Measuring Impacts of Invasive European Green Crabs on Maine Salt Marshes: A Novel Approach

Report to the Maine Outdoor Heritage Fund

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Wells National Estuarine Research Reserve

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Wells National Estuarine
Research Reserve

This project was made possible by the generous support of our partners.

Cover Illustration by Jim Dochterman

Deterioration of marsh peat observed in 2014 in the Webhannet River marsh in Wells, Maine.

Introduction

Invasive European green crab (*Carcinus maenas*) populations have exploded state-wide and threaten Maine's valuable coastal resources, including soft-shell clam flats, sub-tidal eel grass beds, and salt marshes (Trotter 2013). Salt marshes are a vital part of Maine's coast, providing nursery habitat for commercially and recreationally important shellfish and finfish, providing essential habitat for migratory birds and other species, improving water quality by intercepting storm-water run-off, and protecting coastal infrastructure from erosion by large storms, among other ecosystem services. In some areas of Maine's coast that have elevated green crab numbers, anecdotal observations have linked green crab burrowing to pronounced salt marsh erosion and loss. Until now these observations have not been validated in the field through rigorous scientific measurements.

Geography and Methods

This study measures green crab abundance and erosional impacts at three salt marshes in York County (Webhannet River in Wells), Cumberland County (Broad Cove in Yarmouth), and Lincoln County (Day Cove in Damariscotta) (Figure 1). We selected marsh study sites based on (a) degree of perceived green crab impact based on stakeholder input from the 2013 Maine Green Crab Summit (York: low, Cumberland: high, Lincoln: moderate; event hosted by Maine Sea Grant), (b) broad geographic distribution across three counties in southern and mid-coast

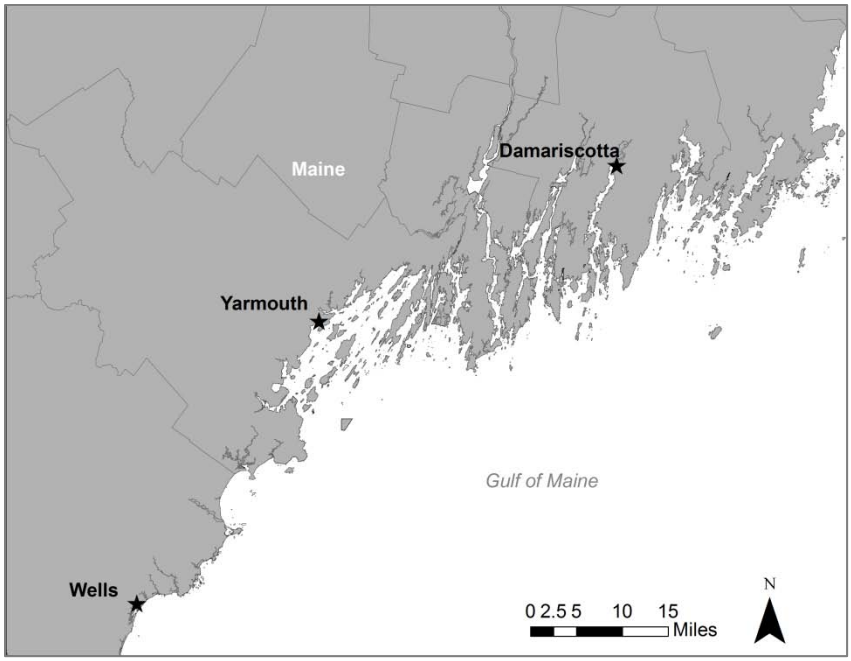
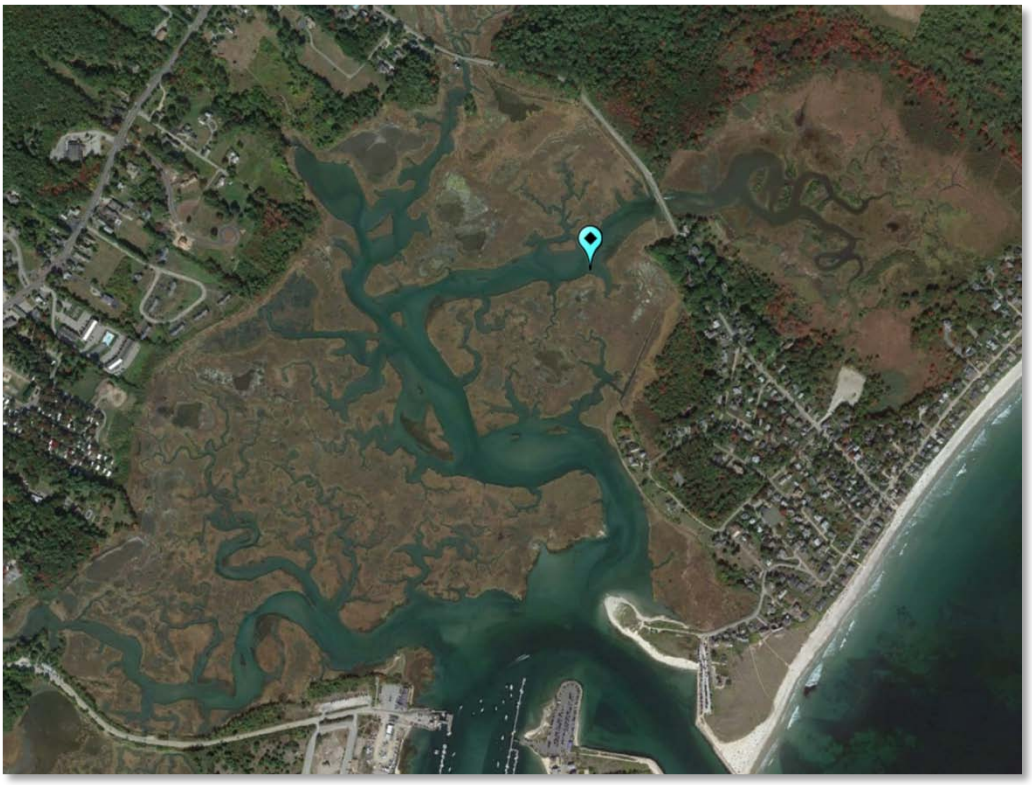


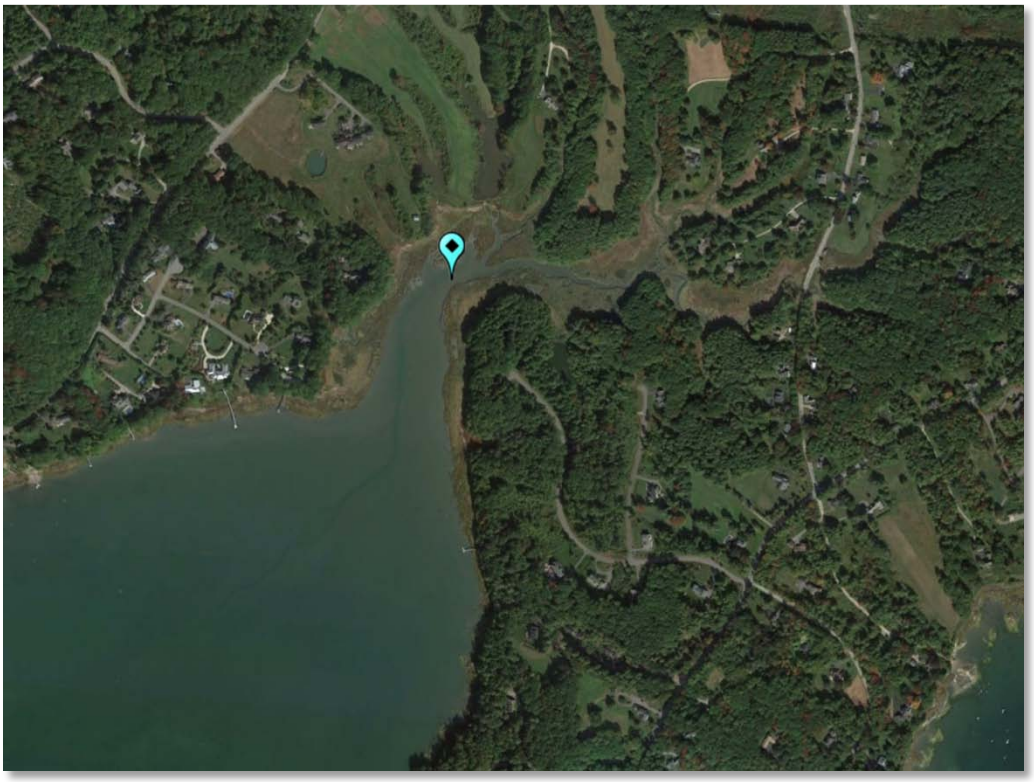
Figure 1. Maine study sites in York, Cumberland, and Lincoln Counties.

Maine, maximizing study influence, and (c) confirmed access to field sites by local landowners. We hypothesized that marshes with greater numbers of green crabs would have weakened salt marsh peats, greater salt marsh erosion, and decreased nearshore water clarity due to green crab activities. The original scope of this project included one season of observations; however a project extension was requested and granted in 2015 to allow for an additional season of observations to identify multi-year trends in green crab abundance.

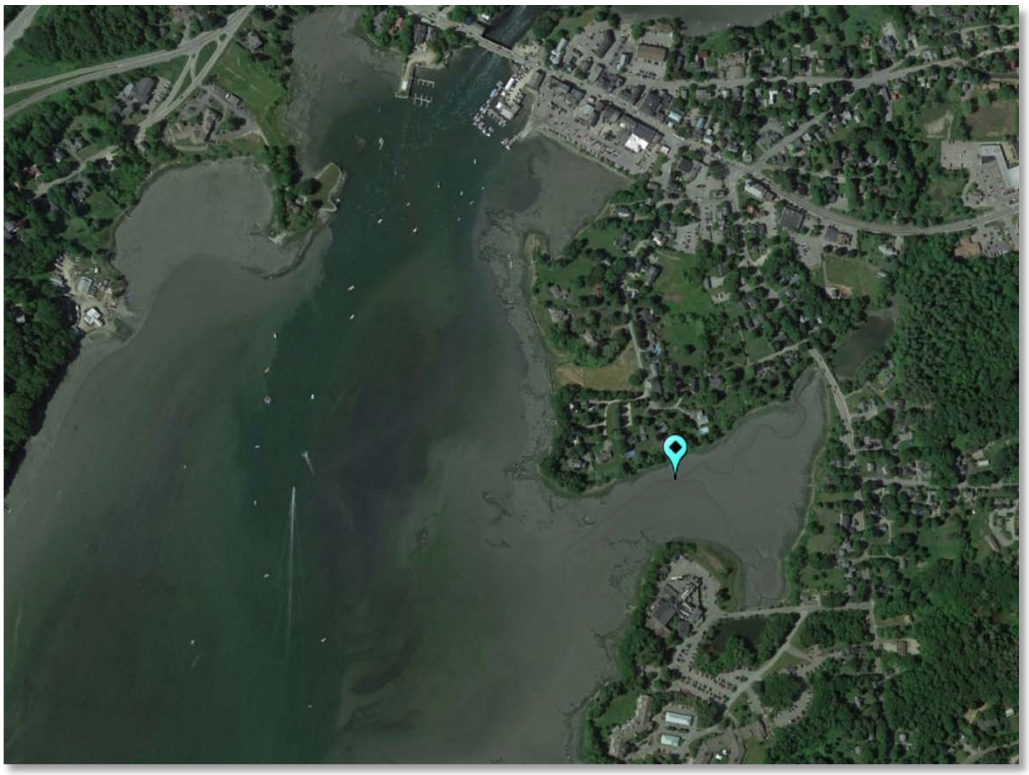
In 2014, we used fyke nets to measure green crab abundance over two consecutive tidal cycles, once a month at each site in late June/early July, early August, and late October. We also deployed two baited crab traps for 24 hours at each site every two weeks from early July through October in 2014. Based on results from the 2014 study it was decided to continue trapping in 2015 from early June through October. Catch was retrieved and returned to Wells Reserve for processing. All crabs were frozen prior to processing. Biological measurements were taken for each crab including carapace width, wet weight, sex, and gravid condition (presence of eggs for females). Crabs were sub-sampled for isotopic analysis (carbon and nitrogen stable isotopes) to identify variations in diet between populations at each study site and to investigate if crabs were eating the salt marsh foundation species, *Spartina alterniflora*. For this analysis, meat from legs was prepared by drying and then grinding with mortar and pestle. Prepared samples were sent to Bates College and processed by Dr. Beverly Johnson. To measure water-quality parameters that may correlate with green crab abundance and erosional impacts, we deployed a YSI 6600 V2 multi-parameter data sonde at each site during the study period to collect 15-minute water-quality data, including temperature, water depth, pH, dissolved oxygen, conductivity, salinity, and turbidity (an indicator of water clarity).



Webhannet River sampling site Wells, ME.



Broad Cove sampling site Yarmouth, ME.



Day Cove sample site Damariscotta, ME.

We measured salt marsh erosion at each site in multiple ways, using (1) stake arrays and repeat measurements to track erosion of the lateral edge of the salt marsh over time (with Dr. Dan Belknap from the University of Maine), (2) replicate shear vane strength measurements (a measure of torque) to assess peat strength and integrity, and (3) computed tomography (CT) scans of geologic cores, the first time this technology has been applied to a conservation question in the State of Maine (with Dr. Earl Davey, US EPA, Atlantic Ecology Division, Narragansett, RI). While CT scans are a routine technology, their application to geological questions is novel, as recent studies in Rhode Island and Virginia show (Davey *et al.* 2011; Blum and Davey 2013). This study is the first time CT scans have been used to measure and image geologic cores from Maine salt marshes and the first to apply the technique to quantitatively assess belowground impacts of green crab activities in the state (e.g., burrowing and void space, removal of salt marsh plant roots and rhizomes). At each site, we collected paired cores, one inside (impacted) and one outside (reference) the green crab high impact zone. Cores were prepped at the Wells Reserve then scanned at Southern Maine Health Care in Biddeford, ME. Core preparation and scanning, image processing, image analysis, and interpretation of results were carried out by Wells Reserve staff with guidance and training by Dr. Earl Davey (US EPA Narragansett, RI).

Green Crab Population Characteristics

The addition of sampling using baited traps was made possible through collaboration with several state partners also investigating the impacts of green crabs on near shore habitat, including the Maine Department of Environmental Protection, the Casco Bay Estuary Partnership, and the U.S. Geological Survey. Traps and bait were provided to the Wells Reserve and a standardized protocol was used in sampling by all collaborators. Use of baited traps was far more successful for assessing green crab abundance than fyke net sampling. This became apparent early in the project when fyke net catch was very low and baited trap catch was relatively high in comparison. It was decided to trap on a more frequent basis, ultimately occurring every two weeks. Fyke netting was originally included as a more reliable technique for measuring marsh nekton abundance, and to link the current study with historic studies carried out by the Wells Reserve. Instead, relative abundance of green crabs is presented here from trapping carried out over two sampling seasons in 2014 and 2015.

Bates College intern Dana Cohen-Kaplan retrieving a full crab trap in Damariscotta, ME.

The Webhannet River in Wells had the highest abundance of crabs, followed by Day Cove in Damariscotta, with Broad Cove in Yarmouth having the lowest (Figure 2). This trend carried across both sample years. In 2014, abundance in Wells and Damariscotta remained fairly high throughout the season while abundance in Yarmouth was very low until September when it increased substantially. Overall, numbers at all sites were lower in 2015 compared to 2014. It is unknown if this is a trapping effect from 2014 or if it is the result of actual population declines at each site.

Crabs tended to be larger in Damariscotta than in Wells or Yarmouth based on carapace width (Figure 3). The ratio of female to male green crabs varied between sites and from month to month (Figure 4). At Damariscotta males represented over 50% of the population for all months except for October 2015. In Wells, females made up the majority of the population from August to October 2014 and September to October 2015. In Yarmouth, males made up the majority of the population in July and August 2014, and June, July, August, and October 2015.

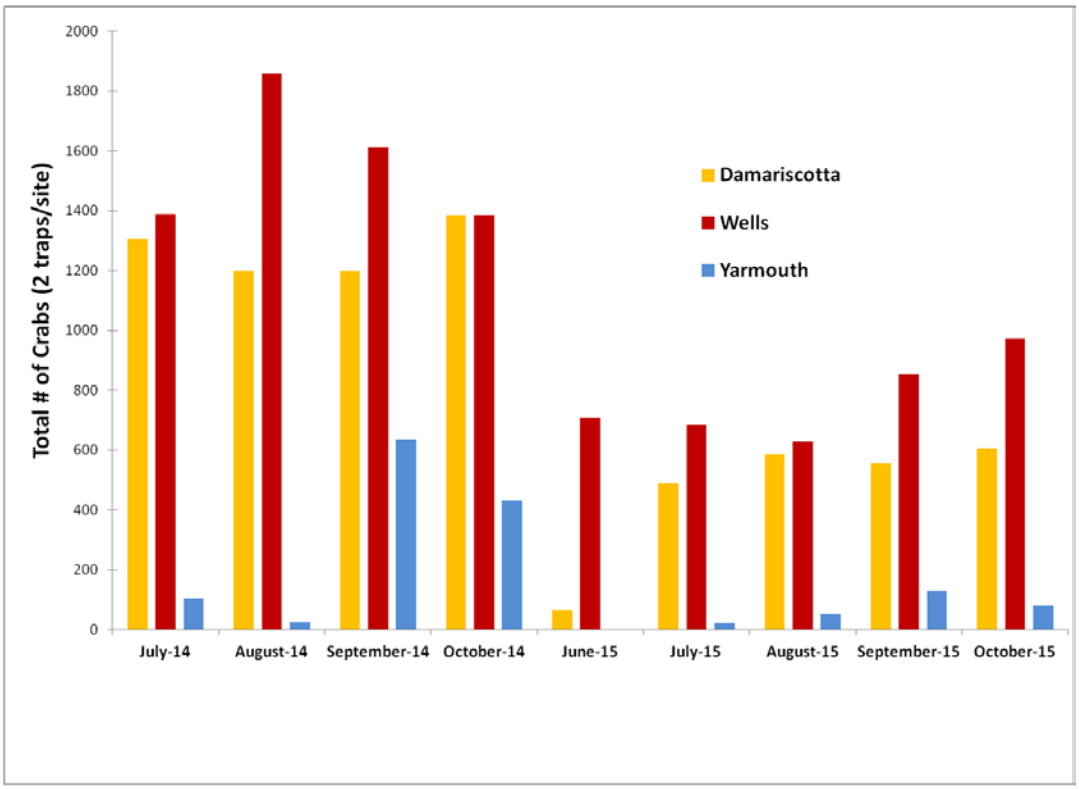


Figure 2. Green crab catch by site and month.

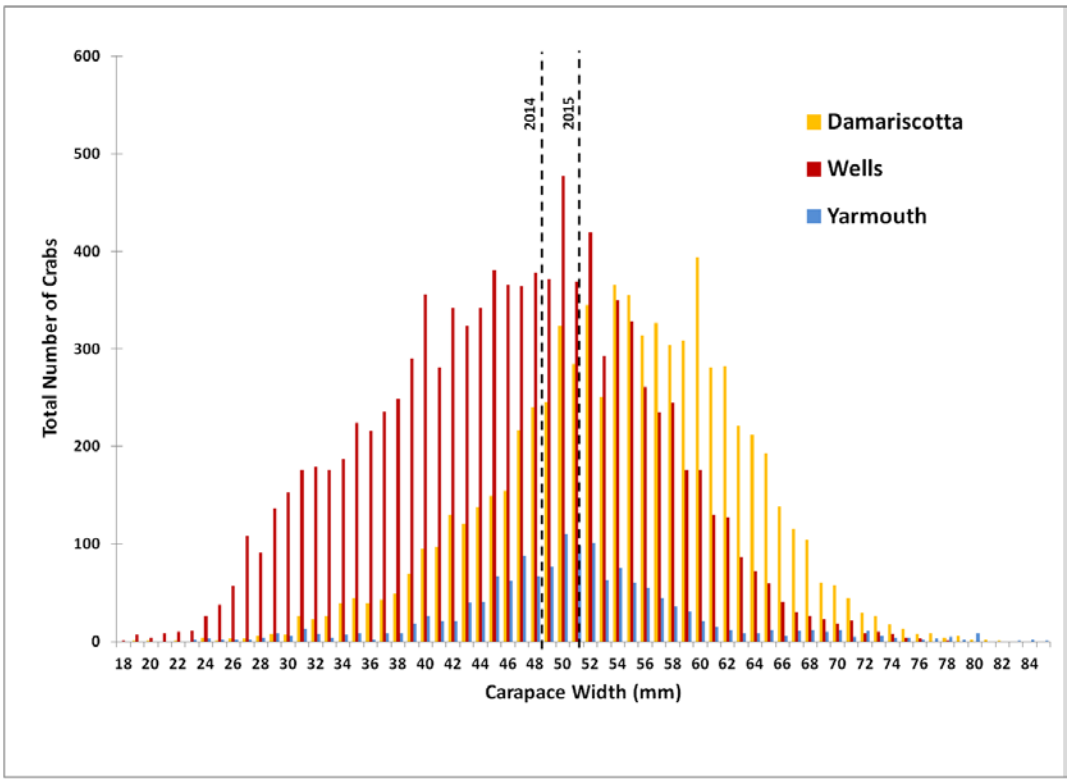


Figure 3. Green crab size distribution by site, with median values shown for both sample years.

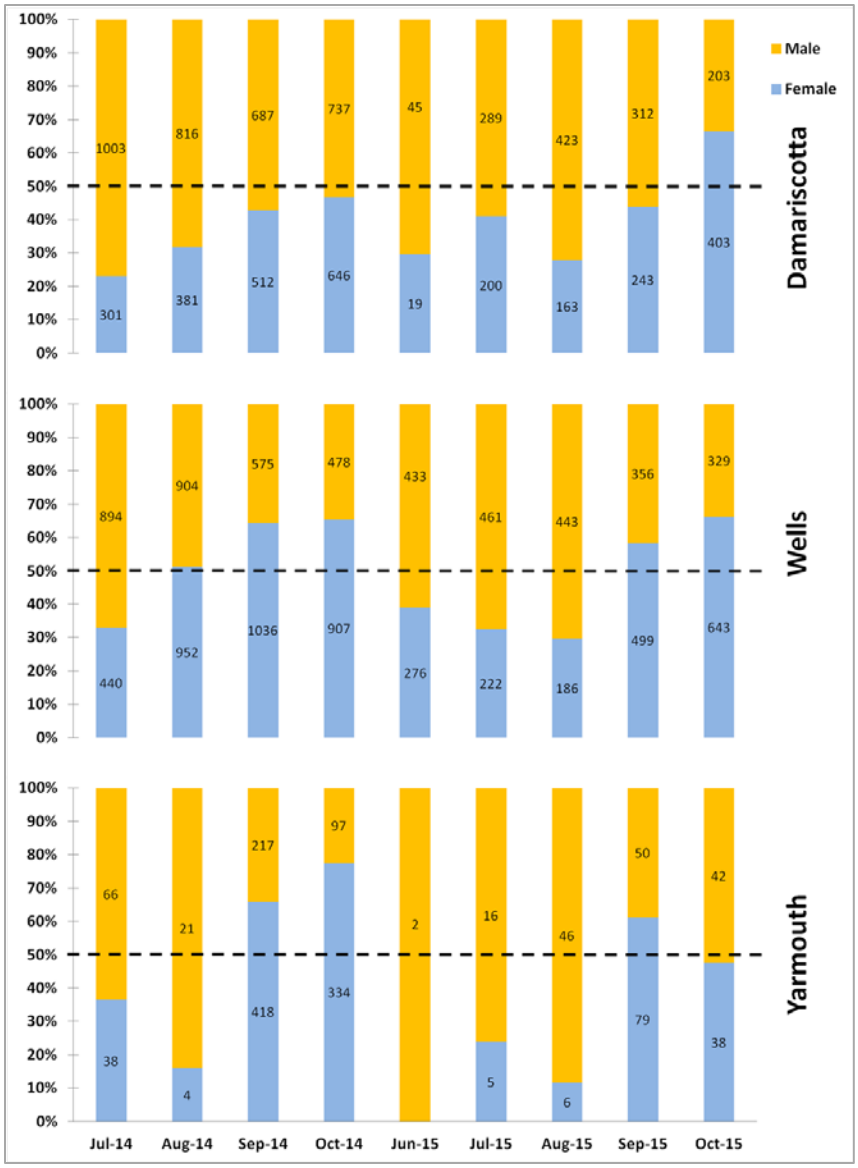


Figure 4. Green crab sex ratio comparison by site, with sample month and year on the X axis, and count data shown on bars.

The ratio of females to males increased from summer to fall in both years at all sites. We only identified gravid female crabs at Yarmouth and Wells (Table 1). The relative number of gravid females to overall females sampled was very low (<1%) and these females were only sampled in July and August 2014 and June, July, and August in 2015.

Water temperatures were highest in Damariscotta and lowest in Wells in both years, and higher overall in 2015 than 2014 (Figure 5). In 2014 salinity was highest at Wells and lowest in Yarmouth, while in 2015 salinity was highest in Damariscotta and lowest in Yarmouth (Figures 6). Other measured water quality parameters did not yield results that can be reliably interpreted. Logistical problems with sedimentation around sensors created doubt around the validity of turbidity and dissolved oxygen measurements. Despite our initial plan to

Table 1. Gravid females were an overall small percentage of total females sampled, and were absent from Yarmouth.

		Jul-14	Aug-14	Sep-14	Oct-14	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15
Damariscotta	female	301	381	512	646	19	200	163	243	403
	gravid									
Wells	female	440	952	1036	907	276	222	186	499	643
	gravid	16		14			36	11	3	
Yarmouth	female	38	4	418	334	0	5	6	79	38
	gravid	2	2							

Less than 1% of female crabs were gravid.

measure water clarity in relation to green crab activity we were unable to carry out this analysis and these data are not presented here.

Analysis of carbon and nitrogen stable isotopes was carried out for 2014 samples only, and included a total of 24 samples from each site (72 total), comprised of male crabs only, of a size that would supply an adequate amount of tissue for analysis (32-77 cm carapace width) . Additional sub-samples were collected in 2015, and may be analyzed if funding can be secured. The results of the analysis indicate that green crab diet varies between sites (Figure 7). Green crab tissues from Wells were highest in both $\delta^{13}C$ and $\delta^{15}N$, while tissues from Yarmouth were lowest in $\delta^{15}N$ and tissues from Damariscotta were lowest in $\delta^{13}C$. Damariscotta

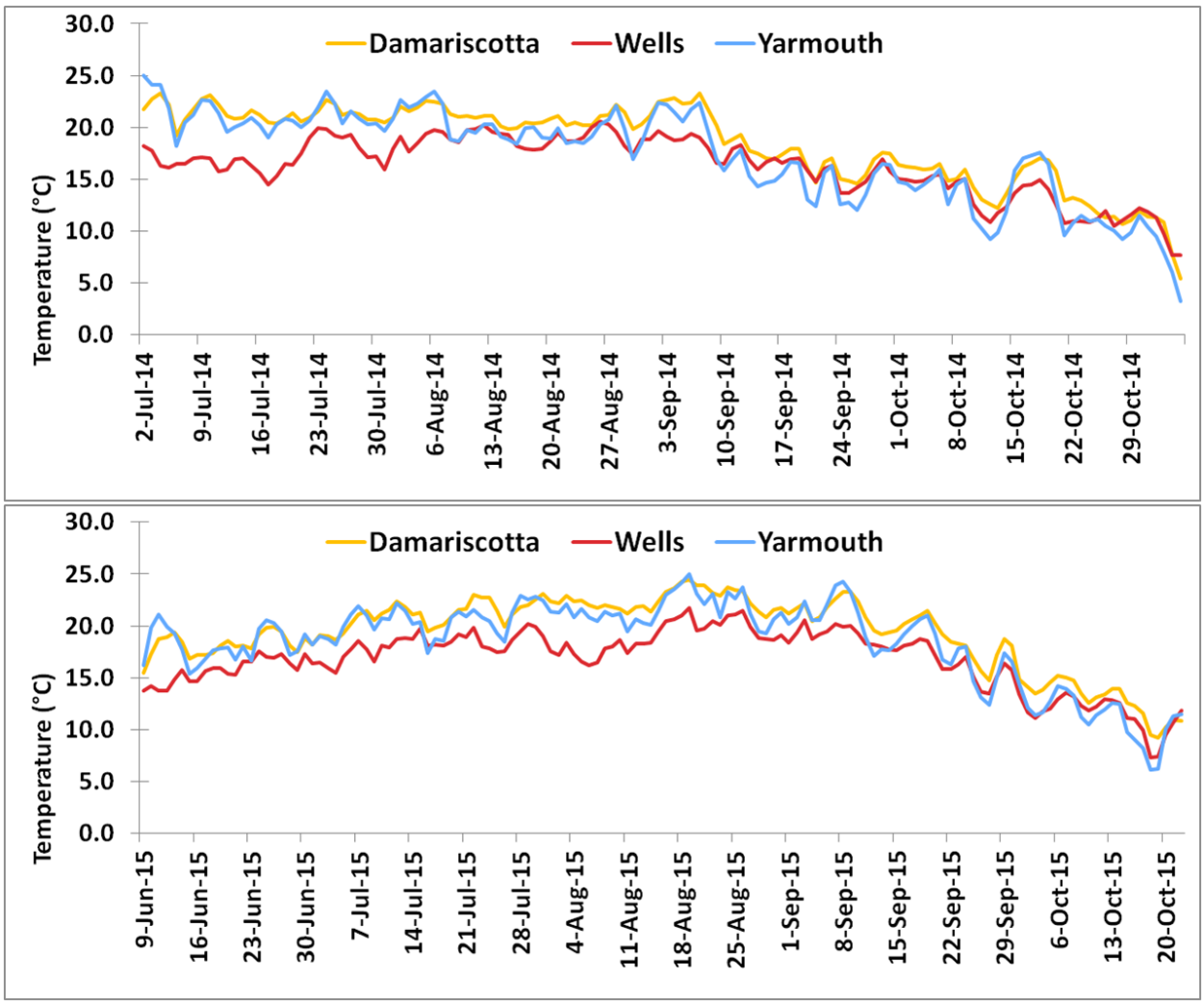


Figure 5. Water temperature was measured at 15-minute intervals throughout the study. Daily average values shown here.

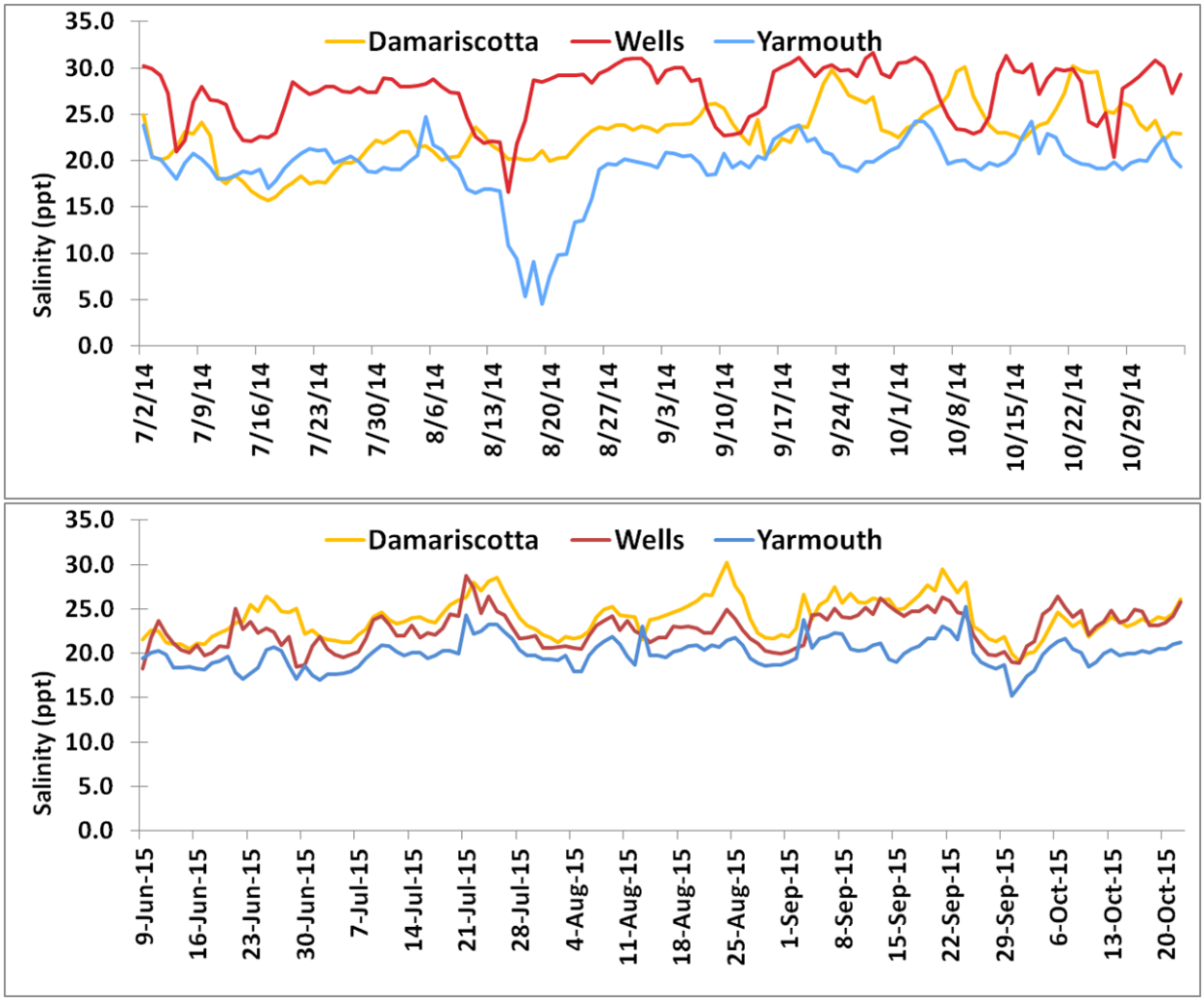


Figure 6. Salinity was measured at 15-minute intervals throughout the study. Daily averages shown here.

and Yarmouth crab tissues were most similar. These results suggest that the green crabs sampled were not eating the salt marsh cord grass, *Spartina alterniflora*, which tends to have a similar $\delta^{13}C$ value, but a much lower $\delta^{15}N$ value (typically around 6). Instead, the data suggest that these crabs are eating organisms higher in the salt marsh food web, like Atlantic silversides, smooth periwinkles, blue mussels, and mummichogs (Jaschinski *et al.* 2008, Riera *et al.* 1999, Vafeiadou *et al.* 2013). Less negative $\delta^{13}C$ values and higher $\delta^{15}N$ values for crabs from the Wells site, suggest that marine food sources may be more important at that site compared to Damariscotta and Yarmouth. These results may reflect the gross geomorphological context of the marshes at each site: Wells is a back-barrier salt marsh located within the arcuate embayment coastal compartment of Maine's coast, while both Damariscotta and Yarmouth are fluvial minor marshes within the indented shoreline coastal compartment (Kelley *et al.* 1988; Tanner *et al.* 2006).

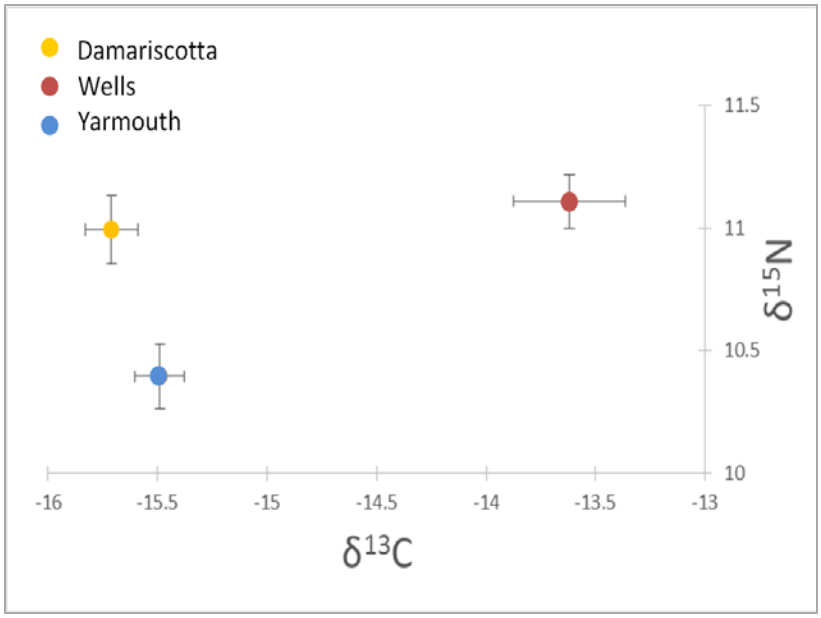


Figure 7. Stable isotope ratios provide insight to variations in crab diet between study sites.

Marsh Impacts

Marsh stability was measured through replicate shear vane torque measurements taken in reference and impacted locations (25 in each, 50 per site) along the marsh creek banks at each site (Figure 8). Our measurements indicated that in healthy vegetated marsh creek banks peat at shallow depths (10 cm) was stronger than peat at deeper depths (50 cm at Damariscotta and Wells, 30 cm at Yarmouth). For crab impacted marsh creek banks there was no difference in peat strength with depth. Our measurements also showed that crab impacted marsh creek banks were more erodible overall than vegetated creek banks, which is likely the result of lack of live root and rhizome structure to help maintain bank integrity. Damariscotta marsh creek banks appear to have the highest strength while Wells marsh creek banks had the lowest.

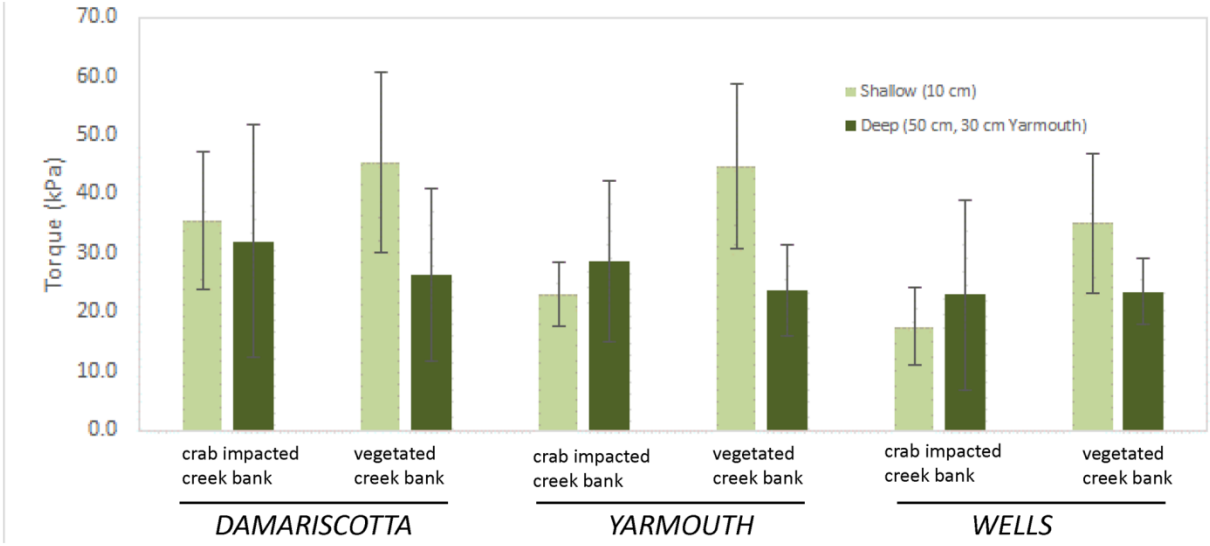


Figure 8. Marsh stability was measured by torque strength for deep and shallow depths.

CT scanning a marsh core at SMHC Biddeford, ME.

Cores were scanned by computed tomography from vegetated reference locations and impacted burrowing locations at each site. Analysis of the scans indicates that while the total volume of the cores is similar between reference and impacted cores for each site the composition of materials differs. Scans also reveal significant compositional differences between sites (Figure 9). Impacted cores tended to have a greater percentage of gas, fewer live roots and rhizomes (except Yarmouth), greater water volumes (especially Wells), lower peat volumes (except Wells), lower particulates (except Wells), and higher percentages of sand (except Wells). It is unknown why Wells has such a different compositional

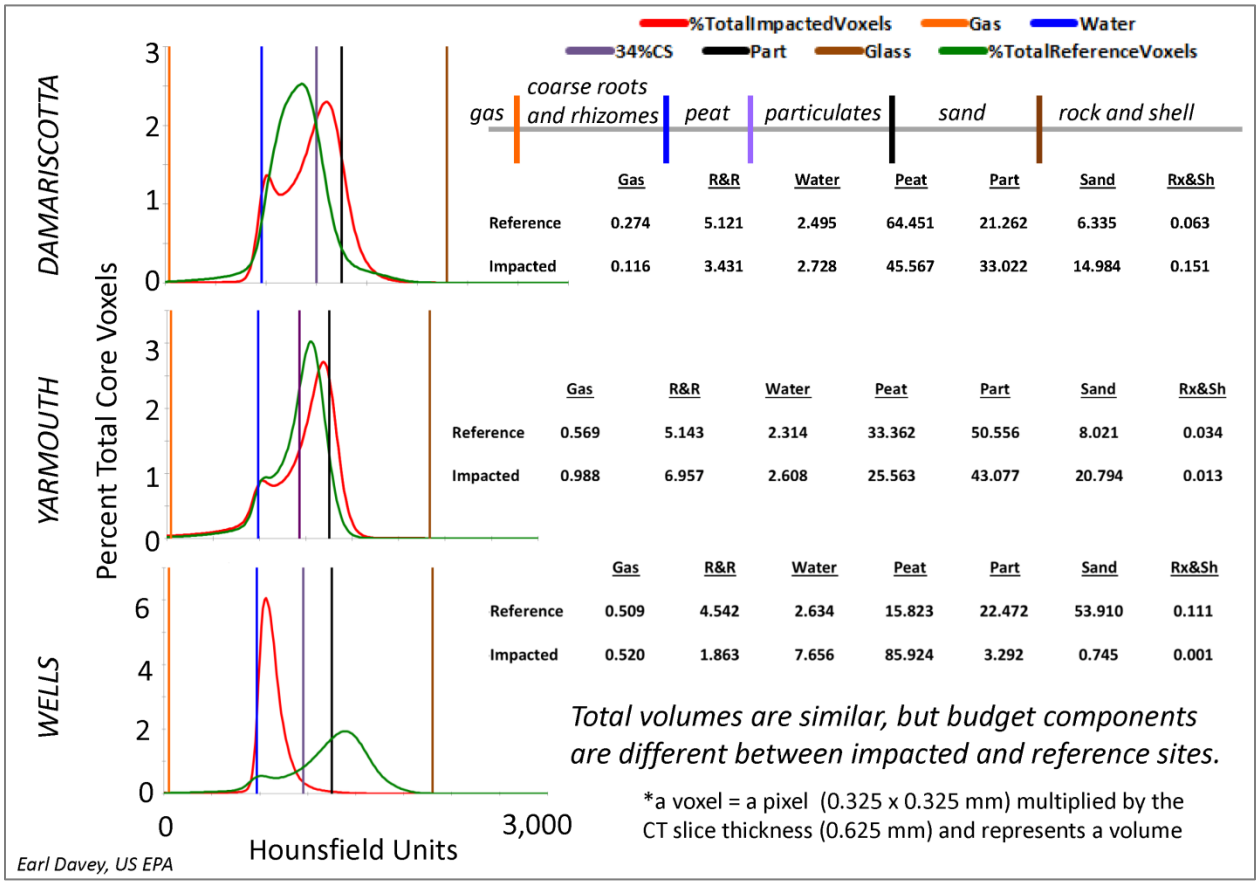


Figure 9. CT imaging analysis provides a comparison of material volume percentages between reference and impacted sites.

signature compared to the other two sites; increased sample size would have helped interpret these signals.

Scans that focus on live roots and rhizomes only (Figure 10), show large differences between reference and impacted cores, especially for Damariscotta and Wells (data not shown for Wells). It appears that sites with greater green crab abundance (Wells and Damariscotta), exhibited decreased live belowground biomass in the upper marsh peat, information supported by the torque measurements. Together, these data suggest that impacted marsh creek banks are more erodible than reference locations.

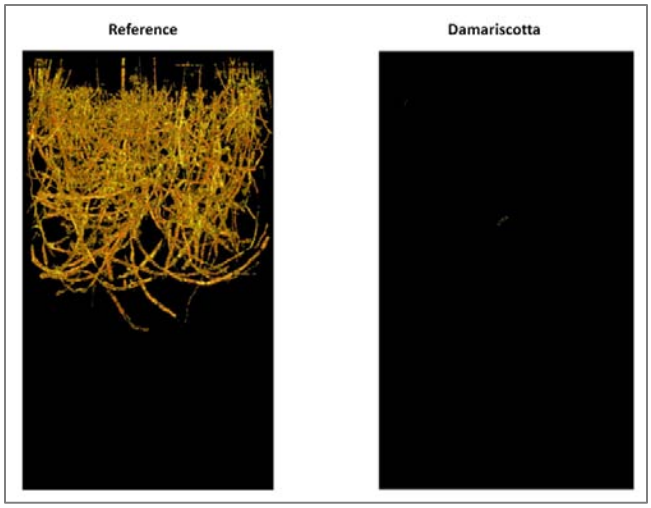


Figure 10. CT scans of marsh cores show a stark contrast between reference and impacted site belowground biomass.

Of great interest was the ability of the CT scans to pick out crab burrows in our marsh peat cores. These burrows were observed in multiple cores, and in one we even put our Dutch core directly through a burrowing crab. This provides direct evidence of burrowing activity by green crabs in our salt marsh study sites.

Our findings do not support the initial identification of high, medium, and low impact sites, with the "low" impact site (Wells) experiencing the highest abundance of crabs and the lowest stability of salt marsh peat. It is likely that the study sites chosen may not be representative of the conditions observed during pre-study planning discussions. The opposite may also be true, in which case our study results would imply that the problem of marsh degradation due to green crab activity may be farther reaching than was previously thought.

Project Communication

Study results were widely communicated during the study and after completion. From December 2014 to October 2015, Wells Reserve staff gave seven project-related public presentations. From October 2014 to November 2015, Wells Reserve and partners gave six presentations of project findings to professional meetings, including the New England Estuarine Research Society, the Northeast Aquaculture Conference & Exposition, and the Northeast Geological Society of America Meeting. Findings were also shared with regional partners at three working group meetings from October 2014 to May 2015. The project provided significant, educational opportunities for students. One graduate student, 24 undergraduate students, and 12 high school students were engaged on the project from 2014 to 2015. Finally,

Wells Reserve researcher Dr. Kristin Wilson hits a burrowing green crab while collecting a Dutch core.

throughout the course of this project, Wells Reserve created and disseminated eight different project related media items including online and print articles and video. The project also received specific mention in one press article. The Maine Outdoor Heritage Fund was acknowledged in both articles and presentations as the leading funder of our study. Please see Appendix A for a list of these communication products. Finally, two peer-reviewed articles are in preparation as a result of this work. As these are submitted, we will notify the MOHF.

Project Objectives and Outcomes

We are extremely pleased with this project which turned out to be much broader in scope and outcomes than originally anticipated. Our objectives to document the erosive impacts of invasive European green crabs on Maine salt marshes using conventional techniques and the novel application of CT technology were achieved through careful project planning and collaboration. Wells Reserve staff received training in CT collection and analysis techniques and graduate and undergraduate students were trained in ecological and geological field sampling methods, data management, and analyses skills over the course of two field seasons. Study results were broadly communicated with appropriate audiences, including the conservation community and public.

St. Josephs College students unload a green crab trap at Wells Reserve.

We feel that we were able to significantly improve understanding of the erosional impacts of invasive European green crabs on Maine salt marshes. Capacity of Wells Reserve staff was enhanced by our ability to now image and quantify belowground processes occurring in salt marshes by applying new technology (CT scans) to geologic cores. A substantial number of students received hands-on training and exposure to ecological and geological field and laboratory techniques. We were successful in forging new partnerships with a non-traditional partner in Southern Maine Health Care. Finally, the results and lessons learned from this project were widely communicated to professional and lay audiences through extensive outreach efforts.

Future Work

Wells Reserve expects to continue various aspects of this study as time and resources allow over the coming years. We anticipate that our findings will be presented in peer reviewed publications. Additional sampling work is planned for 2016 to further identify trends in green grab abundance and additional isotopic analysis may be conducted. As our work progresses we will continue to disseminate project related information and look forward to sharing our continuing positive relationship with the Maine Outdoor Heritage Fund.

Acknowledgments

This project would not have been possible without the high level of support we received from partner organizations and collaborators. We would like to thank Curtis Bohlen of the Casco Bay Estuary Partnership, Angela Brewer of the Maine Department of Environmental Protection, and Hillary Neckles of the U.S. Geological Survey for their support of our study design and trapping activities. We would like to thank Dr. Dan Belknap of the University of Maine for allowing us access to his marsh in Damariscotta and for support in study design and field data collection.

Research assistants Tim Dubay and Amelie Jensen, and graduate student Sydney Nick portion a barrel of herring for bait.

We would like to thank Eliza Cronkite (University of Maine M.S.) for help in the field. We would like to thank Dr. Beverly Johnson of Bates College for her help in developing and carrying out the stable isotope analysis. We would like to thank Dr. Earl Davey of the U.S. Environmental Protection Agency for his significant contributions to this project including extensive guidance and lab support for collection, processing and analysis of marsh core CT scans.

This project would not have been possible without the financial and technical support of staff with Southern Maine Health Care, and in particular we would like to thank Steve Keegan Vice President of Ancillary Services. We would like to thank our partner the Laudholm Trust for facilitating the cooperation with SMHC.

This project could not have been carried out without substantial effort in the field and the lab by our research interns Emily Harris, Florence MacGregor, Dana Cohen-Kaplan, Emma Swartz, and Madhu Cornelius. We would like to thank our dedicated research assistants Tim Dubay and Amelie Jensen, and graduate student/volunteer Sydney Nick who spent literally months counting and measuring over 18,000 crabs. Thanks also to Wells Reserve staff members Jeremy Miller, Tin Smith, and Sue Bickford.

At one point green crabs filled a 21 cubic foot chest freezer at Wells Reserve!

We also wish to thank the organizations that made this project possible with generous financial support. Maine Sea Grant and the Casco Bay Estuary Partnership provided initial matching funds for this project. Additional matching funding was provided by the George and Eleanor Ford Fund. The majority of our project funding was provided by the Maine Outdoor Heritage Fund.

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Appendix A. Project Outreach and Communication

Public Presentations

- Miller, J., Wilson, K.R. Green Crab Research at the Wells NERR, Oral Presentation, Laudholm Trust Annual Meeting and Holiday Gathering. Dec 3, 2014, Wells, ME.
- Wilson, K.R., Davey, E., Aman, J., Miller, J., Belknap, D. A green crab explosion: understanding impacts of a marine invader in southern Maine marshes. York County Community College, Wells, ME. Apr 13, 2015, Wells, ME.
- Wilson, K.R. The green crab invasion: impacts in southern Maine marshes. Wells NERR Lunch n' Learn Series. May 5, 2015, Wells, ME.
- Miller, J. "Impacts of the Invasive Green Crab on Salt Marsh Ecosystems." L.L. Bean Lecture Series. Jul 10, 2015, Freeport, ME.
- Jensen, A. "Studying the Invasive European Green Crab." Wells Reserve Meet the Scientist Presentation Series. Sep 14, 2015, Wells, ME.
- Wilson Grimes, K. "An alien invasion! European green crab impacts in Southern Maine marshes." Invited talk, University of the Virgin Islands, First Friday Seminar Series. Oct 2, 2015. St. Thomas, VI.
- Jensen, A. Wells Reserve Green Crab Study. Presentation to York High School 10th grade class. Oct 20, 2015 Wells, ME.

Professional Meetings

- Wilson, K.R., Belknap, D.F., Aman, J., and Miller, J. Linking patterns in European green crab abundance in three southern Maine salt marshes to observed changes in marsh morphology. Oral presentation, New England Estuarine Research Society. Oct 16-18, 2014, Groton, CT.
- Wilson, K.R. 2015. European green crabs in southern Maine marshes: trends in abundance and marsh impacts. Northeast Aquaculture Conference & Exposition. Jan 14-16, 2015, Portland, ME.
- Belknap, D. and Wilson, K.R. Invasive European green crabs: sudden increase in erosion potential on salt marshes in southern and central coastal Maine. Northeast Aquaculture Conference & Exposition. Jan 14-16, 2015, Portland, ME.

- Belknap, D.F., and Wilson, K.R. Effects of invasive green crabs on salt marshes in Maine. Northeast Geological Society of America Meeting. Mar 22-25, 2015 Bretton Woods, NH.
- Wilson, K.R., Davey, E., Aman, J., Miller, J., Belknap, D.F. European green crabs in Maine: trapping, peat stability measurements, and computer-aided tomography of cores reveal marsh impacts. Northeast Geological Society of America Meeting. Mar 22-25, 2015, Bretton Woods, NH.
- Davey, E. and K. Wilson. Maine belowground marsh destruction from the European green crab documented by computer-aided tomography. 23rd Biennial Conference of the Coastal & Estuarine Research Federation. Nov 8-12, 2015, Portland, OR.

Work Groups

- Wilson, K.R. Green crab update: Wells NERR. Oral presentation, State of Maine Green Crab Researcher Meeting, sponsored by the Casco Bay Estuary Partnership, Oct 8, 2014, Portland, ME.
- Miller, J., Wilson, K.R., Beal, B. Update on green crab research at the Wells NERR. Oral presentation, Maine Marine Invasive Species Workgroup. Dec 12, 2014, Portland, ME.
- Miller, J.,Wilson, K.R., Davey, E., Aman, J., Belknap, D.F. The green crab invasion: impacts to southern Maine salt marshes. Northeast Aquatic Nuisance Species Panel Spring Meeting; Species Spotlight Session. May 12-13, 2015, Portland, ME.

Media: Wells Reserve blog articles (The Wrack) and newsletter articles (Watermark), and video (Youtube)

- "2015 Green Crab Trapping Update." The Wrack Nov 6, 2015. http://www.wellsreserve.org/blog/763-2015_green_crab_trapping_update
- "Talking about green crabs at the Northeast Aquaculture Conference." The Wrack Jan 16, 2015. http://www.wellsreserve.org/blog/678-talking_about_green_crabs_at_northeast_aquaculture_conference
- "Green crab project update." The Wrack Jan 14, 2015. http://www.wellsreserve.org/blog/677-green_crab_project_update
- "How to Catch 5,000 Green Crabs." The Wrack Sep 11, 2014. http://www.wellsreserve.org/blog/644-how_to_catch_5_000_green_crabs
- "CT Scanning: A Novel Technique for Studying Salt Marsh Mud." Watermark Fall 2014. http://www.wellsreserve.org/writable/files/watermark/watermark_31-2_web.pdf
- "From Away: Voracious Green Crabs Digging Deep in Maine Marshes." Watermark Summer 2014. http://www.wellsreserve.org/writable/files/watermark/watermark_31-1_summer-2014.pdf
- "Wells Reserve 2014 Damariscotta crab trap time lapse." Wells Reserve at Laudholm, Youtube channel. Oct 7, 2014. https://www.youtube.com/watch?v=-oIH6F5Cjg0
- "When You Need Data." Wells Reserve at Laudholm Youtube channel. Sep 21, 2015. https://www.youtube.com/watch?v=QkoeDUWSzbE

Press

- “Invasive green crabs – and threat to Maine’s clams – dwindle.” Portland Press Herald. Sep 15, 2014.

Students Engaged in Green Crab Study

- Sydney Nick, M.S. student, University of New Hampshire
- Madhu Cornelius, B.S. student, Washington College
- Dana Cohen-Kaplan, B.S. student, Bates College
- Emily Harris, B.S. student, Washington College
- Florence MacGregor, B.S. student, Smith College
- Emma Swartz, B.S. student, Smith College
- St. Joseph’s College, Environmental Science Semester, 8 students
- Bates College Advanced Ecology Class, 5
- York County Community College Marine Biology Class, 6 students
- Katilyn Tonra, Kennebunk High School
- Connor Seeley, Berwick Academy
- York High School 10th grade, 6 students