



GULF RESEARCH PROGRAM

Project Title: Modeling Stress-Associated Health Effects of Multiple Impacted Ecosystem Services in the Gulf of Mexico

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I. ORIGINAL PROJECT SUMMARY (from proposal)

This proposal responds to the "Linking Ecosystem Services Related to and Influenced by Oil and Gas Production to Human Wellbeing" topic described in the RFA. The proposed work will examine multiple ecosystem stressors (especially the Deep Water Horizon incident and recent hurricanes) that impact ecosystem services (benefits humans derive from nature) in the Gulf of Mexico, develop a conceptual model of how impacted ecosystem services produce stressors that causes a variety of human health and well-being effects for people; evaluate availability and utility of existing data on human stress associated with the DWH incident and recent hurricanes in the Gulf; utilize some existing data to evaluate the conceptual model and assess its potential to identify likely stress effects of future incidents, accidents, and extreme events; and design new experiments and data collection activities targeted to fill priority information gaps and elucidate potential mechanisms of action of any salutatory or protective effects that exposure to natural and biodiverse coastal habitats may have in reducing event-associated stress. This work is innovative because it will be the first, or certainly among the first, to examine human health outcomes of major disasters like the DWH oil catastrophe through the lens of impacted ecosystem services and how rapid restoration of ecosystem services, or exposure to healthy ecosystem services elsewhere, may help alleviate or prevent some of the stress-associated human health effects. The research will also encompass other less-studied services such as subsistence fishing, coastal protection, and the foundational values of biodiversity, including approaches for robust testing of the hypothesis that healthy coastal environments and marine biodiversity support improved human health.

This project is expected to improve understanding of the linkages between impacts to a suite of ES and resulting damages to human health and well-being. In addition, this project could lead to significant improvements in resilience and recovery planning, clearer understanding of likely health and other effects of future extreme events, identification of significant data collection needs for future event response, and enhanced ability to quickly respond to, ameliorate or prevent some negative health outcomes. The proposed work will build upon existing data and will provide products that, while specifically tailored to the Gulf of Mexico, will also be useful in other geographic contexts. Findings will be important to improving safety of workers who may be exposed to acute stress during response activities and of residents who may experience high levels of event-associated chronic stress. Results may also be useful for protecting potential stress-alleviating "green spaces" from being degraded through use as debris disposal areas, which often happens following hurricanes. In addition, the results should shed new light on cumulative effects of disasters on ecosystem services and thereby on the functioning of the overall Gulf of Mexico ecosystem.

II. PROJECT RESULTS

Accomplishments

"Most previous work on effects of environmental disasters on human health and well-being has focused on traumatic injury and exposure to infectious diseases or toxic agents, while studies of environmental effects have principally targeted ecological damages to specific habitats or resources. Few conceptual frameworks illustrate how disaster-caused environmental damage ultimately results in long-term negative human health outcomes. Even fewer attempt to connect disaster-associated injuries to, and disruptions of ecosystem services (the benefits humans derive from nature and that make it possible for people to survive and prosper on Earth) to human and community health outcomes. In addition to immediate direct traumatic effects, disasters also result in acute and chronic stress, which appear to be primary factors associated with negative health outcomes. This project addressed the potential linkages between impacts disasters have that degrade ecosystem services and, in turn, the short- and long-term human health effects associated with the stress caused by loss or diminution of important and individual ecosystem services, particularly those that affect livelihoods and quality of life.

The study had four objectives:

1. Develop a detailed conceptual model of cumulative stress impacts on human health and well-being of the Deepwater Horizon catastrophe (DWH) and recent hurricanes in the Gulf of Mexico, based on effects these events had on specific ecosystem services.
2. Determine the availability and utility of existing data on environmental impacts and human stress associated with the DWH incident and recent hurricanes in the Gulf of Mexico.
3. Utilize identified data to evaluate the conceptual model and assess its potential to identify likely stress effects of future accidents and extreme events.
4. Using one or more interdisciplinary expert workshops, plan experiments/data collection to fill gaps and determine the value and mechanisms of action of any salutary health effects of exposure to natural and biodiverse coastal habitats.

This work was conducted by a multi-disciplinary team of seven co-investigators and two graduate students, with additional input from a number of expert participants from two workshops. Areas of

expertise among the investigators included data management and mining, ecology, ecosystem modeling, ecosystem services, ecotoxicology, landscape ecology, mental health, public health, psychiatry, and stress physiology. Workshop participants added more areas of expertise.

We assessed relevant models of environmental and human health effects of disasters via a targeted literature review and detailed discussions with a wide range of experts individually and in focused workshops. We found a number of useful frameworks, but none connected disasters to health effects through impacts to ecosystem services. We utilized concepts from several existing frameworks, input from expert workshops, and numerous ideas that originated with the research team to develop a comprehensive, detailed conceptual model that includes likely mechanisms of action for stress-associated health effects. This model is novel and, to the best of our knowledge, the first of its kind.

The literature review was accompanied by two workshops that garnered a wealth of expert opinion from scientists representing diverse disciplines. Workshop 1 was small and focused specifically on development of the model; its participants and output contributed to the model and participants joined the investigators as co-authors of a manuscript describing the model. Workshop 2 was larger and oriented primarily to discussions of data sources and needs related to application of the model to real-world situations and design of future data collection efforts and experiments. In addition to the development of a conceptual model, we assessed the availability and applicability of existing data sources for future use in testing and extending the conceptual model, as per the project objectives listed above.

Primary results of the project were (1) development of a detailed conceptual model of how degradation of ecosystem services by environmental disasters such as the DWH oil catastrophe and major storms such as Hurricane Katrina leads to acute, cumulative, and chronic stress which in turn negatively impacts mental, physical, and community health, and (2) identification of and comprehensive assessment of available environmental, ecosystem services, human health and community characteristics data for the Gulf of Mexico and the affected coastal counties of TX, LA, MS, AL and FL.

Initial Outcomes

All project and workshop participants were enthusiastic about the project and its outcomes, the opportunity to interact with such a broad range of experts and the study outputs. Participants expressed strong interest in remaining engaged with the project team and each other going forward. As this project has now ended, how to facilitate such continuing engagement is a topic of ongoing conversation. The project has already spawned several new activities, including one additional funded project by the Principal Investigator, at least one Letter of Intent in response to another NAS Gulf Research Program grant application call, plans for development of a new graduate level course linking ecosystem services and human health, one new doctoral dissertation project (under development), and ongoing collaborations among several of the project and workshop participants. Several participants will be continuing investigations into putative health-promoting roles of coastal nature exposure. In addition, this project engaged the Lowcountry Alliance for Model Communities (LAMC), a leading nonprofit organization in Charleston, SC, founded for the purpose of advocating environmental justice and promoting community-based participatory research, to support effective translation and implementation of science to address quality of life issues. The conceptual model developed here, as well as the list of particularly relevant existing data sources, could be used by organizations such as

LAMC to improve community preparedness for dealing with disasters and their health impacts. It will also provide opportunities for other researchers to explore correlations and mechanisms of action by which degradation of ecosystem services results in a host of negative human health outcomes.

In terms of importance to society, our model illustrates how oil spills, hurricanes, and other disasters cause changes in ecosystem components resulting in reductions in individual and multiple ecosystem services that support people's livelihoods, health, and way of life. The model elucidates how damage to ecosystem services produces acute and chronic stress which increases risk of adverse psychological and physiological health outcomes among affected people. It can be employed to identify specific disaster impacts to one or more critical ecosystem services, assess associated stress levels in affected individuals, groups, and communities, and evaluate putative linkages between increased acute and chronic stress and specific short- and long-term behavioral and physical human health outcomes. While developed with Gulf of Mexico hurricanes and oil spills in mind, the framework works equally well for other natural and technological disasters that cause impairment of ecosystem services and is transferable to other geographies.

Unexpected Results

We had expected to find clear connections between damage to ecosystem services and some human health outcomes. What we did not expect was the strength of some of these connections, particularly between impacts on services related to livelihoods and quality of life. We also discovered that ecosystem services per se basically have not been considered in previous analyses of disaster impacts and that restoration of these services and the development of innovative ways of reducing mental and physical stress and their associated negative health impacts through nature exposure should be major considerations in future work.

Project Relevance

Researchers, educators, community leaders, state government officials, federal government officials, the private sector, and disaster preparedness officials and first responders would be interested in the results of this project.

Use of the conceptual model in planning exercises by first responders, environmental scientists, and public and mental health specialists will improve responses to future disasters. In addition, the model could be applied to help society more fully account for the costs and benefits of potential management responses. In conjunction with other tools, the model could be used to direct investments in improving capabilities of the public health community, biomedical researchers, and environmental scientists, and to help guide development and implementation of an integrated, rapid disaster research response capacity. The model could also be used to support educating the impacted communities through public forums and by training community leaders on strategies to lessen environmental exposures and improve health. Finally, the model could also be used in the classroom to provide illustrate multiple connections between environmental impacts and human health.

Education and Training

Number of students, postdoctoral scholars, or educational components involved in the project:

- Undergraduate students: 0

- Graduate students: 2
- Postdoctoral scholars: 0
- Other educational components: 2

Two interdisciplinary workshops were held as part of the project. The first was targeted to help define the conceptual model, which is the centerpiece of the project. The second was a much larger workshop and focused primarily on data needs, sources and availability. Both workshops included the 2 master's students who were supported by the project, and the 2nd one included 2 additional master's students who assisted with meeting logistics and note-taking. These were important informal educational opportunities for the graduate students. In addition, the PI made formal platform presentations on project results at two national scientific meetings.

III. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Data
- Information products

DATA

See attached Data Report.

Other activities to make data discoverable:

As a requirement of the grant, this project did not collect new data, but it did involve an extensive data mining initiative focusing on available ecosystem pressure, ecosystem state, ecosystem services, human health and community characteristics data for the Gulf of Mexico and the affected coastal counties of TX, LA, MS, AL and FL. The initial data mining efforts determined that 1.) there exists a significant number of data portals providing access to data related to environmental conditions in the Gulf of Mexico prior to and following DWH. The time period for discovery of data, determined in part by the availability of identified data, was primarily from 2000 to near present (although some data from as early as 1964 were also considered) to support an understanding of conditions prior to and following DWH. Only those data sets that were available and included sufficient metadata to allow for a minimal assessment of when, where, why, and how the data were collected and quality checked were assessed for consideration use with the conceptual DPSEERH model. Based upon the initial review of metadata, data sets were binned as having been collected to assess or address issues of ecosystem pressure (106 data sets), ecosystem state (197 data sets), ecosystem services (17 data sets), human health and community environment characteristics (22 data sets).

Following the initial assessment of available data sets, a workshop was held on 17-18 November 2015 at the College of Charleston (SC). This workshop brought together a broader mix of carefully selected experts in biomedical (e.g., stress biomarkers, other indicators of mental and physical health, human microbiome), clinical (involved in assessing and treating disaster victims), and ecological (ecosystem services, ecosystem processes, biodiversity) sciences, as well as health scientists and ecologists with recent experience in or related to the Gulf of Mexico. The purpose of the workshop was to review the available data in the context of our conceptual DPSEERH modelling approach and identify existing data that can be used more effectively to assess health effects of disasters and potentially to validate our model. We asked workshop participants to focus on the following topics:

- 1) Consider the Gulf of Mexico human populations most likely to be vulnerable to disaster-related stress, based on differing levels of exposure and their interactions with and reliance on specific ecosystem services.
- 2) Identify and prioritize psychological and physiological health metrics that could be most readily extracted from existing data sources or collected de novo in the future to provide

- robust data regarding disaster effects and potential ameliorating effects of exposure to greenspace, natural areas and biodiversity.
- 3) Suggest nature/biodiversity metrics that could be extracted from existing data sources or collected to evaluate which elements of nature have the most significant effects on health outcomes and through what processes or mechanisms such effects may be mediated.
 - 4) Recommend how dose/response relationships may be investigated for exposures to disaster-impacted ecosystems services and to healthy environments.
 - 5) Design a case study-type evaluation of the conceptual model previously developed in this project using existing data.

While time constraints prevented full consideration of all these topics, a significant product of the workshop was the identification of the types of available data to support a future case study-type evaluation of the conceptual model previously developed in this project using existing data. These types of data include:

Health outcomes /stress impacts:

- Depression / PTSD
- Substance abuse
- CVD
- Inflammatory disease
- Adolescent behavior
- Gastrointestinal disorders (youth and elderly)
- Fibromyalgia
- Endocrine systems
- Reproductive /reproductive health
- Birth data
- Smoking

Sociodemographic / socioeconomic / community characteristics:

- Vulnerable populations
- Displacement
- Population changes and demographic shifts
- Race, sex, employment, education, poverty, ethnicity, marital status, income
- Crime / safety
- Mental health services
- Government intervention services
- Sense of place

Responses to ecosystem services impact:

- Fisheries / shellfish closures
- Consumption advisories
- Fisheries yields
- Seafood sales and consumption
- Tourism measures (including gambling)
- Unemployment

Environmental impacts on:

- Bacterial water quality – Swimming beaches and shellfish grounds
- Dolphins – Ingestion and inhalation
- Red snapper
- Shrimp
- Oysters

While not an initial funded objective of this project, the investigators recognize the importance of making the results of the data mining and assessment exercise, and the identification of data sets for inclusion in

the DPSEH, available to a broader audience. Project PIs are working with existing Gulf of Mexico data portal maintainers (e.g. Southeast Coastal Ocean Observing Regional Association) to provide access to the results of the data mining and assessment efforts.

INFORMATION PRODUCTS

Citations for project publications, reports and monographs, and workshop and conference proceedings:

No publications have yet been produced. As detailed below one paper has been submitted for consideration for publication and two presentations on project activities have been made at scientific meetings. More presentations are planned.

Other activities to ensure access to information products:

The investigator/participant team has submitted a manuscript, entitled “A Conceptual Model to Assess Stress-Associated Health Effects of Multiple Ecosystem Services Degraded by Disaster Events in the Gulf of Mexico and Elsewhere,” for journal consideration. We hope to make the publication open access, so that it is not only easily accessible but also can be uploaded to literature portals such as researchgate.net, individual investigator websites, and other portals for ease of discovery and acquisition. We also intend to distribute the paper via the national Sea Grant network, the Gulf of Mexico Research Initiative, and any other open portals that appear likely to be useful in getting the word out. Investigators will likely continue to make presentations at scientific conferences and workshops based on the project and individual follow-on activities, and one or more additional papers may be prepared later. The Principal Investigator has already given one invited address about the project’s conceptual model at the 2016 Gulf of Mexico Oil Spill & Ecosystem Science conference and a contributed platform presentation at the 2016 annual meeting of the Ecological Society of America. The project hosted two expert workshops that included a wide range of scientists, each of whom is now very familiar with the work and with project participants. If additional funding becomes available, the investigators would like to run one or more training workshops/webinars to demonstrate the utility of the model in pre-disaster planning exercises and perhaps develop an interactive web application based on the model. Knowledge gained in the project has led to new collaborations and proposals for follow-on activities and funding. The Principal Investigator has already received one small follow-on grant that is supporting development of a new graduate-level course on coastal ecosystem services and human health and preparation of a white paper on nature/biodiversity exposure and health. Co-investigators and workshop participants have submitted or are preparing proposals for NIEHS and NAS funding that would build on the DPSEH model and results from our second workshop, and some co-investigators are planning for new doctoral student research related to the model developed here.

Data Report										
<i>Italicized text are sample answers.</i>										
DataType: Select the option (from the dropdown) that best matches the data's domain or discipline (e.g., earth science data, ecological data, human health data)	DigitalResourceType: Select the option (from the dropdown) that best matches the resource format (e.g., data set, text, image or visual data, etc.)	Title: Provide a title for the resource	FileName: Provide the name of the digital file(s) (including file extension)	Creators: Provide the names of the persons who produced the resources (last name, first name; last name, first name; etc.)	Point of Contact: Provide person responsible for answering questions about the data if other than project PI	PublicationYear: Provide the year that the resource was published or made available	RepositoryName/Publisher: Provide the name of the digital repository or curation facility where the resource is archived and available	DOI or Persistent URL: Provide a persistent identifier for the resource's location	Dataset Keywords: Please list any keywords used to describe the resource.	Publications: Provide the DOI for any publication that uses or references this resource
DataType	DigitalResourceType	Title	FileName	Creators	PointofContact	PublicationYear	RepositoryName	DOI or Persistent URL	Keywords	Publications
<i>Physical and Computational Sciences</i>	<i>Tabular/Spreadsheet</i>	<i>Gravity Tests</i>	<i>GravityRawData.txt</i>	<i>Galieli, Galileo; Newton, Isaac</i>	<i>Lab Manager labmanager@science.edu 123-456-7890</i>	<i>1700</i>	<i>Really Big Digital Repoitory</i>	<i>doi: 10.1000/grav.1000</i>	<i>Gravity, object mass, force</i>	<i>doi: 10.1000/grav.1000.000, doi: 55.1097/science.4567</i>