

# RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress

Emily Carrington

Impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA

R/SFA-1

Submitted On: 05/17/2016 04:16:07 PM

## METRICS & MEASURES

Metric/Measure	Value	Note
Acres of coastal habitat	0	
Fishermen and seafood industry personnel	0	
Communities - economic and environmental development	0	
Stakeholders - sustainable approaches	0	
Informal education programs	0	
Stakeholders who receive information	1750	presentations - 750 conservative estimate of media reach - 1000
Volunteer hours	0	
P-12 students reached	0	
P-12 educators	0	

## REQUESTED INFORMATION

### Publications

#### **Mussels as a model system for integrative ecomechanics.**

**Publication Type:** Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents

**Publication Year:** 2015

**Publication Authors:**

**Publisher Info:**

**Notes:**

**Related URLs:**

**Keywords:**

**Publication URLs:**

**Abstract:**

**Citation:** Carrington, E., J.H. Waite, G. Sara and K. Sebens, 2015. Mussels as a model system for integrative ecomechanics. Annual Review of Marine Science 7: 443-469.

**Citation for Coverage:**

**SG can post PDF online?:**

**Uploaded File:** [Carrington\\_et\\_al\\_2015\\_ARMS.pdf](#)

#### **Elevated temperature and ocean acidification alter mechanics of mussel attachment**

**Publication Type:** Theses / Dissertations (complete versions)

**Publication Year:** 2015

**Publication Authors:**

**Publisher Info:**

**Notes:**

**Related URLs:**

**Keywords:**

**Publication URLs:**

**Abstract:**

**Citation:** Newcomb, L.A., 2015. Elevated temperature and ocean acidification alter mechanics of mussel attachment. Ph.D. dissertation, University of Washington. 116 p

**Citation for Coverage:**

**SG can post PDF online?:**

**Uploaded File:** [Newcomb\\_Dissertation\\_FINAL.pdf](#)

## Students Supported

**Laura Newcomb** (Continuing Student)

[newcombl@uw.edu](mailto:newcombl@uw.edu)

University of Washington, BIOLOGY

**Field of Study:**

**Advisor:**

**Degree Type:** PhD

**Degree Year:** 2015

**Student Project Title:**

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):**

**Post-Graduation Plans (employer, grad school, etc.):** Knauss Fellow at NOAA in Silver Spring MD

**Was this thesis/dissertation supported by Sea Grant?:** Yes

**Thesis / Dissertation:** Newcomb, L.A., 2015. Elevated temperature and ocean acidification alter mechanics of mussel attachment. Ph.D. dissertation, University of Washington. 116 p.

**New or Continuing?:** continuing

**Degree awarded this reporting period?:** Yes

**Financially supported?:** Yes

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**Emily Roberts** (Continuing Student)

[earobert@uw.edu](mailto:earobert@uw.edu)

University of Washington, Biology

**Field of Study:**

**Advisor:**

**Degree Type:** PhD

**Degree Year:** 2019

**Student Project Title:**

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):**

**Post-Graduation Plans (employer, grad school, etc.):**

**Was this thesis/dissertation supported by Sea Grant?:** No

**Thesis / Dissertation:**

**New or Continuing?:** continuing

**Degree awarded this reporting period?:** No

**Financially supported?:** Yes

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**Matt George** (Continuing Student)  
**mngorge@uw.edu**  
**University of Washington, Biology**

**Field of Study:**

**Advisor:**

**Degree Type:** PhD

**Degree Year:** 2017

**Student Project Title:**

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):** water sampling

**Post-Graduation Plans (employer, grad school, etc.):**

**Was this thesis/dissertation supported by Sea Grant?:** No

**Thesis / Dissertation:**

**New or Continuing?:** continuing

**Degree awarded this reporting period?:** No

**Financially supported?:** Yes

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**Narratives**

**Carrington Year 2 Narrative**  
**Uploaded File:** [WSG\\_Narrative\\_Yr\\_2\\_2016.docx](#)

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**Partners This Period**

**Jan Newton (NANOOS)**  
**Types:** Government  
**Scale:** REGIONAL  
**Notes:**

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**Penn Cove Shellfish LLC**  
**Types:** Industry/Business  
**Scale:** LOCAL  
**Notes:** Ian Jefferds

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**Taylor Shellfish Company**  
**Types:** Industry/Business  
**Scale:** INTERNATIONAL  
**Notes:** Gordon King

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**Olympic National Park, National Park Service (US DOI, NPS)**  
**Types:** Government  
**Scale:** FEDERAL or NATIONAL

Notes: Steve Fradkin

## Washington State Department of Natural Resources

Types: Government

Scale: STATE

Notes: Cinde Donoghue

## Northwest Association of Networked Ocean Observing Systems (NANOOS)

Types: NGO

Scale: REGIONAL

Notes: Jan Newton

### STANDARD QUESTIONS

#### Impacts and Accomplishments

(1)

Type	accomplishment
Title	Washington Sea Grant research probes effects of ocean acidification and warming on farmed and wild mussels in Puget Sound
Relevance	Mussels are valued delicacies worldwide and dominant species on rocky temperate shorelines, which they cling to with strong, powerfully adhesive byssal threads. But ocean warming and acidification (OA) are already depleting other shellfish species. Growers and resource managers urgently need to understand how warming and OA will affect byssal strength and mussel survival.
Response	Washington Sea Grant-supported researchers studied the effects of temperature and pH changes on byssal strength in two native mussel species, <i>Mytilus trossulus</i> and <i>M. californianus</i> , and the introduced species, <i>M. galloprovincialis</i> . They assessed: mussel attachment and condition at three far-flung Puget Sound aquaculture sites; byssal strength in wild mussels in Olympic National Park; and byssal effects of varying food supply, temperature and pH.
Results	Two years of observations revealed a pronounced seasonal cycle in attachment strength, with attachment stronger in winter and weaker in summer, especially in surface waters. Preliminary analyses suggest warming and pH are the best predictors of weak attachment. But responses to acidification varied seasonally according to the three species' different breeding schedules. Effects on byssal strength were less obvious during breeding, when the animals were already nutritionally stressed. <i>M. galloprovincialis</i> adapted better than <i>M. trossulus</i> in higher salinity. When temperature exceeded 20 degrees Celsius, <i>M. trossulus</i> produced fewer byssal

	threads and <i>M. californianus</i> production held steady; <i>M. galloprovincialis</i> produced more, giving it a competitive advantage as oceans warms.
<b>Recap</b>	Washington Sea Grant-supported research on three mussel species catalogued the effects of acidification and temperature on byssal attachment strength, which is essential to their survival.
<b>Comments</b>	
<b>Primary Focus Area</b>	Sustainable Fisheries and Aquaculture
<b>Secondary Focus Areas</b>	Healthy Coastal Ecosystems
<b>Goals</b>	Ocean and coastal resources are managed using ecosystem-based approaches. Aquaculture operations and shellfish harvests are safe, environmentally sustainable and support economically prosperous businesses.
<b>Partners</b>	Northwest Association of Networked Ocean Observing Systems (NANOOS) Olympic National Park, National Park Service (US DOI, NPS) Penn Cove Shellfish LLC Taylor Shellfish Company Washington State Department of Natural Resources
<b>PI Draft</b>	

## Tools, Technologies, Information Services / Sea Grant Products

(1)

<b>Description</b>	Live-stream of water sampling data (temperature, salinity, pH, etc.) at two shellfish growing areas in Puget Sound on NANOOS Visualization System.
<b>Developed (in the reporting period)?</b>	Yes
<b>Used (in the reporting period)?</b>	Yes
<b>Used for EBM?</b>	No
<b>ELWD product?</b>	No
<b>Number of managers</b>	0
<b>Description/Names of managers</b>	
<b>Reported in previous year?</b>	

## Economic Impacts

No **Economic Impacts** information reported

## Community Hazard Resilience

No Community Hazard Resilience information reported

## Meetings, Workshops, Presentations

(1)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Carrington, E. Effects of Ocean Acidification in Wild and Cultured Marine Fauna, a symposium for the 145th Annual Meeting of the American Fisheries Society in Portland OR, 16-20 August, 2015. Invited participant. Title: "Ecomechanics of Wild and Farmed Mussels in a Warmer, Acidified Ocean".
<b>Event Date</b>	08-16-2015
<b>Number of Attendees</b>	70

(2)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	invited seminar - University of Rhode Island, Kingston RI, October 2015.
<b>Event Date</b>	10-01-2015
<b>Number of Attendees</b>	200

(3)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	invited seminar - Institute of Systems Biology, Seattle WA, June 2015.
<b>Event Date</b>	06-01-2015
<b>Number of Attendees</b>	25

(4)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	invited seminar - Dauphin Island Sea Labs, Dauphin Island AL, April 2015.
<b>Event Date</b>	04-01-2015
<b>Number of Attendees</b>	30

(5)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	invited seminar - Friday Harbor Laboratories, May 2015.

<b>Event Date</b>	05-01-2015
<b>Number of Attendees</b>	40

(6)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	invited seminar - Friday Harbor Laboratories, October 2015.
<b>Event Date</b>	10-01-2015
<b>Number of Attendees</b>	40

(7)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., Jefferds, I., Strenge, R., Friedman, C.S., Carrington E. Congener mussel species show opposite responses to elevated temperature. Society of Integrative and Comparative Biology, Portland, OR. January 2016
<b>Event Date</b>	01-01-2016
<b>Number of Attendees</b>	80

(8)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., Jefferds, I, Carrington, E. Monitoring Risk: Ocean Conditions Influence Mussel Attachment. Pacific Coast Shellfish Growers Association Annual Conference, Hood River, OR, USA. September 2015
<b>Event Date</b>	09-01-2015
<b>Number of Attendees</b>	70

(9)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., Jefferds, I, Carrington, E. (2015). Measuring Risk: Uncovering the role of water temperature and pH on seasonal changes in mussel attachment strength. National Shellfisheries Association Annual Meeting, Monterey, CA, March 22-24 2015
<b>Event Date</b>	03-22-2015
<b>Number of Attendees</b>	80

(10)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., Community Forum on Ocean Health sponsored by the Northwest Straits Commission and Island County Marine Resource Committee, "Monitoring for possible effects of ocean acidification and temperature stress on farmed mussels in Penn Cove", May 5, 2015, Langley, WA
<b>Event Date</b>	05-05-2015
<b>Number of Attendees</b>	100

(11)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., Island County (WA) Marine Resources Committee Meeting: "Monitoring for possible effects of ocean acidification and temperature stress on farmed mussels in Penn Cove", May 5, 2015, Oak Harbor, WA
<b>Event Date</b>	05-05-2015
<b>Number of Attendees</b>	15

(12)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Newcomb L.A., 22nd Conference for Shellfish Growers invited talk: "Measuring risk: The role elevated temperature and ocean acidification play on weakened mussel attachment", February 2015, Union, WA
<b>Event Date</b>	02-01-2015
<b>Number of Attendees</b>	0

## Leveraged Funds

(1)

<b>Purpose</b>	Impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA - conference travel
<b>Source</b>	National Shellfisheries Association
<b>Amount</b>	388
<b>Start Date</b>	09-01-2015
<b>End Date</b>	09-01-2015



(2)

<b>Purpose</b>	Impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA - conference travel
<b>Source</b>	National Shellfisheries Association
<b>Amount</b>	1050
<b>Start Date</b>	03-22-2015
<b>End Date</b>	03-26-2015

(3)

<b>Purpose</b>	Impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA - graduate student support
<b>Source</b>	National Science Foundation
<b>Amount</b>	70000
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016

(4)

<b>Purpose</b>	Impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA - water sampling equipment
<b>Source</b>	Washington State Department of Natural Resources
<b>Amount</b>	30000
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016



attachment) for the nonnative species, *M. galloprovincialis*. This study was included in Laura's dissertation (Dec 2015, pdf included) and will be submitted to Nature Climate Change in May 2016.

- c. In Spring of 2015 we conducted another laboratory experiment with the same three species, this time manipulating food supply with different combinations of OA and warming conditions. We were unable to detect an effect of food. We suspect this was due to the short term nature of the experiment. Graduate student Molly Roberts is following up with longer term experiments in Spring/Summer 2016.

**2) Quantify the environmental conditions native and naturalized mussels encounter in wild and farmed habitats, at both the macro and microhabitat scale (e.g., near the mussel where their attachment structures are formed).**

*Progress in Year 2:*

- a. Partnering with Penn Cove Shellfish, we continue to deploy two YSI data sondes near mussel rafts in Penn Cove, WA (*M. trossulus*). We partner with NANOOS (NOAA) to live-stream these data to a public visualization platform. Our preliminary monitoring (since August 2014) indicates threshold values known to weaken byssus (pH < 7.6, temp > 20°C) are exceeded for periods of up to two weeks. We also see that low pH events are coupled with reduced DO and, in some cases, hypoxia. In addition, seasonal freshet events reduce surface salinity and often co-occur with warming in summer and cooling in winter. These findings are included in Laura Newcomb's dissertation (Dec 2015, pdf included) and will be submitted for publication in June 2016.
- b. We expanded our observation network to Quilcene Bay WA, a site where Penn Cove Shellfish grows *M. galloprovincialis*, partnering with the WA Department of Natural Resources. WA-DNR provided funds to purchase two more YSI data sondes for this site; since July 2015, these data are now live-streamed to NANOOS.
- c. Due to time and budgetary constraints, we have not monitored conditions for wild mussel populations.

**3) Assess the field performance and retention of mussels in both natural and farmed populations.**

*Progress in Year 2:*

- a. We now have over two years of monthly mussel attachment and condition measurements at Penn Cove (Laura Newcomb and Molly Roberts). Mussels show a strong seasonal cycle in attachment strength (especially in surface waters) and preliminary analyses suggest water warming and pH are the best predictors of weak attachment. This finding is included in Laura Newcomb's dissertation (Dec 2015) and will be submitted for publication in June 2016.
- b. In October 2014 we added two more sites for these monthly monitoring efforts, at Quilcene Bay (Penn Cove Shellfish) and Totten Inlet (Taylor Shellfish). These preliminary data show mussel attachment at these two sites is overall weaker than in Penn Cove. There is no seasonal trend in these data.
- c. Working with Steve Fradkin of Olympic National Park, Laura Newcomb made bi-monthly measurements of mussel attachment strength of mussels (*Mytilus*

*californianus*) in Olympic National Park. She learned that mussel attachment strength is greater in the winter and weaker in the summer. This was due to a change in thread strength, as there was no change in thread number over this time period. The results of this project are written up in the appendix of Chapter 3 of her dissertation.

- d. Molly Roberts ran a preliminary field experiment to measure field growth in the summer of 2015. She will scale this experiment up and monitor retention in spring and summer 2016 at Penn Cove.

#### **4) Outreach—Develop a high school chemistry curriculum and summer field camp curriculum on ocean acidification.**

*Progress in Year 2:*

- a. We have nearly completed the development of the chemistry curriculum. Carolyn Friedman is heading up the next phase of testing it in the classroom (at Spring Street International School and Friday Harbor High School). We will then buy supplies for more kits and set up distribution, perhaps through WSG
- b. We have engaged the scientific community and general public through scientific presentations, public talks and several media outlets. These activities are outlined in the Project Documents and Publications section of this report.
- c. FHL Open House. In May 2015, we showcased our science research and educational activities to over 600 people at the Friday Harbor Laboratories open house.

### **Project Documents and Publications**

#### **Publications:**

Carrington, E., J.H. Waite, G. Sara and K. Sebens, 2015. Mussels as a model system for integrative ecomechanics. *Annual Review of Marine Science* 7: 443-469.  
doi:10.1146/annurev-marine-010213-135049.

Newcomb, L.A., 2015. Elevated temperature and ocean acidification alter mechanics of mussel attachment. Ph.D. dissertation, University of Washington. 116 p.

#### **Presentations:**

Carrington, E. *Effects of Ocean Acidification in Wild and Cultured Marine Fauna*, a symposium for the 145th Annual Meeting of the American Fisheries Society in Portland OR, 16-20 August, 2015. Invited participant. Title: “Ecomechanics of Wild and Farmed Mussels in a Warmer, Acidified Ocean”. 70 participants.

Carrington, E. Several invited seminars were giving at academic institutions featuring this project:

University of Rhode Island, Kingston RI, October 2015. 200 participants

Institute of Systems Biology, Seattle WA, June 2015. 25 participants

Dauphin Island Sea Labs, Dauphin Island AL, April 2015. 30 participants  
Friday Harbor Laboratories, May 2015. 40 participants.  
Friday Harbor Laboratories, October 2015. 40 participants

Newcomb L.A., Jefferds, I., Strenge, R., Friedman, C.S., Carrington E. Congener mussel species show opposite responses to elevated temperature. Society of Integrative and Comparative Biology, Portland, OR. January 2016, Audience 80 people. Housing support from SICB.

Newcomb L.A., Jefferds, I, Carrington, E. Monitoring Risk: Ocean Conditions Influence Mussel Attachment. Pacific Coast Shellfish Growers Association Annual Conference, Hood River, OR, USA. September 2015, awarded best student talk, audience 70 people, supported by the Pacific Coast Section of the National Shellfisheries Association (\$388)

Newcomb L.A., Jefferds, I, Carrington, E. (2015). Measuring Risk: Uncovering the role of water temperature and pH on seasonal changes in mussel attachment strength. National Shellfisheries Association Annual Meeting, Monterey, CA, March 22-24 2015, audience 80 people, supported by the Pacific Coast Section of the National Shellfisheries Association (\$250) and the National Shellfisheries Association Student Housing award (housing for 4 nights).

Newcomb L.A., Community Forum on Ocean Health sponsored by the Northwest Straits Commission and Island County Marine Resource Committee, “Monitoring for possible effects of ocean acidification and temperature stress on farmed mussels in Penn Cove”, May 5, 2015, Langley, WA. Audience 100 people

Newcomb L.A., Island County (WA) Marine Resources Committee Meeting: “Monitoring for possible effects of ocean acidification and temperature stress on farmed mussels in Penn Cove”, May 5, 2015, Oak Harbor, WA. Audience 15 people

Newcomb L.A., 22<sup>nd</sup> Conference for Shellfish Growers invited talk: “Measuring risk: The role elevated temperature and ocean acidification play on weakened mussel attachment”, February 2015, Union, WA. Audience 100 people

Media Publications featuring our project:

Sudermann, Hannelore, 2015. The Dream Lab. Our work was part of a feature story on Friday Harbor Laboratories in the December issue of UW Columns Magazine.

<http://www.washington.edu/alumni/columns-magazine/december-2015/features/ocean/>.

Sakamoto, Stacy, 2016. University of Washington’s Friday Harbor Labs. Our research was featured in a video produced by University of Washington’s UW360 series. Published on Mar 4, 2016. <http://uwtv.org/watch/zk4E8nh55pI/>

- Cooney, Elizabeth, 2015. Hanging by a thread. Feature story in Autumn 2015 issue of *Sea Star*, a newsletter published by Washington Sea Grant. <https://wsg.washington.edu/wordpress/wp-content/uploads/seastar/Sea-Star-Aut-2015.pdf>.
- Cooney, Elizabeth, 2015. Hanging by a thread. National Sea Grant website, feature story on September 24, 2015. <http://seagrant.noaa.gov/News/FeatureStories/TabId/268/ArtMID/715/ArticleID/588/Hanging-by-a-Thread.aspx>
- Governor Jay Inslee, 2015. Tweets about his visit to Penn Cove Shellfish. March 24, 2015. <https://twitter.com/GovInslee/status/580420810323673089>  
<https://twitter.com/GovInslee/status/580418466429198336>
- Hickey, Hannah, 2015. UW Press Release, March 12, 2015. Naturally acidic waters of Puget sound surround UW's Friday Harbor Labs. <http://www.washington.edu/news/2015/03/12/naturally-acidic-waters-of-puget-sound-surround-uws-friday-harbor-labs/>