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Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1340008
Project Title:	RAPID: Ecological Resistance of Multiply Stressed Populations: the response of tidal marsh birds and plants to Hurricane Sandy
PD/PI Name:	Brian Olsen, Principal Investigator Chris S Elphick, Co-Principal Investigator Greg Shriver, Co-Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	06/01/2013 - 05/31/2015
Reporting Period:	06/01/2014 - 05/31/2015
Submitting Official (if other than PD\PI):	N/A
Submission Date:	N/A
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	N/A

Accomplishments

* What are the major goals of the project?

This research was intended to provide a direct, quantitatively rigorous, assessment of Hurricane Sandy's impact on coastal ecosystems and advance our understanding of how major disturbances affect coastal marsh resilience. Scientific goals centered on two topics:

1. Distinguishing alternative models for the impact of accumulated stressors. Conventional theory suggests that the accumulation of stressors decreases a system's ability to withstand major perturbations (Folke et al. 2004. *Ann. Rev. Ecol., Evol., Syst.* 35:557-581.). Populations and communities subject to multiple anthropogenic impacts are thus predicted to be less resilient when faced with a large disturbance. This dogma, however, has been challenged by Côté and Darling (2010. *PLoS Biol* 8(7): e1000438) who question the link between vulnerability to climate-related disturbances and anthropogenic degradation, based on evidence from coral reefs. They propose an alternative model whereby accumulated impacts increase resilience by replacing the most vulnerable species/individuals with those more tolerant to perturbation. This new model has broad implications because it suggests a mechanism whereby actions designed to benefit a system, though perhaps helpful in the short term, may facilitate counterintuitive state-shifts over time.

2. Understanding spatial patterning of resilience. Large-scale disturbances are often assumed to have strong spatially autocorrelated effects, with important implications for extinction risk. A competing hypothesis is that local conditions matter and that spatial autocorrelation is disrupted by variation in resilience caused by local anthropogenic stressors. Distinguishing these alternatives has important repercussions for how catastrophic events are incorporated into population models. Using the extensive spatial resolution of our sampling scheme we tested whether (a) within-species impacts show strong spatial autocorrelation, (b) disturbance intensity explains the magnitude and spatial patterning of impacts, (c) alternative, chronic local stressors (fragmentation, urbanization, etc.) better explain spatial patterns, and (d) whether disturbance has spatially consistent community effects.

Broader impacts. In addition to our central scientific goals we anticipated substantial broader impacts of this research by providing land managers with the ability to prioritize specific tidal marshes for conservation and restoration better. This grant also was expected to provide a key bridge in research funding during the critical year immediately after Hurricane Sandy (2013), but before management agency funds associated with researching the storm's effects were available. Data collection in 2013 was considered particularly crucial given the existence of detailed data collected in the years immediately prior to the storm (2011-12).

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Bird and plant data collected in 2013, under RAPID funding, were compiled with data from 2011-12 and 2014 into a single comprehensive database, which will also serve as a platform for 2015-16 and any future data collection. Additional data describing the characteristics of each marsh patch across this region were compiled into a spatial GIS layer for use in describing potential stressors of marsh biota. Hierarchical models were then used to test for systematic changes in the bird and plant communities of tidal marshes from Virginia to Maine as a result of Hurricane Sandy's passage through the region, and to test whether biotic changes could be related to different stressors. Similar analyses were conducted using data from 2011-12 to test for an effect of Hurricane Irene, although these are far less conclusive due to the nature of the storm's path and limited spatial information on the magnitude of the storm surge.

Results from this study have been presented in 10 talks at scientific conferences and to various stakeholder groups, and preparation of several manuscripts is underway (see below). One PhD student associated directly with this project has completed her degree and two others are in their final year and have partially written dissertations. Four other PhD students from our collaborative group – all of whom have benefited from the work funded by the RAPID grant, but who were not directly involved with its data collection and analysis, have also completed their degrees.

Specific Objectives: Nothing to report.

Significant Results: Although large changes in marsh conditions have been reported anecdotally and in certain locations, we found little evidence for systematic, widespread effects of

Sandy on either vegetation communities or focal bird populations. This result lies in contrast to most published studies of the effects of hurricane disturbance on natural communities. Previous such efforts, however, are likely to be highly biased due to their post-hoc nature of investigation, whereby studies are likely to be (a) small-scale, (b) retrospective, and (c) biased towards places where effects are especially pronounced, because the appearance of change is likely to prompt research. Our study, in contrast, provided an unusual opportunity to examine disturbance systematically across the entire path of a storm, using pre-storm baseline data from a large number of locations (>1500) chosen via a rigorous two-step randomization process. Rather than producing a picture of widespread ecological change as a result of storm disturbance that is common from prior studies, our results suggest high ecological resistance to change. Clearly, this result does not mean that substantial ecological changes do not occur at small spatial scales, but it reinforces the idea that these are localized effects and that ecological communities are robust even to natural disturbance events that appear highly destructive.

A second key finding of this research is that the documented resistance to change was not limited to “high quality” marshes. We found no effect of potential anthropogenic stressors (rate of sea-level rise, amount of marsh cover in landscape, amount of urbanization in landscape, marsh patch size) on the magnitude of any storm-related change, suggesting that sites that are highly modified due to human activities are no more affected than those that are not. Similarly, we found no evidence for the converse expectation: that sites that are protected would be more resistant to change. Nonetheless, we did find evidence that vegetation changed more in areas where the rate of sea-level rise is greater, with a shift towards plant communities that are found in wetter conditions. This result is consistent with other research being conducted by our group, which shows substantial change in this direction, consistent across multiple marsh systems, since 2002 (Field et al. manuscript in review). That such a change was detectable in our comparison of data from 2012 and 2013, gives high confidence that we have adequate sampling to have detected any similar changes caused by the storm. Such sea-level changes in marsh conditions have serious repercussions for the viability of saltmarsh-nesting birds that are vulnerable to tidal flooding. Moreover, they are likely to have a large influence on the nature and magnitude of other ecosystem services provided by coastal marshes.

We found that residual spatial autocorrelation at the < 1 km scale had a greater effect than any of our other variables examined for all vegetation variables and bird species. We did not, however, find evidence that this spatial patterning was explained by disturbance intensity (i.e., storm surge) or by any of the chronic anthropogenic stressors examined. We also found little evidence for community-wide disturbance effects, with only weak correlations among species.

Key outcomes or
Other achievements:

In addition to the short-term scientific goals outlined under “Significant Results” (above), this project has had several important outcomes related to long-term coastal management. As a direct result of our comprehensive baseline and RAPID post-storm data, we received funding from the U.S. Fish and Wildlife Service (USFWS) through the Hurricane Sandy Recovery and Resilience program to obtain a fourth year (2014) of survey data at all of the sites sampled for this RAPID grant. We received additional funding to use our sampling platform as the basis for evaluating the efficacy of restoration activities planned on National Wildlife Refuges and non-federal other sites. With these funds we are sampling most sites where 2013 Disaster Relief Appropriations Act funds are being used to

conduct coastal marsh management. This sampling is designed to provide before-after, control-impact information at all sites using the standardized protocols we have developed (see Products, below) in order to examine the effects of large-scale tidal marsh manipulations in a semi-experimental/adaptive management framework. Wherever possible we have used existing sample points from our 2011-14 sampling as control points for the experimental sites in order to further expand our time series on ecological change in coastal marshes. To date we have funding for 2015 and 2016 to extend this work, and we will seek additional funding to further develop our data sets in order to test questions relating to long-term change in this system. In particular, we plan to use this data platform (a) to test for any longer-term storm effects not apparent via the short-term analysis made possible through this RAPID grant, and (b) to assess the long-term consequences of sea-level rise on coastal marsh ecosystems along the eastern seaboard of the US.

A second important outcome of the work we have recently completed has been the development of plans to expand systematic regional research throughout the Atlantic and Gulf coast states. These plans take two forms. First, the creation of a working group focused on developing plans to expand the region covered by our systematic surveys to include eastern states south of Virginia. The focus of this working group is to expand baseline sampling of vegetation and breeding birds during the summer, and to develop field protocols to enable parallel work during the winter for migratory bird species. Second, we have initiated a systematic assessment of the conservation status of bird populations that rely on eastern salt marshes. We have completed an assessment of threats faced by these species, using an approach developed by the International Union for Conservation of Nature and Natural Resources, and are in the process of identifying appropriate and cost-effective actions that can be used to address these threats. For more details see http://www.tidalmarshbirds.org/?page_id=1682.

*** What opportunities for training and professional development has the project provided?**

We hired and trained 19 field technicians in field ecological research. Further, the project has provided ecological, supervisory, and analytical training for three Ph.D. students (Maureen Correll at the University of Maine, Whitney Wiest at the University of Delaware, and Chris Field at the University of Connecticut), and support in the development of one early career investigator (Brian Olsen, University of Maine).

As a result of this grant we ran a multi-institution on-line graduate seminar on ecological resilience in 2013, in which 9 graduate students from four universities (University of Connecticut, University of Delaware, University of Maine, and University of New Hampshire) participated. In 2014, we ran a second course focused on quantitative methods employed by members of our larger tidal marsh ecology research group, which included students working on this grant. Fourteen students from five institutions (University of Connecticut, University of Delaware, University of Maine, and University of New Hampshire, State University of New York – College of Environmental Science and Forestry) participated in this second course.

In addition to formal training, graduate students involved in this grant participated in all aspects of project development and execution including full participation in: weekly conference calls between the different institutions and agency partners; annual 2-day meetings for all members of our larger research group, which involve faculty and students from 5 universities, and at which students present their work and help plan research for the forthcoming field season; conference symposia organized by the project PIs; a workshop focused on setting conservation priorities for eastern North American tidal marsh birds; a USFWS-sponsored workshop for all researchers engaged in research linked to Hurricane Sandy and improved coastal resilience; and several 1-2 day “writing sessions” focused on manuscript development for our larger research program.

*** How have the results been disseminated to communities of interest?**

Results of this work have been presented at international scientific conferences focused on wetlands (Society for Wetland Scientists, 2015, Providence) and conservation biology (International Congress for Conservation Biology, 2015, Montpellier, France), at regional conferences focused on bird conservation (Partners in Flight Joint Meeting, 2014, Virginia Beach) and management (Atlantic Coast Joint Venture meetings, 2013, Mystic and 2015, Albany), and at specialized local meetings focused on saltmarsh ecology (LTER all scientists meeting, Woods Hole, 2015) and on Hurricane Sandy and coastal resilience (USFWS, Hadley, 2014). In addition, our results have been conveyed to a wide variety of conservation and management organizations, including Federal and state agencies, nongovernmental conservation organizations and land trusts, and private landowners, through various informal communications (including targeted invitations to join our weekly project conference calls) and via PI and student participation on various science advisory and other committees.

Information about our overall research program is widely disseminated to the broader public via our project web site (www.tidalmarshbirds.org), blog (<http://www.tidalmarshbirds.org/?cat=134>), Facebook page (<https://www.facebook.com/TidalMarshBirds>), and Twitter (#SHARPbirds). Our work has also been featured on the PBS Nature show Animal Homes (<http://www.pbs.org/wnet/nature/animal-homes/11674/>), on the children's television show Aquakids (<https://www.youtube.com/watch?v=L6DPkRHmjCE&feature=youtu.be&app=desktop>), in articles on the USFWS's web site (e.g., <https://usfwsnortheast.wordpress.com/2014/08/07/looking-sharp-students-salt-marshes-and-that-elusive-sparrow/>), and via multiple newspaper articles.

Products

Books

Book Chapters

Conference Papers and Presentations

Shriver, WG, and WA Wiest (2014). (*invited talk*) *Indices of tidal marsh integrity and resiliency: marsh indices and optimizing tidal marsh conservation value..* Hurricane Sandy Marsh Resiliency Working Group Workshop. Hadley, MA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shriver, WG, WA Wiest and K. Chadbourne (2014). (*invited talk*) *Metrics, protocols, and data management for assessing tidal marshes in National Wildlife Refuges and SHARP..* Hurricane Sandy Marsh Resiliency Working Group Workshop. Hadley, MA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick, C.S. (2013). (*invited talk*) *SHARP: history, current status and future directions.* Annual meeting, Atlantic Flyway Council. Mystic, CT, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick, C.S., J. Cohen, T. Hodgman, A. Kovach, B. Olsen, G. Shriver, M. Correll, C. Field, R. Kern, K. Ruskin, and W. Wiest (2015). (*invited talk*) *SHARP: overview of survey and demography results..* Summer meeting, Atlantic Coast Joint Venture. Albany, NY, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick CS, J Cohen, T Hodgman, A Kovach, B Olsen, and G Shriver (2015). (*invited talk*) *The Saltmarsh Habitat and Avian Research Program's Hurricane Sandy research.* All scientists meeting, Plum Island Ecosystems LTER. Woods Hole, MA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick CS, CR Field, WA Wiest, MD Correll, WG Shriver, TP Hodgman, JB Cohen, AI Kovach, and BJ Olsen (2015). (*invited talk*) *Using the Saltmarsh Habitat and Avian Research Program sampling framework to study resistance, restoration, and resilience following Hurricane Sandy..* Annual meeting, Society of Wetland Scientists. Providence, Rhode Island, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick, C.S., and C. Field (2014). (*invited talk*) *Wetland change after Hurricane Sandy..* Hurricane Sandy Marsh Resiliency Working Group Workshop. Hadley, MA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Correll, MD, BJ Olsen, TP Hodgman, W Wiest, WG Shriver (2014). *A regional change comparison of obligate and*

non-obligate birds in tidal marshes of the North Atlantic.. Joint Meeting of the American Ornithologists' Union, Cooper Ornithological Society, and the Society for Canadian Ornithology.. Estes Park, CO, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Correll, MD, WA Wiest, TP Hodgman, WG Shriver, BJ Olsen (2015). *A sliding scale of habitat specialization in tidal marsh birds of the Northeastern United States*. 39th Annual Meeting of the Waterbird Society. Bar Harbor, ME, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wiest, W, MD Correll, BJ Olsen, TP Hodgman, CS Elphick, D Curson, and WG Shriver (2015). *Estimating tidal marsh bird population sizes and identifying priority areas for conservation in the Northeast USA*. Joint Conference of the Association of Field Ornithologists, the Wilson Society of Ornithology, and the Society of Canadian Ornithologists / Société des ornithologistes du Canada. Wolfville, Nova Scotia, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick, CS, CR Field, WA Wiest, MD Correll, WG Shriver, TP Hodgman, and BJ Olsen (2015). *Resistance of coastal marsh ecosystems to large-scale perturbations: Regional effects of Hurricane Sandy on saltmarsh vegetation and bird populations in the Northeastern USA*. Biennial meeting, International Congress for Conservation Biology. Montpellier, France. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Correll, MD, WA Wiest, TP Hodgman, WG Shriver, CS Elphick, and BJ Olsen (2015). *Specialist avifaunal collapse in northeastern tidal marshes*. Joint Conference of the Association of Field Ornithologists, the Wilson Society of Ornithology, and the Society of Canadian Ornithologists / Société des ornithologistes du Canada. Wolfville, Nova Scotia, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shriver, WG, WA Wiest, MD Correll, BJ Olsen, CS Elphick, TP Hodgman, JB Cohen, and CR Field (2014). *The SHARP sampling framework: inventory and monitoring tidal marsh birds in the Northeast*.. Northeast and Southeast Partners in Flight joint meeting. Virginia Beach, VA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Correll, MD, WA Wiest, TP Hodgman, WG Shriver, CS Elphick, K O'Brien, BJ Olsen (2015). *Tidal restriction drives specialist avifaunal collapse in northeastern tidal marshes*. 39th Annual Meeting of the Waterbird Society. Bar Harbor, ME, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elphick, CS, CR Field, MD Correll, WA Wiest, JB Cohen, TP Hodgman, AI Kovach, BJ Olsen (2014). *Using the SHARP sampling framework to quantify the effects of Hurricane Sandy on coastal marshes and the efficacy of post-Sandy restoration actions*.. Northeast and Southeast Partners in Flight joint meeting. Virginia Beach, VA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

Correll, MD, WA Wiest, TP Hodgman, WG Shriver, CS, Elphick, BJ McGill, K O'Brien, and BJ Olsen. (2015). Tidal restriction drives specialist avifaunal collapse in northeastern tidal marshes.. *PNAS - Sustainability*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Elphick, CS, CR Field, WA Wiest, MD Correll, WG Shriver, TP Hodgman, and BJ Olsen (). High resistance of salt marshes to hurricane disturbance irrespective of chronic stressors or land protection.. (*Manuscript in early development*). . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wiest, WA, MD Correll, BG Marcot, BJ Olsen, CS Elphick, TP Hodgman, GR Guntenspergen, and WG Shriver (2015). A Bayesian approach for estimating tidal marsh bird distributions and identifying priority areas for conservation. *Manuscript complete, submission anticipated soon to "Biological Conservation"*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wiest, WA, MD Correll, BJ Olsen, CS Elphick, TP Hodgman, DR Curson, and WG Shriver (2015). A regional monitoring framework for estimating the distribution and abundance of tidal marsh birds in the Northeast USA.

Submitted to The Condor: Ornithological Applications, revision invited. . Status = UNDER_REVIEW;
Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses

Other Products

Databases.

In spring 2015, our joint research group began work to develop a consistent, comprehensive, database that contains all avian and vegetation survey data collected by our group between 2011 and the present. The Microsoft SQL Server database is linked to a web-based data entry form to allow individuals to enter future data into a web form and have it committed directly to the multi-year database. We have also created a Microsoft Access 2013 database with connections to all the SQL tables in the new database. The interface was created using a framework called “Bootstrap” that enables the automatic scaling of the webpage from phone to desktop monitor size screens (see <http://getbootstrap.com/>). Long-term data storage will occur on an SQL server located at the University of Maine and the database will be linked directly to our program web site (www.tidalmarshbirds.org). All hard copy data (field forms) have been photocopied, scanned as PDF, and stored with the USFWS Region 5 Inventory & Management data manager and at the University of Delaware. Recently, we entered into discussions with the National Park Service (NPS), which is interested in using our database for the management and storage of data from their tidal marsh surveys.

Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).

We generated a spatially explicit GIS layer from Virginia to Maine to define salt marsh patches using the National Wetlands Inventory Estuarine Intertidal Emergent Wetland (code ‘E2EM’) designation. We chose patch features that are known to influence bird species distribution and abundance and that can be obtained from remote-sensing data for the entire Northeast. We recorded 22 covariates at four spatial scales for each of 13,332 defined patches: location and dimension, land use land cover, geomorphic setting, sea level trend, and human disturbance. The salt marsh patch layer attribute table is populated with values for all 22 co-variates and can be used by salt marsh managers and conservationists to estimate these features in a regionally consistent way. We have also estimated avian abundance for 27 species in each sampled patch and used a Bayes Net to predict the abundance of our focal species in all patches.

Protocols.

All of the data collection methods used in this project, and by our research group, have been formalized as standard operating procedures (SOPs) and posted on our program web site: (http://www.tidalmarshbirds.org/?page_id=131).

Many of these SOPs are now used by other investigators and some have been downloaded 100s of times (see web link above, for details). The SOPs for the survey portions of our work (i.e., those that relate most closely to the RAPID grant) now form the basis for tidal marsh monitoring at 100s of locations throughout the Northeast and Mid-Atlantic regions, including on most coastal National Wildlife Refuges and at many others sites where Hurricane Sandy relief funding is being used for coastal marsh management and restoration.

Other Publications

Hodgman, T., C. Elphick, B. Olsen, G. Shriver, A. Kovach, J. Cohen. (2014). *The Saltmarsh Habitat and Avian Research Program: Compiled overview report for the 2013 field season.*. Annual report (16 pp.) of research activities published on research group website (<http://www.tidalmarshbirds.org>). Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hodgman, T., C. Elphick, B. Olsen, G. Shriver, A. Kovach, J. Cohen. (2015). *The Saltmarsh Habitat and Avian Research Program: Compiled overview report for the 2014 field season.* Annual report (28 pp.) of research activities published on research group website (<http://www.tidalmarshbirds.org>). Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hodgman, T., C. Elphick, B. Olsen, G. Shriver. (2015). *The conservation of tidal marsh birds: Guiding action at the*

intersection of our changing land and seascapes.. Final report to the U.S. Fish and Wildlife Service regarding the status of tidal marsh bird populations in the northeastern US states (160 pp).. Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes

Patents

Technologies or Techniques

Thesis/Dissertations

Wiest, W.A.. *Tidal marsh bird conservation in the Northeast, USA*. (2015). University of Delaware. Acknowledgement of Federal Support = Yes

Websites

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Olsen, Brian	PD/PI	3
Elphick, Chris	Co PD/PI	3
Shriver, Greg	Co PD/PI	3
Hodgman, Thomas	Co-Investigator	3
Boettcher, Ruth	Other Professional	1
Castelli, Paul	Other Professional	1
Davis, Christina	Other Professional	1
Denmon, Pam	Other Professional	1
Elbin, Susan	Other Professional	1
Farina, Michael	Other Professional	1
Guiteras, Susan	Other Professional	1
Hanlon, Heidi	Other Professional	1
Holcomb, Kevin	Other Professional	1
Iaquinto, Kate	Other Professional	1
Johnson, Luanne	Other Professional	1
Kalasz, Kevin	Other Professional	1

King, Erin	Other Professional	1
Larson, Annie	Other Professional	1
O'Brien, Kate	Other Professional	1
Papa, Steve	Other Professional	1
Pau, Nancy	Other Professional	1
Ries, Lindsey	Other Professional	1
Rogers, Derek	Other Professional	1
Sewall, Laura	Other Professional	1
Smith, Rhonda	Other Professional	1
Whitbeck, Matt	Other Professional	1
Zitani, Brian	Other Professional	1
Coffee, Julie	Technician	3
Comeau, Ellen	Technician	3
Davis, Glen	Technician	3
Ferguson, Taylor	Technician	3
Freiday, Tim	Technician	3
Garretson, Alex	Technician	3
Hojnacki, Kaytee	Technician	3
Inserillo, Daniel	Technician	3
Levandowski, Matt	Technician	3
Levy, Charlotte	Technician	3
Liberati, Mauri	Technician	3
Munafo, Kristin	Technician	3
Santillo, Dave	Technician	3

Sheridan, Ross	Technician	3
Stevenson, Lindsay	Technician	3
Szura, Katelyn	Technician	3
van Boer, Alex	Technician	3
West, Chris	Technician	4
Whalen, Michael	Technician	3
Young, Emma	Technician	3
Giblin, Anne	Staff Scientist (doctoral level)	1
Chris, Field	Graduate Student (research assistant)	12
Correll, Maureen	Graduate Student (research assistant)	12
Walsh, Jen	Graduate Student (research assistant)	3
Wiest, Whitney	Graduate Student (research assistant)	12
Abbott, Darryl	Undergraduate Student	6
Lefave, Sarah	Undergraduate Student	6
Masi, Madison	Undergraduate Student	6

Full details of individuals who have worked on the project:

Brian Olsen

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Most Senior Project Role: PD/PI

Nearest Person Month Worked: 3

Contribution to the Project: Idea formulation, research design, field work supervision, manuscript drafting and editing.

Funding Support: UMaine, US Fish and Wildlife Service, USDA

International Collaboration: No

International Travel: No

Chris S Elphick

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Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 3

Contribution to the Project: Idea formulation, research design, field work supervision, manuscript drafting and editing.

Funding Support: UConn, US Fish and Wildlife Service, NOAA, Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Greg Shriver

Email: gshriver@udel.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 3

Contribution to the Project: Idea formulation, research design, field work supervision, manuscript drafting and editing.

Funding Support: UDelaware, US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Thomas Hodgman

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Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 3

Contribution to the Project: Supervised field efforts, assisted in manuscript writing and editing.

Funding Support: Maine Department of Inland Fisheries and Wildlife

International Collaboration: No

International Travel: No

Ruth Boettcher

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: VA DGIF

International Collaboration: No

International Travel: No

Paul Castelli

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: USFWS - Forsythe NWR

International Collaboration: No

International Travel: No

Christina Davis

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: NJ ENSP

International Collaboration: No

International Travel: No

Pam Denmon

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: USFWS - Eastern Shore VA NWR

International Collaboration: No

International Travel: No

Susan Elbin

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in New York Harbor

Funding Support: New York City Audubon

International Collaboration: No

International Travel: No

Michael Farina

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Long Island, New York

Funding Support: Town of Hempsted, New York

International Collaboration: No

International Travel: No

Susan Guiteras

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: USFWS - Bombay Hook NWR

International Collaboration: No

International Travel: No

Heidi Hanlon

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: USFWS - Cape May NWR

International Collaboration: No

International Travel: No

Kevin Holcomb

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: USFWS - Chincoteague NWR

International Collaboration: No

International Travel: No

Kate Iaquinto

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Luanne Johnson

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Martha's Vineyard, Massachusetts

Funding Support: Biodiversity Works

International Collaboration: No

International Travel: No

Kevin Kalasz

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Delaware

Funding Support: Delaware NREC

International Collaboration: No

International Travel: No

Erin King

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Annie Larson

Email: Annabella_Larson@fws.gov

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: USFWS - Prime Hook NWR

International Collaboration: No

International Travel: No

Kate O'Brien

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Steve Papa

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Long Island, New York

Funding Support: US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Nancy Pau

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics and data collection

Funding Support: US Fish and Wildlife Service

International Collaboration: No

International Travel: No

Lindsey Ries

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Long Island, New York

Funding Support: National Park Service

International Collaboration: No

International Travel: No

Derek Rogers

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Collected plant and bird community data in Long Island, New York

Funding Support: The Nature Conservancy

International Collaboration: No

International Travel: No

Laura Sewall**Email:** lsewall@bates.edu**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 1**Contribution to the Project:** Field logistics**Funding Support:** Bates College**International Collaboration:** No**International Travel:** No**Rhonda Smith****Email:** rhonda_smith@fws.gov**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 1**Contribution to the Project:** Field logistics and data collection**Funding Support:** US Fish and Wildlife Service**International Collaboration:** No**International Travel:** No**Matt Whitbeck****Email:** matt_whitbeck@fws.gov**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 1**Contribution to the Project:** Field logistics**Funding Support:** USFWS - Blackwater NWR**International Collaboration:** No**International Travel:** No**Brian Zitani****Email:** enb@dec.ny.gov**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 1**Contribution to the Project:** Collected plant and bird community data in Long Island, New York**Funding Support:** Town of Babylon, New York**International Collaboration:** No**International Travel:** No**Julie Coffee****Email:** jcoffey35@gmail.com**Most Senior Project Role:** Technician**Nearest Person Month Worked:** 3

Contribution to the Project: Collected plant and bird community data in Cape Cod, Massachusetts

Funding Support: this grant

International Collaboration: No

International Travel: No

Ellen Comeau

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in Midcoast Maine

Funding Support: this grant

International Collaboration: No

International Travel: No

Glen Davis

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Taylor Ferguson

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in Southern Maine

Funding Support: this grant

International Collaboration: No

International Travel: No

Tim Freiday

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Alex Garretson

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Kaytee Hojnacki

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in Northern Massachusetts

Funding Support: this grant

International Collaboration: No

International Travel: No

Daniel Inzerillo

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Long Island Sound

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Matt Levandowski

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Charlotte Levy

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Long Island Sound

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Mauri Liberati

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data throughout the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Kristin Munafo

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Dave Santillo

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data throughout New England

Funding Support: this grant

International Collaboration: No

International Travel: No

Ross Sheridan

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Mid-Atlantic

Funding Support: this grant

International Collaboration: No

International Travel: No

Lindsay Stevenson

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in Northern Massachusetts

Funding Support: this grant

International Collaboration: No

International Travel: No

Katelyn Szura

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in Rhode Island

Funding Support: this grant

International Collaboration: No

International Travel: No

Alex van Boer

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Long Island Sound

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Chris West

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Most Senior Project Role: Technician

Nearest Person Month Worked: 4

Contribution to the Project: Collected plant and bird community data in Northern Maine

Funding Support: this grant

International Collaboration: No

International Travel: No

Michael Whalen

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Long Island Sound

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Emma Young

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Collected plant and bird community data in the Long Island Sound

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Anne Giblin

Email: agiblin@mbi.edu

Most Senior Project Role: Staff Scientist (doctoral level)

Nearest Person Month Worked: 1

Contribution to the Project: Field logistics

Funding Support: Marine Biological Laboratory, Woodshole, MA

International Collaboration: No

International Travel: No

Field Chris

Email: chrisfield22@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 12

Contribution to the Project: Developing hierarchical Bayesian model to predict marsh resilience and assisted with training and supervision of field technicians in Connecticut and New York.

Funding Support: Connecticut Department of Energy and Environmental Protection

International Collaboration: No

International Travel: No

Maureen Correll**Email:** maureen.correll@maine.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 12**Contribution to the Project:** Trained and supervised all field technicians and surveys conducted from Maine to New York and ran QA/QC on data**Funding Support:** NSF IGERT, US Fish and Wildlife Service**International Collaboration:** No**International Travel:** No**Jen Walsh****Email:** jlw27@wildcats.unh.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 3**Contribution to the Project:** Collected plant and bird community data in New Hampshire**Funding Support:** UNH, US Fish and Wildlife Service**International Collaboration:** No**International Travel:** No**Whitney Wiest****Email:** wwiest@udel.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 12**Contribution to the Project:** Trained and supervised all field technicians and surveys conducted from New Jersey to Virginia and ran QA/QC on data**Funding Support:** US Fish and Wildlife Service**International Collaboration:** No**International Travel:** No**Darryl Abbott****Email:** Darryl_Abbott@umit.maine.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 6**Contribution to the Project:** Assisted in QA/QC of data**Funding Support:** this grant**International Collaboration:** No**International Travel:** No**Sarah Lefave****Email:** Sarah_Lefave@umit.maine.edu

Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 6

Contribution to the Project: Assisted in QA/QC of data

Funding Support: this grant

International Collaboration: No
International Travel: No

Madison Masi

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Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 6

Contribution to the Project: Assisted in QA/QC of data.

Funding Support: this grant

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Audubon Society	Other Nonprofits	Various State Chapters
Bates College	Academic Institution	Lewiston, ME
Town of Hempsted	State or Local Government	Hempsted, New York
US Fish and Wildlife Service - Region 5	Other Organizations (foreign or domestic)	Hadley, Massachusetts
University of New Hampshire	Academic Institution	Durham, New Hampshire
Virginia Department of Game and Inland Fisheries	State or Local Government	Richmond, VA
Connecticut Dept. of Energy and Environmental Protection	State or Local Government	Hartford, CT
Delaware Dept. of Natural Resources & Environmental Control	State or Local Government	Dover, DE
Maine Department of Inland Fisheries and Wildlife	State or Local Government	Bangor, Maine
Marine Biological Laboratory	Academic Institution	Woodshole, MA

National Park Service - Northeast Region	Other Organizations (foreign or domestic)	Philadelphia, Pennsylvania
New Jersey Division of Fish and Wildlife	State or Local Government	Trenton, NJ
The Nature Conservancy	Other Nonprofits	Various State Chapters
Town of Babylon	State or Local Government	Babylon, New York

Full details of organizations that have been involved as partners:

Audubon Society

Organization Type: Other Nonprofits

Organization Location: Various State Chapters

Partner's Contribution to the Project:

Financial support

Facilities

Collaborative Research

More Detail on Partner and Contribution: Assisted with surveys, field logistics, and funded a field technician.

Bates College

Organization Type: Academic Institution

Organization Location: Lewiston, ME

Partner's Contribution to the Project:

Facilities

More Detail on Partner and Contribution: Field housing

Connecticut Dept. of Energy and Environmental Protection

Organization Type: State or Local Government

Organization Location: Hartford, CT

Partner's Contribution to the Project:

In-Kind Support

Collaborative Research

More Detail on Partner and Contribution: Assisted with field surveys and logistics.

Delaware Dept. of Natural Resources & Environmental Control

Organization Type: State or Local Government

Organization Location: Dover, DE

Partner's Contribution to the Project:

Facilities

Collaborative Research

More Detail on Partner and Contribution: Conducted field surveys and assisted with field logistics.

Maine Department of Inland Fisheries and Wildlife

Organization Type: State or Local Government

Organization Location: Bangor, Maine

Partner's Contribution to the Project:

In-Kind Support

Collaborative Research

More Detail on Partner and Contribution:

Marine Biological Laboratory

Organization Type: Academic Institution

Organization Location: Woodshole, MA

Partner's Contribution to the Project:

Facilities

More Detail on Partner and Contribution: Assisted with field housing

National Park Service - Northeast Region

Organization Type: Other Organizations (foreign or domestic)

Organization Location: Philadelphia, Pennsylvania

Partner's Contribution to the Project:

In-Kind Support

Facilities

More Detail on Partner and Contribution: NPS provided housing, access to marshes, and advice at many locations with federally owned land.

New Jersey Division of Fish and Wildlife

Organization Type: State or Local Government

Organization Location: Trenton, NJ

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Assisted with surveys and field logistics.

The Nature Conservancy

Organization Type: Other Nonprofits

Organization Location: Various State Chapters

Partner's Contribution to the Project:

In-Kind Support
Facilities
Collaborative Research

More Detail on Partner and Contribution: Assisted with field surveys and logistics.

Town of Babylon

Organization Type: State or Local Government
Organization Location: Babylon, New York

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Employees of the town surveyed marshes in their jurisdiction.

Town of Hempsted

Organization Type: State or Local Government
Organization Location: Hempsted, New York

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Employees of the town surveyed marshes in their jurisdiction.

US Fish and Wildlife Service - Region 5

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Hadley, Massachusetts

Partner's Contribution to the Project:

In-Kind Support
Facilities

More Detail on Partner and Contribution: USFWS provided housing, access to marshes, and advice at many locations with federally owned land.

University of New Hampshire

Organization Type: Academic Institution
Organization Location: Durham, New Hampshire

Partner's Contribution to the Project:

In-Kind Support

More Detail on Partner and Contribution: Researchers from UNH assisted with surveys in New Hampshire and southern Maine marshes.

Virginia Department of Game and Inland Fisheries

Organization Type: State or Local Government

Organization Location: Richmond, VA

Partner's Contribution to the Project:

In-Kind Support

Collaborative Research

More Detail on Partner and Contribution: Assisted with surveys and field logistics

What other collaborators or contacts have been involved?

Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The biggest impact of this work will likely be to provide one of the most objective assessments of the regional effects of major storms on an ecological system to date. Most studies of large-scale disturbances, such as hurricanes, have to be conducted retrospectively because one cannot predict exactly when or where the disturbance will occur. Moreover, it is rare to have adequate baseline data to investigate the ecological effects over large spatial scales, and assessments tend to lack either baseline (pre-storm) data or be limited to locations that were chosen for some other research purpose. Consequently, it is rarely possible to know whether study sites are representative, and it is likely that they are often not. Given the nature of our initial study design (randomly selected sites than span >1400 km of coastline), our high sampling rate (>1500 locations), and that we have baseline sampling from immediately prior to the storm, our study avoids these problems and allows us to eliminate the biases inherent to most ecological studies of major storm effects.

Our discovery that Sandy had no widespread effects on either dominant tidal marsh vegetation or on the populations of specialist saltmarsh birds, and that change in these ecological variables was not related to the magnitude of the storm's effect, demonstrates the resilience of these systems to natural disturbances of this type. Moreover, our finding that storm surge effects on ecological variables were not magnified by anthropogenic stressors or lessened by land protection, provides additional insight into the ecological resistance of this system. This last result is especially important to land managers as it suggests that even small, fragmented marshes in urban settings can support resistant ecosystems and should be considered a valuable component of conservation portfolios.

In contrast, our discovery that marsh vegetation changes are associated with local rate of sea-level rise, with only a 2-year comparison, suggests that there are limits to the resilience of coastal marshes. The data suggest that we can anticipate that future sea-level rise, especially if the rate accelerates, will result in widespread shifts to lower-elevation marsh habitats. This discovery is consistent with results from other, longer-term, studies that we are conducting, and has substantial implications for the persistence of species that require higher elevation marsh to breed (e.g., ground nesting birds).

What is the impact on other disciplines?

The main impact of this project on other disciplines is likely to emanate from the data sets we have produced. Our ecological data will be of value to other scientists seeking to build inter-disciplinary bridges to ecology. Because our data were collected with standardized protocols over a large region and have moderately high spatial resolution, the potential for overlap with work being done by others is high. As evidence, we have received multiple requests for data, either for specific locations (e.g., a given National Wildlife Refuge) or for portions of the region over which we work (e.g., Long Island Sound). These requests come largely from regulatory agencies or conservation organizations, but have also come from researchers in scientific disciplines other than ecology (e.g., physical oceanography, coastal geomorphology) seeking to combine ecological data with other sources of information (e.g., in the context of

quantifying wetland vulnerability or assessing ecosystem services). Similarly, the spatial data layers we have generated encompass a variety of non-ecological variables that are likely to be of use to researchers in other fields (e.g., coastal geomorphology, coastal policy and planning).

What is the impact on the development of human resources?

The direct training provided by this grant is expected to have substantial benefits for conservation. The first of three PhD students trained through this grant has completed her dissertation and was immediately hired by the USFWS to help manage endangered species, including those found in coastal marshes. A second student funded through our larger research program has also been hired by USFWS into a wildlife management position, while two others obtained academic postdoctoral positions before finishing their PhDs to build on their dissertation research. All four of these students are female. We anticipate that additional students trained through this grant will follow this path and contribute prominently in both the research and management realms.

An additional human resources impact of this work is that we trained 19 early career (undergraduate or recently-graduated) field technicians using RAPID funds. These technicians join >100 similar technicians trained through our research program since 2011, many of whom contributed to the data collection used in this study.

Through our extensive interactions with land management and wildlife conservation practitioners, we have provided considerable informal education about the ecological consequences of disturbance and coastal ecosystem resilience. We have provided additional information of this type through our interactions with school groups, TV productions, and the lay public.

What is the impact on physical resources that form infrastructure?

Nothing to report.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

This project has contributed importantly to the development of baseline data sets required to assess future change in coastal ecosystems, to standardized field protocols that are being widely used for data collection in both our study and by others, and to ongoing efforts to expand standardized baseline data collection in coastal areas throughout the eastern United States.

Additionally, the project has contributed to collaborative work between federal agencies (USFWS, NPS) and our group to develop online databases that will act as a repository for all of our data collection (both from this grant and others). These databases will make information available to management agencies, and will facilitate both new data entry and data retrieval. The systematic collection and unified storage of such data is especially valuable in light of the federal government's substantial investment in coastal recovery and restoration actions following Hurricane Sandy.

What is the impact on technology transfer?

The main form of technology transfer emanating from this project is through our work to make data collected at our survey points fully available to government agencies for coastal planning purposes. We have developed, through extensive and ongoing consultation with the USFWS, an online database to house all of the data we have collected during this project and others. This database will be used for our future data collection and we have recently been approached by the NPS, which is interested in taking advantage of this infrastructure for archiving its own tidal marsh survey data. This database is new (final development is still underway, as it is funded through multiple grants), but we anticipate additional benefits as it becomes fully functional.

What is the impact on society beyond science and technology?

The societal impacts of this research go well beyond science and technology per se. Our results can be expected to influence policy relating to coastal management, especially our evidence that sea-level rise is changing the vegetation of coastal marshes. This result, coupled with our other research, is already playing a role in multiple federal and state agency discussions centered on the decline and endangerment of tidal marsh specialist species. Placing (often substantial) declines in species populations caused by human activities in the context of high resilience to natural disturbances such as hurricanes reinforces the notion that humans are dramatically altering coastal ecosystems, which is expected to influence coastal planning decisions. Indeed, we are already using data collected during this project, in conjunction with other data sets we have developed, as part of coast-wide conservation planning exercises designed to determine not only how best to protect natural resources, but also how to do so in the most cost-effective manner. Further, the ecosystem resilience we demonstrate here stands in stark contrast to the lack of resilience evidenced by built infrastructure in the same region from the same storm. In light of this difference, our results underscore the importance of maintaining and expanding coastal marshes as green infrastructure to protect coastal towns and cities.

Changes/Problems

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.