Profitability of the Aquiculture Industry in Florida? [Paper presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Washington, DC.

Chagaris, D. (2024, February 20). Assessing ecological and economic impacts of land use and climate change in the Suwannee River watershed and estuary [Paper presentation]. Gulf of Mexico Conference, Tampa, FL.

Lee, D. (2024, February 20). Analyzing the Impacts of Climate Change and Land Use Change on Water Availability in the Suwannee River Basin, FL [Poster Presentation]. UF Water Institute Symposium, Gainesville, FL.

Marcillo, E. (2024, February 20). How Do Environmental Risks Affect the Profitability of the Aquaculture Industry in Florida? [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Allen, M. (2024, February 20). Projecting Future Land Use And Climate Change Impacts On The Suwannee River Estuary [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Reaver, N. (2024, February 20). Quantifying Impacts of Climate and Land Use Change on the Waters of the Suwannee River Basin [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Rooj, R. (2024, February 20). Simulating nitrate concentrations at the outlet of the Suwannee River by combining SWAT-MODFLOW with MODPATH [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Koeneke, R. (2024, February 20). Suwannee River Estuary Non-Market Valuation Studies of Recreational Saltwater Fisheries [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Honeycutt, S. (2024, February 20). Engaging Stakeholders to Enhance Resilience in the Suwannee River Basin [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Honeycutt, S. (2024, February 20). Community Advisory Committees and Communication Toolkits: Creating Solutions for Water-Related Issues [Poster Presentation]. UF Water Institute Symposium, Gainesville, FL.

Koeneke, R. (2024, April 6). Estimating the Potential Economic Impacts of Land Use and Environmental Changes in the Suwannee River Basin [Paper presentation]. Southern Regional Science Association, Washington, DC.

Honeycutt, S. (2024, September 21). Community Input on Ecological and Economic Impacts of Climate Change and Extreme Weather Events [Paper presentation]. Extension Disaster Education Network Annual Meeting, Savannah, GA.

3. Data Management

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

When the form is completed, you may click "Mark as Complete" at the bottom of the page to save your work and return to the dashboard.

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3. DATA MANAGEMENT

In this section, please provide a response to each question to complement the **Data Report** in the GRP Data Reporting Excel worksheet.

3.1 If you listed multiple data sets in the data reporting table, please briefly describe how these data sets relate to one another. *

We are compiling the final data sets for uploading into GRIIDC, and they will have notes linking those data sets where appropriate.

3.2. Please provide a list of additional documentation to describe the data listed in the reporting table (e.g., code books, lab manuals, workflow procedures). Enter none if you did not produce any additional documentation to describe the data. *

None in this category.

3.3. Beyond depositing data and metadata in a repository, what other activities have you undertaken or will undertake to ensure that others (e.g., researchers, decision makers, and the public) can easily discover project data? What other activities have you undertaken to ensure that others can access and re-use these data in the future? *

Nearly all the data for this project came from publicly available sources through partner agencies (e.g., USGS, Florida FWC, etc.). Data collected for objective 3 will be uploaded to GRIIDC. We have summarized description of these data sets to our advisory committee as well as online. All data are stored on the servers at the University of Florida and are secure with backup, along with pending uploading to GRIIDC. All data sets are available to the public upon request.

3.4. Are any data products you produced sensitive, confidential, and/or proprietary? *

No

4. Information Products

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

When the form is completed, you may click "Mark as Complete" at the bottom of the page to save your work and return to the dashboard.

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4. INFORMATION PRODUCTS

In this section, please provide a response to each question to complement the **Information Products Report** in the **GRP Information Products Management** Excel worksheet.

4.1. Please select the type(s) of information products that your project produced. *

Responses Selected:

2. Websites or data portals
5. Models or simulations

Websites or data portals *

Please provide a list of project websites and data portals (including the website URL).

Websites about the project:

https://piecenter.com/2020/10/06/nas-suwannee/

https://waterinstitute.ufl.edu/research/featured-projects/ecological-and-economic-impacts-of-land-use-and-climate-change-on-coastal-food-webs-and-fisheries/

How long beyond the grant period will you maintain the project website/data portal and its contents? Please describe plans to archive the website/data portal and its contents after regular maintenance concludes.*

This project was part of an ongoing research program that will continue to be promoted and accessible through web communication, blogs, and connections to local governments for a minimum of two years here at UF, in addition to the GRIIDC upload which will be available for a minimum of five years..

Curricula for education and training, GIS applications, Models or simulations, Software packages or digital tools, or other interactive media, and Other *

If you produced any additional documentation to describe information products, please provide a list of this documentation (e.g., model or simulation documentation, software manuals, source code annotation).

No training materials created.

4.2. Beyond depositing information products in a repository, what other activities have you undertaken or will undertake to ensure that others (e.g., researchers, decision makers, and the public) can easily discover and access the listed information products? *

Our workshops with the advisory committee have highlighted the ability of scientists, NGO's and local business leaders to access the study results and consider other simulations in the future. The project created tools that are now developed and ready for future refinement and use.

4.3. Are any of the information products you produced confidential, proprietary, or subject to special license agreements? *

No

5. Project Outcomes

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

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5. PROJECT OUTCOMES

Outcomes refer to the **impact(s), consequence(s), result(s), or effect(s)** that occur from carrying out the activities or outputs of the project. Outcomes may be environmental, behavioral, health-related, or programmatic. Example outcomes include, but are not limited to: increased learning, knowledge, skills, and motivation; policy changes; actions taken by a group as a result of information generated by your project.

5.1. Please describe the outcomes achieved during your project and how they were assessed. For this question, we are interested in learning about the immediate short-term outcomes that have already occurred during or as a result of your project. Do not include long-term outcomes you foresee your work contributing to beyond the end of the project. *

The tools developed in this project were guided by our advisory committee with active input and scenario development from this team.

Members of the community and scientific advisory committee, with affiliations.
Name Affiliation
Barry, Savanna University of Florida
Bauer, Mace Agronomist
Campbell, Lauren Florida Dept. of Environmental Protection
Clark, Mark University of Florida
Day, Lauren The Conservation Fund
Dehaven, Mark Florida Department of Agriculture and Consumer Services
Gude, Andrew Lower Suwannee National Wildlife Refuge
Hetrick, Susanna Suwannee River Water Management District
Hill, Melissa National Wildlife Federation
Hinkle, Anthony Clam Farmer
Hochmuth, Bob University of Florida
Kenworthy, Matt Florida Fish and Wildlife Conservation Commission
King, Sean Suwannee River Water Management District
Lewis, Kristy University of Central Florida
Miller, Hunter Oceana, NGO
Perry, Rebecca The Conservation Fund
Sache, Jake Sache Farms
Sturmer, Leslie University of Florida
Thompson, Tommy Charter Captain/Journalist
Valez, Darlene University of Florida
Webb, Matt Genesis Timber
Whitehurst, Tisha Levy County Tourism
Wynn, Chris Florida Fish and Wildlife Conservation Commission

This study would not have been possible without the strong engagement of our advisory committee and the partner state and federal agencies that provided so much of the data synthesized and analyzed here. Our research team is grateful for the collaboration and support received to conduct an analysis across so many agency

jurisdictions. We especially thank our partners in the Suwannee River Water Management District, Florida Department of Agriculture and Consumer Services, Florida Fish and Wildlife Conservation Commission, US Geological Survey, Florida Department of Environmental Protection, and the Lower Suwannee National Wildlife Refuge. Further support was provided with strong engagement from the Cedar Key Aquaculture Association, Levy County, The Conservation Fund, the City of Cedar Key, and the Florida Wildlife Federation.

5.2. We're interested in hearing not just the results of your project but what are their implications for or contributions to:

- **offshore energy system safety,**
- **environmental protection and stewardship, and/or**
- **health and community resilience**

Please describe what you consider to be the most remarkable accomplishment or finding of your project. What can others learn from your accomplishment and finding? How do you see it fitting in with your greater field of study or community of practice? *

This project clearly showed that land management will influence coastal natural resources, including fisheries, aquaculture, and tourism. Major highlights with implications to policy and management:

• The hydrological (Objective 1) and ecological (Objective 2) models were effective at predicting both river discharge to the estuary and estuarine food web composition relative to historical data in the watershed and estuary.
• Both land-use and climate scenarios were predicted to influence the estuarine food web and the natural resources (e.g., fisheries and aquaculture) it supports.
• Nutrient loading was driven largely by land use in the future scenarios, with the agricultural expansion scenario delivering the most nutrients to the estuary and complete restoration forestry the least.
• Total value added and employment levels in the Suwannee River Basin were strongly linked to agriculture, timber, and aquaculture operations, where land-use scenarios that reduced these activities generally reduced both value added and employment. However, modest changes in land use relative to current conditions exhibited decreases in value added and employment that were not offset by minor increases in these variables within some agriculture, forestry, and fishing related sectors.

The overall conclusion is that land use and climate will interact to determine the quality of natural resources, and this information is critical for land and conservation managers. The engagement of our committee was outstanding, and this tasks completed through collaboration have momentum for further development and use.

6. Communication

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

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Note to Grantees: In Section 6, we seek input from you to help us evaluate the Gulf Research Program's funding strategy. This section will not be made available to the public.

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6. Information to Inform GRP Evaluations

6.1. Sharing the difficulties you encountered helps us learn from your experience. Describe any challenges you encountered in your project and how you addressed or overcame them. Challenges are inherent to conducting any complex project. These may include (but are not limited to): unexpected staffing changes, changes in the community you are working in, appearance of a new technology or dataset in the field you are working in, challenges accessing a field site, policy or regulatory changes that affect the issue you are addressing, low recruitment rates, delays in setting up services, or other problems in implementing and conducting your project. *

Our biggest challenge was the immediate engagement with the advisory committee due to Covid restrictions, but after working through that the project went smoothly with heavy engagement from state and federal agency cooperators, NGO's, and business leaders in the region.

The other difficulty we did not anticipate was the need for a linkage model between the hydrologic and ecological models. Our team worked diligently on this and overcame it, with new methods developed to link hydrological watershed model with the estuary food web model. This is the first time to our knowledge these processes have been linked in this way via both the hydrological and ecological models, to explore policy options for land management.

6.2. We like to hear about what you learned from your work and how you feel it affects future work or the work of others. Think back on your project strategies, methods, and activities, what worked and what did not? Is there anything you would do differently in the future? If so, tell us what and why. *

In the future we would have actually gotten county and city commissioners to participate on the advisory panel, in addition to the agencies, NGO's, and business leaders. Doing this would engage them earlier, which we are doing now.

6.3. What are the next steps for this work, either for you and your project team or other researchers? Has this project led to other opportunities to work in this area? *

The value of a study like this is not in the specific predictions, as it is not possible to predict the future of a complex large watershed and estuary with high certainty. Our goal was to explore the extremes and build tools to explore how land use and climate could influence agricultural and natural resources in the Suwannee River Basin. We showed that both factors are important to the economy of the region, and that land management practices in the basin have direct influences on estuarine natural resources. The extensive data synthesis and model construction conducted this project will hopefully provide a framework for further data collection to reduce data gaps, and serve as a tool to guide future policy decisions and future data needs. Specific next steps should include:

• Improvements in the hydrological and climate models should include more localized measures of how land use influences groundwater recharge, groundwater residence times, and the interactions between ground and surface waters.
• There is a need for more localized measures of how land use will influence groundwater recharge and nitrate loading to the surface and groundwaters, and how natural resources will respond to changes in nutrient loading and occurrence of drought/flood conditions.
• Improved best management practices for agriculture are currently underway, including novel strategies for time-release fertilizer and irrigation methods that have been able to reduce water use for agriculture. Exploring the effects of these strategies at both local and larger scales is a clear need, to assess the potential benefits of these approaches if adopted across the landscpe.
• Future work should focus on improving predictions of estuarine water quality as a function of watershed flows and nutrient inputs. Additional collection of estuarine water quality data, particularly colored dissolved organic matter (CDOM), would help to better calibrate the estuarine linkage model, improving predictions of future estuarine ecological change. With greater data availability, the structure of the ELM (currently based on quantile linear regressions) can be expanded to explore machine learning techniques such as random forest and gradient boosting techniques.
• The food web model synthesized substantial long term data from the estuary, but data gaps remain, particularly around invertebrate community composition and impacts of changes in benthic habitats on invertebrates, which would cascade to upper trophic levels including fisheries. There is a need to better quantify invertebrate abundance and composition and how these vary with changes in benthic habitats (oyster reefs, seagrass, salt marsh, mangroves).
• Substantial uncertainty remains on how fish recruitment will respond to changes in river discharge and salinity, and long term data sources should continue to be assessed to quantify impacts of flood and droughts on fish recruitment and abundance.
• The translation of outputs from the watershed model and the SREM for use within the regional economic model could benefit from improved data on historical commodity prices that reflect seasonality and local/regional

heterogeneity as well as an understanding of how these commodity prices might evolve over time within each land use and climate scenario.

• Data and methodological limitations prevented the valuation of changes in economic activity associated with changes in recreation as well as changes in the provision of ecosystem services or non-use values in the region. Further research will explore the inclusion of these additional values, and their multiplier effects (in the case of changes in recreational activity only) to further support informed decision-making related to land use changes in the Suwannee River Basin.

• An improved understanding of the impact of changes in biomass/population of target species for recreational fishers on recreational fishing effort will allow for the economic impacts of changes in recreational fishing expenditures to be accounted for.

• An improved understanding of the impact of changes in water quantity and/or quality parameters on non-fishing recreational spending will allow for the economic impacts of changes in recreational fishing expenditures to be accounted for.

• An input-output model was employed for the regional economic modeling component to make comparisons between an “average year” in the baseline scenario and each additional land use and climate scenario. As it is based on a static economic structure, this type of modeling framework is not designed to estimate projected levels of economic activity, especially over mid- to long-term (over five year) projections. Future efforts to improve the economic modeling component should focus on developing a more robust and dynamic regional economic model such as a dynamic, regional computable general equilibrium model.

• Future data collection should include additional surveys to capture other specific use and non-use values. Natural experiments that change the economic landscape could also inform future efforts.

• As with any survey effort, our results may suffer from sample selection bias. Additional work could examine how our respondents compare to populations at large and identify possible sources of bias.

• Future survey work could examine specific scenario outcomes found by other project components that were not possible given the project timeline.

• Future work could examine feedback loops between economic activity in the Nature Coast and its impacts on land use decisions in the Suwannee River Basin.

6.4. Have you developed new collaborations or partnerships (formal or informal) as a result of this work? If yes, please describe the new collaborations or partnerships. *

Absolutely, stronger connections with agency partners, NGO's, and local business leaders in the Suwannee River Basin. For example, this project has resulted in the Suwannee River Basin being selected as a key example in the "Health Farms - Healthy Bays" initiative as part of the Solutions from the Land NGO. See links below for examples. This has also resulted in an upcoming USDA proposal to address this topic of best management practices in the Suwannee River basin to protect both row crop farmers and aquaculture on the coast, which would not have occurred without this project being underway and showing strong progress and partnerships across the basin.

https://www.solutionsfromtheland.org/blog/floridas-healthy-farms-healthy-bays-project-aims-to-foster-farmer-fishermen-collaboration-for-cleaner-water/

https://www.solutionsfromtheland.org/blog/florida-leaders-meet-to-discuss-ecosystem-services-healthy-farms-healthy-bays-initiatives/

6.5. What, if any, positive changes in policy or practice do you foresee as a result of your work? *

None yet, but coming!

6.6. If you could make one recommendation to the Gulf Research Program for how best to build on the work you conducted in this project, what would it be? *

The best strategy is to leverage efforts like this. Where data has been synthesized and policy options explored, look for ways to improve these models with new data collection and adaptive-management strategies, to take advantage of the ground work laid.

7. Communication and Dissemination

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

When the form is completed, you may click "Mark as Complete" at the bottom of the page to save your work and return to the dashboard.

** denotes required fields*

Note to Grantees: In Section 7, we ask you to help us communicate the importance, progress, and accomplishments of your work. Information provided in this section will be used by the Gulf Research Program to highlight its funded projects in print and electronic informational and promotional materials. The intended audience for the information provided in this section is different and should be thought of as a general audience. When you return to the dashboard, you may upload images that represent and illustrate the work of your project.

7.1. Please describe the most exciting or surprising thing you have learned while working on this project in a way that is understandable by a general audience. *

Our most exciting finding is that land use matters! One concern we had is that climate would drive the results with little impact of land use on the estuary, but what we found is that the footprint of agriculture, urban and conservation lands do make a difference downstream, and influence the estuarine food web, fisheries and aquaculture. This has strong policy implications for best management practices, land use planning, and other basin-level management actions (water management, etc.).

7.2. Do you have any stories that capture the impact of this project? (optional)

If so, please share one or two. Examples of what we are interested in include stories of people/communities that the project has helped; lives that have changed; work that led to policy change, such as legislation or regulation; and research breakthroughs.

The best story was that Hurricane Idalia hit the Suwannee River estuary on August 30, 2023. This storm caused approximately 80% loss of the clam farm crop and heavy damage to row crop agriculture and poultry operations in the basin. The framework of connections made during this project allowed researchers are farmers throughout the region a common venue for discussions, ways to improve things in the future to increase resiliency to these events. The Healthy Farms - Healthy Bays initiative was well underway using this basin as a key example, and the partnerships developed in this project caused more open communication about impacts and recovery strategies.

7.3. Have any communications, outreach, or dissemination activities occurred in relation to your project?*

Please describe:

- Any press releases issued (other than that issued by the National Academies of Sciences, Engineering, and Medicine) about the project.
- Any media coverage or news stories about the project.
- Any social media accounts, websites, listservs, or other communication vehicles used to communicate information about this project. Please include relevant web addresses if available.

Links of online content and press releases are shown below.

Project Webpage: https://piecenter.com/2020/10/06/nas-suwannee/

Press release: https://blogs.ifas.ufl.edu/news/2021/03/10/how-uf-scientists-are-predicting-the-future-of-the-suwannee-river-basin/#:~:text=

Video: https://www.youtube.com/watch?v=N0M3KcnZrPM

Fact sheets:
Project overview: https://piecenter.com/wp-content/uploads/2021/05/NAS-Info-Sheet.pdf

Year 1 report: https://piecenter.com/wp-content/uploads/2024/03/NAS-Year-1-Infographic.pdf

Year 2 summary: https://piecenter.com/wp-content/uploads/2024/02/NAS-Year-2.pdf

Feature stories:

https://piecenter.com/2023/04/11/future-management-srb/

https://piecenter.com/2021/11/16/building-resilience-in-coastal-communities/

Presentations given at conferences from this project:

Hilsenroth, J. (2022, July 31). Willingness to pay for improvements in recreational fish and seagrass abundance in Florida's Nature Coast [Poster Presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Anaheim, CA.

Harris, H. (2023, March 9). Modeling the Impacts of Climate and Land Use Changes on Coastal Foodwebs and Fisheries [Poster Presentation]. Gulf and Caribbean Fisheries Institute, Fort Walton Beach, FL.

Reaver, N. (2023, March 14). Predicting estuarine water quality response to changes in upstream land use, management, and climate using data-driven modeling [Paper presentation]. North Florida Marine Science Symposium, St. Augustine, FL.

Koeneke, R. (2023, March 31). Evaluating the Economic Contributions of Saltwater Recreational Fishing in Florida's Nature Coast [Paper presentation]. Southern Regional Science Association, Savannah, GA.

Chagaris, D. (2023, June 1). Ecological and economic impacts of land use and climate change on the coastal food web and fisheries in the Suwannee River estuary [Poster Presentation]. FWC Landscape Conservation Summit, Fort Meyers, FL.

Reaver, N. (2023, June 6). Data-driven modeling for predicting estuarine water quality response to changes in upstream land use, management, and climate [Paper presentation]. American Ecological Engineering Society Annual Meeting, Tampa, FL.

Lindsey, A. (2023, June 28). Applying an interdisciplinary initiative to develop resilient communities, preserve industries, and protect the future of the Suwannee River Basin. [Paper presentation]. Development Studies Association Conference, Reading, UK.

Koeneke, R. (2023, July 24). Valuing Recreational Saltwater Fishing in Florida’s Nature Coast Using a Travel Cost Method [Poster Presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Washington, DC.

Marcillo, E. (2023, July 25). How do Climate and Environmental Risk Affect the Profitability of the Aquiculture Industry in Florida? [Paper presentation]. Agricultural & Applied Economics Association (AAEA) Annual Meeting, Washington, DC.

Chagaris, D. (2024, February 20). Assessing ecological and economic impacts of land use and climate change in the Suwannee River watershed and estuary [Paper presentation]. Gulf of Mexico Conference, Tampa, FL.

Lee, D. (2024, February 20). Analyzing the Impacts of Climate Change and Land Use Change on Water Availability in the Suwannee River Basin, FL [Poster Presentation]. UF Water Institute Symposium, Gainesville, FL.

Marcillo, E. (2024, February 20). How Do Environmental Risks Affect the Profitability of the Aquaculture Industry in Florida? [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Allen, M. (2024, February 20). Projecting Future Land Use And Climate Change Impacts On The Suwannee River Estuary [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Reaver, N. (2024, February 20). Quantifying Impacts of Climate and Land Use Change on the Waters of the Suwannee River Basin [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Rooj, R. (2024, February 20). Simulating nitrate concentrations at the outlet of the Suwannee River by combining SWAT-MODFLOW with MODPATH [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Koeneke, R. (2024, February 20). Suwannee River Estuary Non-Market Valuation Studies of Recreational Saltwater Fisheries [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Honeycutt, S. (2024, February 20). Engaging Stakeholders to Enhance Resilience in the Suwannee River Basin [Paper presentation]. UF Water Institute Symposium, Gainesville, FL.

Honeycutt, S. (2024, February 20). Community Advisory Committees and Communication Toolkits: Creating Solutions for Water-Related Issues [Poster Presentation]. UF Water Institute Symposium, Gainesville, FL.

Koeneke, R. (2024, April 6). Estimating the Potential Economic Impacts of Land Use and Environmental Changes in the Suwannee River Basin [Paper presentation]. Southern Regional Science Association, Washington, DC.

Honeycutt, S. (2024, September 21). Community Input on Ecological and Economic Impacts of Climate Change and Extreme Weather Events [Paper presentation]. Extension Disaster Education Network Annual Meeting, Savannah, GA.