Completion Report

Period: 2/1/2014 - 1/31/2015

Project: R/LME-5 - *Effects of early exposure of Pacific oysters to ocean acidification on subsequent performance*

STUDENTS SUPPORTED

Gillon, Daniel, dgillon@uw.edu, University of Washington, School of Aquatic and Fishery Sciences, status: cont, field of study: Fisheries, advisor: Carolyn Friedman, degree type: MS, degree date: 2016-06-01, degree completed this period: No
Student Project Title: *none*
Involvement with Sea Grant This Period:
grad student
Post-Graduation Plans:
will seek employment

Wippel, Bryanda, bjtw@uw.edu, University of Washington, Env Studies, status: new, *no field of study*, *no advisor*, degree type: BA, degree date: 2014-06-01, degree completed this period: Yes
Student Project Title:
Ocean acidification effects on oysters
Involvement with Sea Grant This Period:
student volunteer
Post-Graduation Plans:
grad school

CONFERENCES / PRESENTATIONS

Effects of ocean acidification on oysters. C. Friedman. Fish 250, University of Washington, December 2014., public/profession presentation, 75 attendees, 2014-12-01

Effects of ocean acidification on marine molluscs. C. Friedman. Bio 533, Friday Harbor Labs August 2014., public/profession presentation, 20 attendees, 2014-08-01

Ocean Acidification: Influence on the Pacific oyster: Transgenerational effects. C. Friedman, R. Darmawan, J. Davis, B. Dumbauld, B. Eudeline, M. George, D. Mercer, K. Schaffnit,. Invited Seminar: Friday Harbor Marine Lab, August 2014., public/profession presentation, 30 attendees, 2014-08-01

ADDITIONAL METRICS

P-12 Students Reached:

P-12 Educators Trained:

Participants in Informal Education Programs:

Volunteer Hours:

Acres of coastal habitat protected, enhanced or restored:

Resource Managers who use Ecosystem-Based Approaches to Management:

Annual Clean Marina Program - certifications:	**HACCP - Number of people with new certifications:**

ECONOMIC IMPACTS

No Economic Impacts Reported This Period

SEA GRANT PRODUCTS

Description	Developed?	Used?	ELWD?	Number of Managers	Names of Managers
Potential broodstock treatment to reduce larval losses	Yes	No	No	0	

HAZARD RESILIENCE IN COASTAL COMMUNITIES

No Communities Reported This Period

ADDITIONAL MEASURES

Number of stakeholders modifying practices:	Sustainable Coastal Development **# of coastal communities:**

PARTNERS

Partner Name: Baywater Inc.

Partner Name: Friday Harbor Marine Lab, type: Academic Institution, scale: State

Partner Name: Taylor Shellfish Company

Partner Name: USDA Agriculture Research Station

IMPACTS AND ACCOMPLISHMENTS

Title: **Washington Sea Grant research reveals that the effects of ocean acidification on Pacific oysters may extend across generations and result in more resilient broodstock**
Type: impact
Relevance, Response, Results:
Relevance: While research has explored the effects of ocean acidification (OA) on shellfish larvae, limited work has examined either carryover effects from parent to offspring or the effect of larval exposure on performance in later life. Identifying resilient strains and their distinguishing genetic factors would allow selective breeding of commercially valued shellfish for OA tolerance.
Response: Washington Sea Grant-funded researchers examined the effects of high CO_2 levels on adult Pacific oyster reproduction, gametes, and larvae, and on

survivors’ subsequent performance. Broodstock and larvae were conditioned to high and low CO2 levels. Researchers planted the offspring at three sites and measured survival after 6 and 18 months and yield by weight after 9 months. They also genotyped larval samples.
Results: Larvae whose parents were conditioned to high CO2 levels and who were themselves raised in low levels (high–low) had the highest larval performance, survival, and yield at all three sites. Oysters fared worse within the three other treatment combinations—high–high, low–high, and low–low parent–larvae CO2 exposures—with outcomes varying by experimental parameter. For example, paternal CO2 exposure seemed to affect larval survival more than maternal exposure. These findings suggest that exposure to OA may result in significant cross-generational effects, with CO2-stressed parents producing more resilient offspring. Taylor Shellfish, Washington’s largest oyster producer, is considering using project-generated oysters as broodstock.
Recap:
Recap: Washington Sea Grant-supported research documents cross-generational effects of OA on Pacific oyster viability and yield, with CO2-stressed parents producing more resilient offspring and, potentially, better-adapted broodstock lines.
Comments:
Primary Focus Area: OCEH (SSSS)
Secondary Focus Area: OCEH (HCE), COCC (HRCC)
Associated Goals: Improve understanding and management of emerging and cumulative threats to ocean and coastal health. (SSSS Supply)
Improve understanding and management of emerging and cumulative threats to ocean and coastal health. (HCE Science)
Improve understanding of coastal hazards and environmental change and develop tools and approaches for observation, prediction, planning, and adaptation. (HRCC Capacity)
Partners:
Agriculture Research Service (USDA, ARS)
Baywater, Inc.
Friday Harbor Laboratories
Taylor Shellfish Company
Related Partners: Taylor Shellfish Company

PUBLICATIONS

Title: **Ocean Acidification: Are our shellfish in peril?**
Type: General Public and Advisory Reports, Fact Sheets, Posters Publication Year: 2013
Uploaded File: *none*
URL: *none*
Abstract:
NA
Citation:
Ocean Acidification: Are our shellfish in peril? C. Friedman, J. Bouma, S. Brombacker, E. Carrington, L. Crosson, R. Darmawan, J. Davis, B. Dumbauld, B.

Eudeline, J. Havenhand, D. Mercer, M. O’Donnel,
M. Roberts, K. Schaffnit, E. Timmins-Schiffman. UW College of the Environment Donor Event 2013.
Copyright Restrictions + Other Notes:
Journal Title: *none*

Title: **Elevated pCO2 causes developmental delay in early larval Pacific oysters, Crassostrea gigas.**
Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2012
Uploaded File: oyster_larvae_co2.pdf, 421 kb
URL: http://www.researchgate.net/publication/235922257_Elevated_pCO2_causes_developmental_delay_in_early_larval_Pacific_oysters_Crassostrea_gigas
Abstract:
Increasing atmospheric CO2 equilibrates with surface seawater, elevating the concentration of aqueous hydrogen ions. This process, ocean acidification, is a future and contemporary concern for aquatic organisms, causing failures in Pacific oyster (Crassostrea gigas) aquaculture. This experiment determines the effect of elevated pCO2 on the early development of C. gigas larvae from a wild Pacific Northwest population. Adults were collected from Friday Harbor, Washington, USA (48°31.7′N, 12°1.1′W) and spawned in July 2011. Larvae were exposed to Ambient (400 µatm CO2), MidCO2 (700 µatm), or HighCO2 (1,000 µatm). After 24 h, a greater proportion of larvae in the HighCO2 treatment were calcified as compared to Ambient. This unexpected observation is attributed to increased metabolic rate coupled with sufficient energy resources. Oyster larvae raised at HighCO2 showed evidence of a developmental delay by 3 days post-fertilization, which resulted in smaller larvae that were less calcified.
Citation:
Timmins-Schiffman, E, O'Donnell, MJ, Friedman, CS, Roberts, SB. 2012. Elevated pCO2 causes
developmental delay in early larval Pacific oysters, Crassostrea gigas. Mar. Biol. 160(8): 1973-
1982.
Copyright Restrictions + Other Notes:
doi: 10.1007/s00227-012-. 2055-x
Journal Title: Marine Biology

OTHER DOCUMENTS

No Documents Reported This Period

LEVERAGED FUNDS

Type: influenced Period: 2014-09-26: : 2015-09-25Amount: $20000
Purpose:
Carry-over effects of OA on oyster family lines
Source: USDA Agricultural Research Center

COMPLETION NARRATIVE

Uploaded File: Friedman_9975_completi....1.pdf, 2007 kb

WASHINGTON SEA GRANT PROGRESS REPORT

for the period 2/1/2014 – 1/31/2015

WSG Project Number: R/LME-5
Project Title: Effects of early exposure of Pacific oysters to ocean acidification on subsequent performance

Principal Investigator and Affiliation:
Carolyn Friedman University of Washington, School of Aquatic & Fishery Sciences

1. PROJECT OBJECTIVES (from original proposal)

By assembling a comprehensive team of investigators across key disciplines (biology, pathology, genetics, and aquaculture), collaborators and stakeholders from coastal communities, and science educators, we are in a unique position to ask: 1) if larvae exposed to sublethal levels of OA subsequently exhibit poor performance in the field; 2) whether artificial selection can improve hatchery and field performance under OA conditions; 3) if broodstock exposure to OA has detrimental effects on gamete quality; 4) whether specific genetic markers can be used in a program of marker assisted selection to enhance tolerance to OA in Pacific oysters. This project has two outreach components. The quantitative genetics research will also serve as the first step of a practical breeding effort to produce OA tolerant oyster broodstock to the shellfishg industry. In addition, a public outreach effort will teach high school students about the negative effects of OA and its connection to human actions, hopefully changing behaviors and attitudes leading to future reductions in CO_2 emissions.

We plan to address these problems, within the limits of available funding, and test our hypotheses.

We hypothesize that exposure to increased pCO_2 as adults or larvae will affect subsequent performance (growth, survival, and reproduction) and that Pacific oyster populations harbor high levels of genetic variation for performance traits under high CO_2 conditions.

Specifically, we will:

1. Investigate effects of broodstock exposure to high pCO_2 seawater on gamete and larval quality.
2. Determine if larvae exposed to high pCO_2 seawater subsequently exhibit compromised performance (growth, survival, and maturation) as post-set juveniles and adults under a range of field conditions.
3. Estimate genetic parameters required to implement an effective breeding program for enhanced tolerance of OA conditions:
   a. genetic potential (heritability) for selective breeding to improve larval tolerance of high CO_2 seawater.
   b. trade-offs (negative genetic correlations) with other economically important traits.

Additionally, we will:

4. Outreach—Provide our curriculum on ocean acidification to high schools, and distribute first generation selected broodstock to the shellfish industry.

2. PROJECT PROGRESS

We are investigating the impacts of ocean acidification on Pacific oyster reproduction in our current Washington Sea Grant funded project. Oysters from Pipestem Inlet, B.C., Canada are being investigated by the Washington State shellfish industry to assess their potential for use in commercial oyster lines. As noted above, marine and estuarine organisms experience elevated pCO_2 routinely along the Pacific west coast of North America and in Washington State's inland marine waters (Feely et al. 2004, 2008, Barton et al. 2012). Given the problems experienced at some local commercial hatcheries, we designed our experiment to reflect methods employed at a commercial shellfish hatchery in the State. Adult oysters from nine separate Pipestem families that had been held in South Puget Sound, WA were introduced into a hatchery in Quilcene, WA in January 2013. Half of the oysters from each family were conditioned under ambient and half were conditioned at an elevated pCO_2 (Table 1) for ~2 mo (Figure 1).

Table 1. Seawater conditions and carbonate chemistry used in our ocean acidification study with Pacific oysters. ND indicates not determined.

Period	Treatment	Temperature	Salinity	pH	TA	pCO_2	TCO_2	Ω Aragonite	Ω Calcite
Broostock Conditioning	Ambient	17.2	27.8	7.83	2015.6	641	1915.4	1.34	2.11
	High CO2	17.2	27.8	7.41	1954.8	1747	1969.2	0.53	0.83
Days 1-4 post hatch	Ambient	22.3	28.1	8.13	ND	ND	ND	ND	ND
	High CO2	22.3	28.1	8.15	ND	ND	ND	ND	ND
Days 4-18 post hatch	Ambient	25.1	27.1	7.67	2045.0	1005	1961.99	1.3	2.02
	High CO2	25.1	27.1	7.53	2054.7	1431	2012.83	0.97	1.51

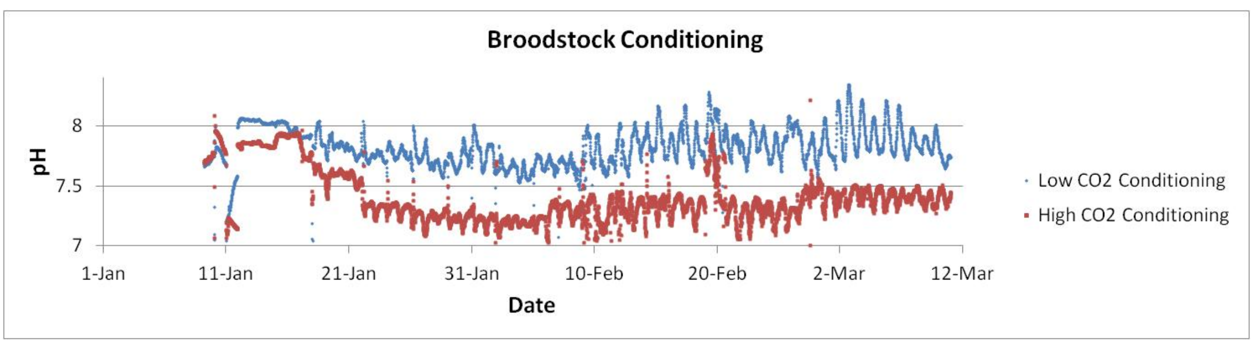


Figure 1. Daily pH trends for broodstock maintained at ambient (Low CO_2, blue line) and elevated pCO_2 (High CO_2, red line).

Due to a pattern of high losses (up to 100%) of spawning and or larval rearing in 2013, gametes were fertilized in and larvae reared for 3.5 days in Na_2CO_3-buffered seawater (pH ~8.2, aragonite saturation 4.2). After this time larvae were transitioned to either raw seawater (ambient) or elevated pCO_2 conditions (Table 1, Figure 2). Maturation conditions did not influence oyster condition as measured by tissue wet weight to shell height ($p>0.05$) or sex ratios ($p>0.05$).

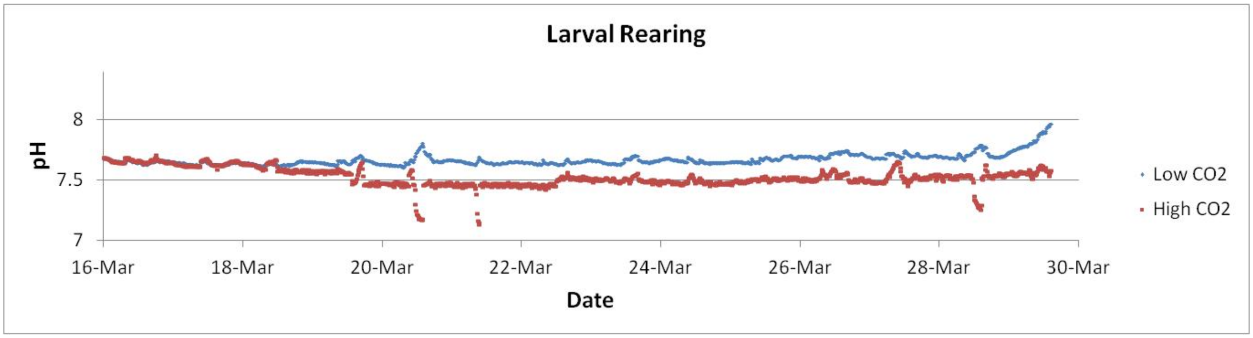


Figure 2. Daily pH trends for larvae maintained at ambient (Low CO_2, blue line) and elevated pCO_2 (High CO_2, red line).

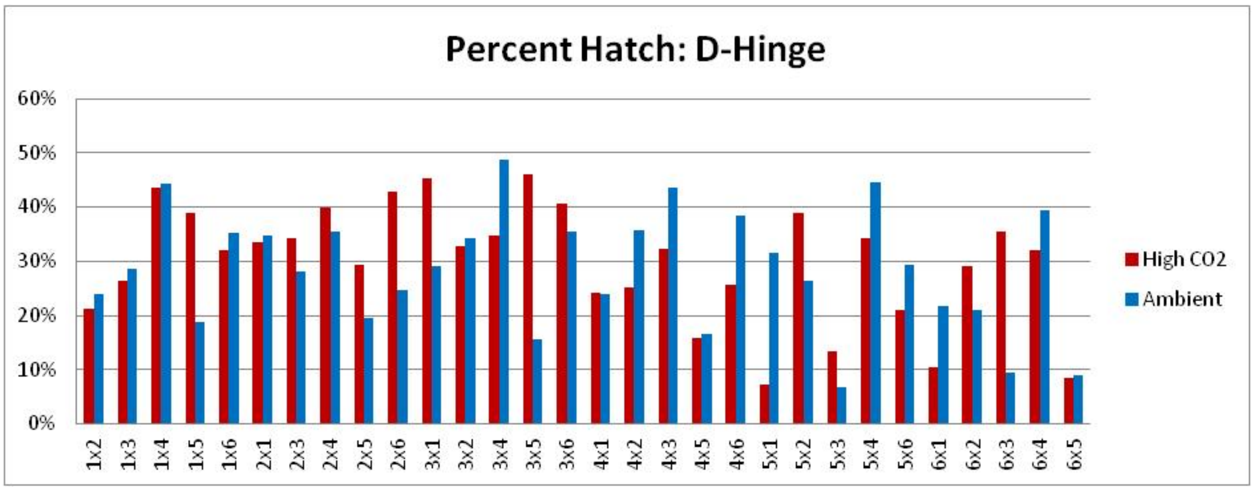


Figure 3. Percentage of larvae hatched and survived to D-hinge (24 hr) for each crossed. Red bars represent those with gametes produced under elevated pCO_2 conditions, while blue bars represent those produced under ambient pCO_2 conditions.

Although the percentage of larvae to hatch and survive to D-hinge (24hpf) did not vary between treatments (ambient versus high pCO2), crosses (families) performed differentially ($F=2.035$, $df=29$, $p=0.03$, Figure 3). Interestingly, family effects were driven by males ($p<0.05$), but only at elevated pCO_2 (Figure 4). Hatching rate under ambient conditions did not predict hatching rate under elevated pCO_2 conditions ($p>0.05$).

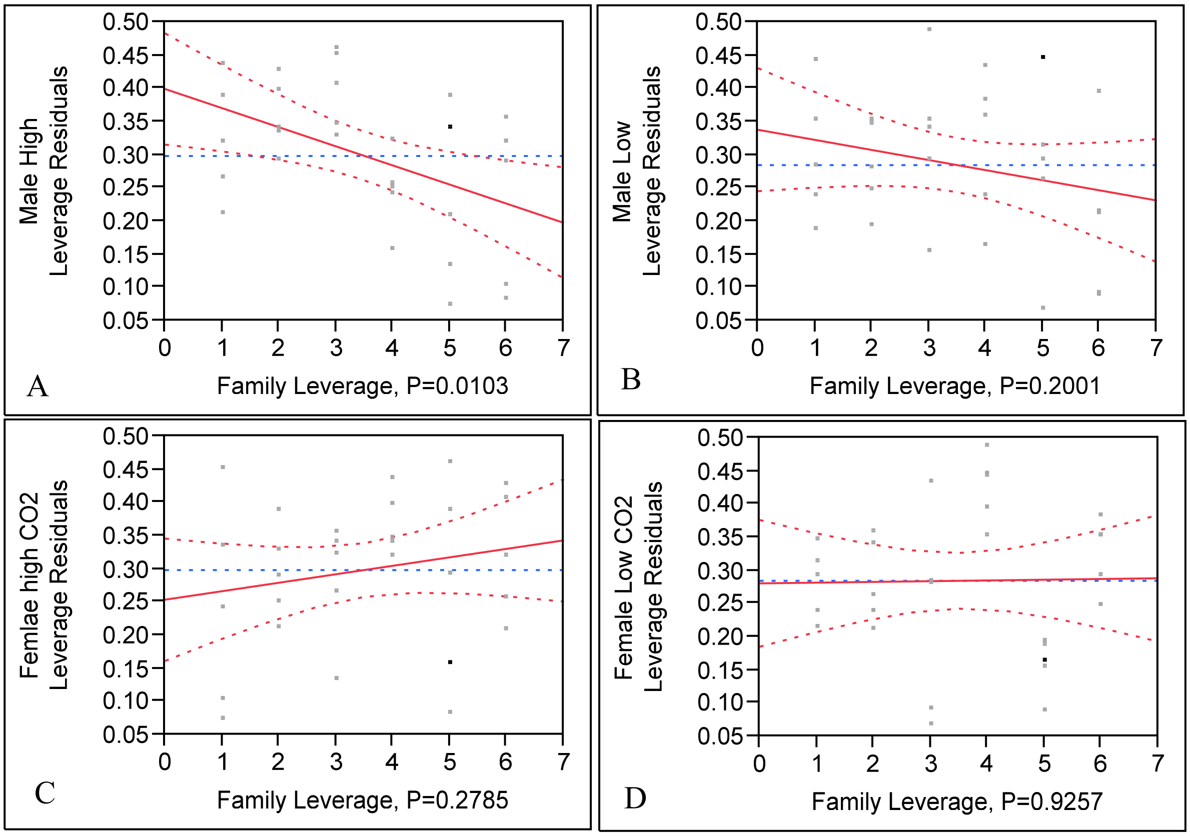
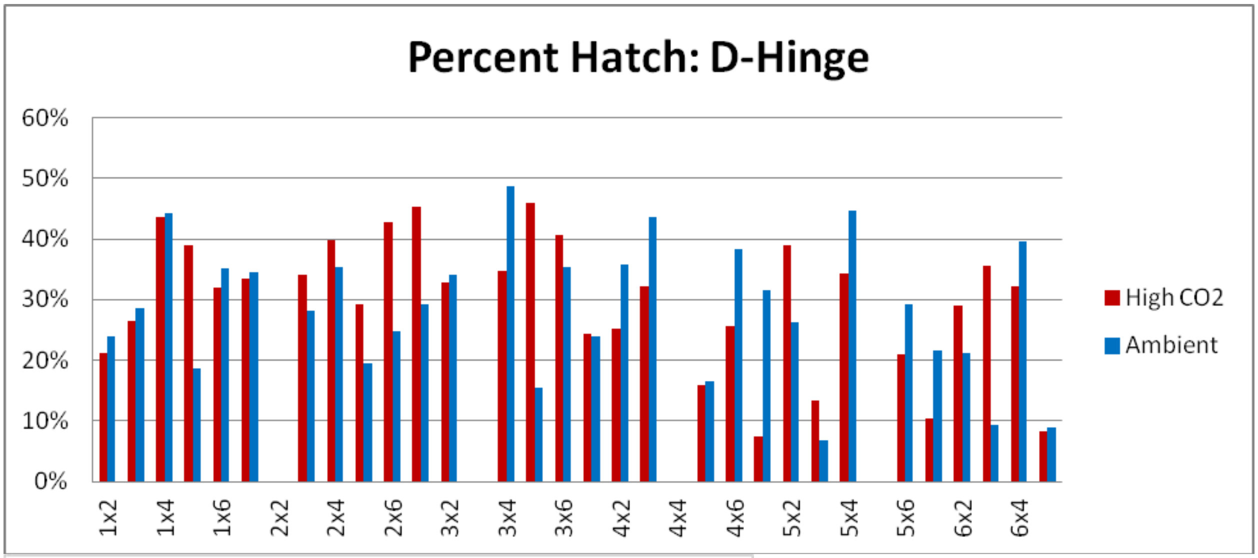
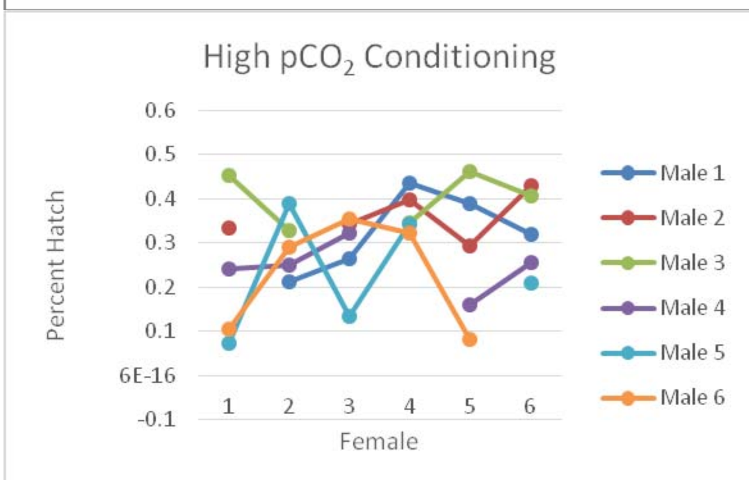
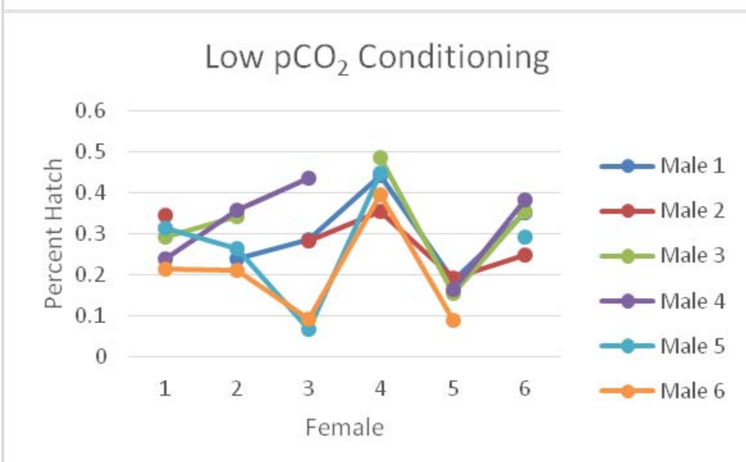


Figure 4.
Family

Leverage Plots of percent hatching by family as driven by male or females from each cross (n=6 male and 6 female oysters used to create a 30 families from a 6x6 full factorial less inbreds mating scheme).







Larval performance varied among treatment combinations of broodstock (Low or High = L or H) and larval rearing conditions (Low or High = L or H) for a total of four conditions (LL, LH, HH, HL; the first letter represents parental maturation conditions and the second letter represents larval rearing conditions). The most larvae were competent to set by day 16 post fertilization in the HL treatment, followed by both low maturation groups (LL and LH), and the least competent larvae were observed in the HH treatment ($p=0.0031$, Figure 5 Analysis of means for transformed ranks plot = ANOMtr). Similar numbers of larvae were competent to set on day 18 post hatch among treatments ($p>0.05$). Trends of the total number of competent larvae among groups followed those observed on day 16 ($p=0.0088$, ANOMtr). However, a significantly fewer number of young spat successfully set and survived to one week after metamorphosis in those whose gametes were produced under ambient conditions but experienced elevated pCO_2 as larvae (LH treatment, $p<0.001$, Figure 6). Thus conditions experienced in both the parental generation and larval phase carried over into the juvenile (seed) stage. More of the HL group survived as (50.45% yield of seed, $p<0.05$) from fertilization to one week post settlement, while losses similar to the mean were observed in the 36.84% of the control group (LL) and 20.20% of the HH groups ($p>0.05$), which were all higher than those in the LH group that experience only 14.31% yield ($p<0.05$, Figure 7). We are in the process of analyzing genotype data from the larval period.

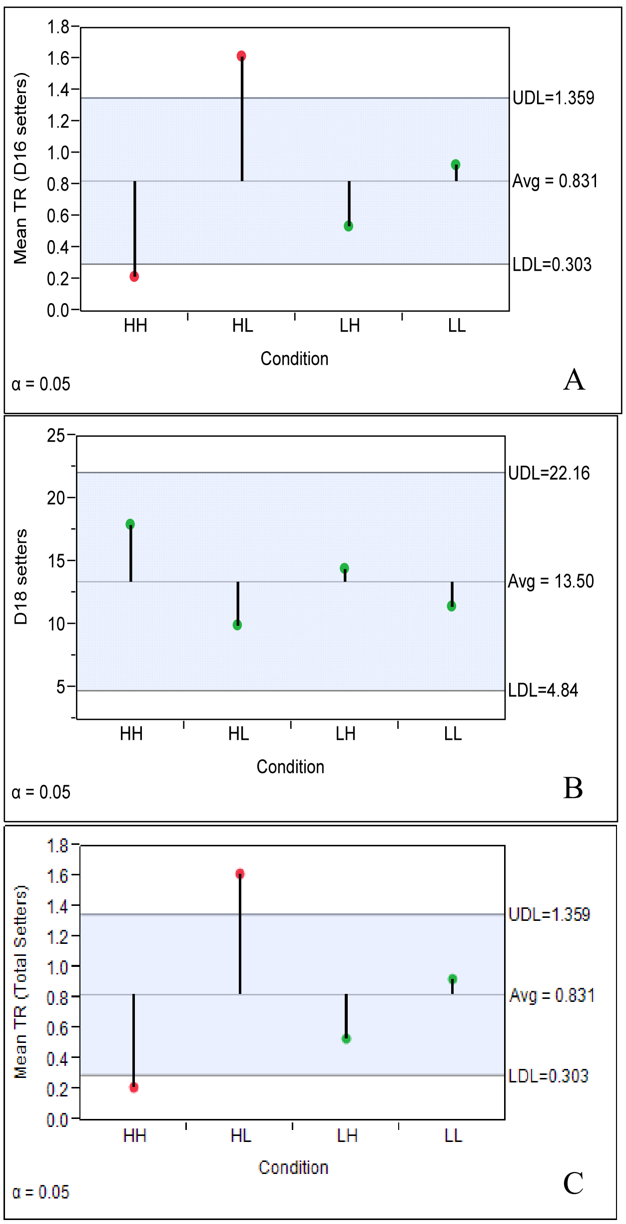


Figure 5. Analysis of means – Transformed Ranks (for unequal variance)(ANOMtr) of A) day 16, B) day 18 and C) total numbers of larvae that were competent to set. Red symbols illustrate groups that are significantly different than the mean (green symbols).

Recent analysis has focused on genotype samples and field assessments as outlined below.

Table 2. Number of larvae assigned to each family based on parent within each sex (male or female).

		Treatment			
Family No.	**Parent**	**HH**	**HL**	**LH**	**LL**
1	**Male**	98	105	38	62
2	**Male**	58	62	54	69
3	**Male**	69	50	61	51
4	**Male**	47	69	111	72
5	**Male**	55	36	64	61
6	**Male**	53	58	52	65
1	**Female**	20	42	121	91
2	**Female**	123	61	88	75
3	**Female**	24	56	28	53
4	**Female**	130	92	66	55
5	**Female**	44	59	43	42
6	**Female**	39	70	34	64

Analysis of genotyping analysis suggests equal representation of families among treatment except for an under representation of families in which the male originated from family 4 in HH treatment. Chi-square analysis suggests that fewer larvae from families using male four mated to females 1, 3 and 6 ($p<0.05$). Examination of pooled data across treatments indicated no influence of male or female family (Table 2).

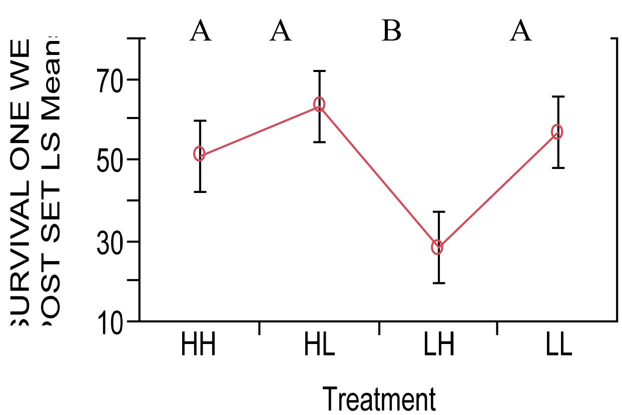


Figure 6. Least Squares Means plot of survival to one week after settlement for the four treatment groups. Different letters signify statistical differences among groups.

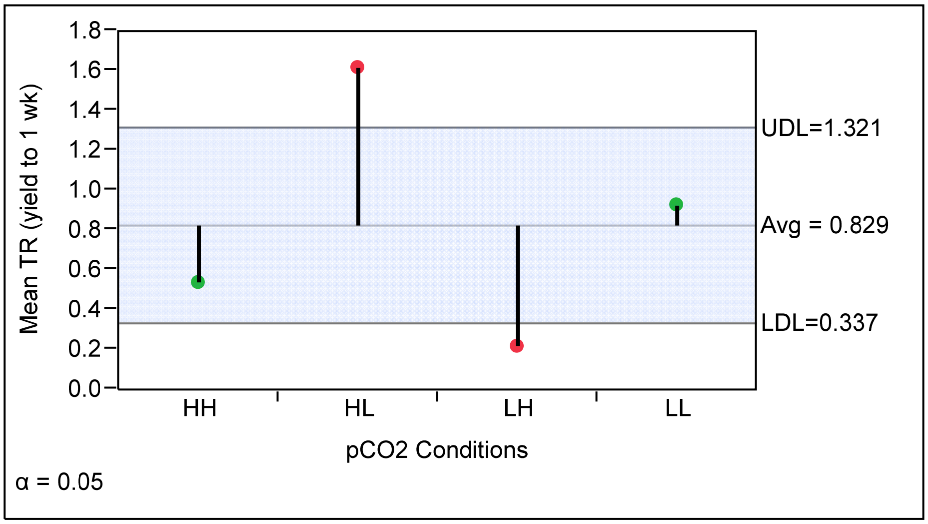


Figure 7. Analysis of means – Transformed Ranks (for unequal variance) total yield of seed from fertilization to one week post settlement. Red symbols illustrate groups that are significantly different than the mean (green symbols).

Fig. 8 shows that juvenile weight on day 103 was influenced more by parental condition than as larvae and illustrates the importance of the *transgenerational* effects of OA. Interestingly, LH conditions mimic those plaguing our regional hatcheries.

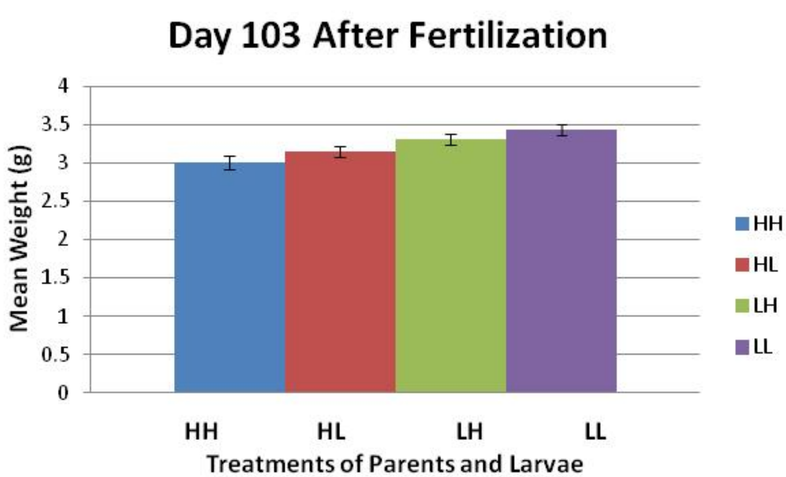


Figure 8. Young Pacific oyster seed weighed less when their parents were exposed to high pCO_2 relative to those that experienced ambient conditions ($p<0.05$). These effects carried over to juveniles over 85 days after cessation of the OA treatment.

Juveniles were planted at three field sites (Sequim Bay, Thorndyke Bay, Totten Inlet) at 3.5 mo in age and were assessed after 6 months and 18 months in at the three field sites (Figs. 9-12).

Figure 9. Oyster bags deployed at one of our field sites.

We calculated percent survival from D-hinge through field planting. In December 2013 (day 282), we observed a site effect on survival. Fewer oysters in Totten Inlet survived (61%) than in the other two sites (94-97%); $p<0.0001$), likely due to a thermal stress after planting. Preliminary analysis of total survival across sites for the four treatments is shown in Figure 10. Survival was highest in the HL treatment and was similar to that in the LL treatment, while those in the LH treatment were intermediate in survival and the least survival was observed in the HH treatment.

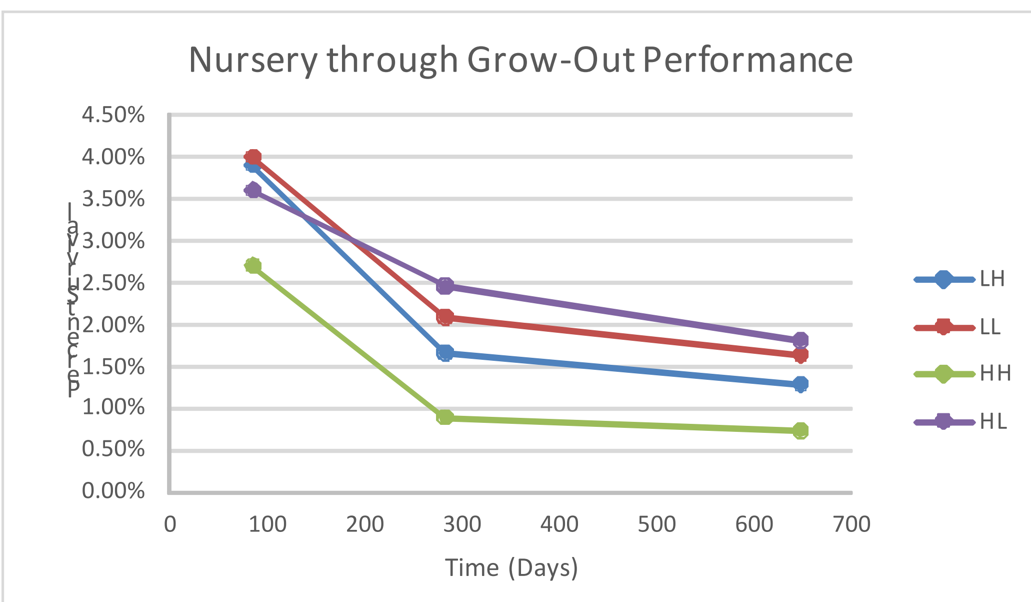


Figure 10. Survivorship of oysters to Day 647 in the four treatments (pooled data from all field sites).

Interestingly hatchery performance (number of larvae competent to set and yield to one week after settlement) seem to correlate with later performance (Figure 11, Table 3). Pearson moment correlation suggested that performance of treatment groups on Day 16 were correlated with that measured on Days 18, 262 and 647 ($p<0.05$). Metrics for Day 16 was number of larvae competent to settle, Day 18 represented the total number of larvae competent to settle, and Days 30, 85, 262 and 647 represented survival from D hinge.

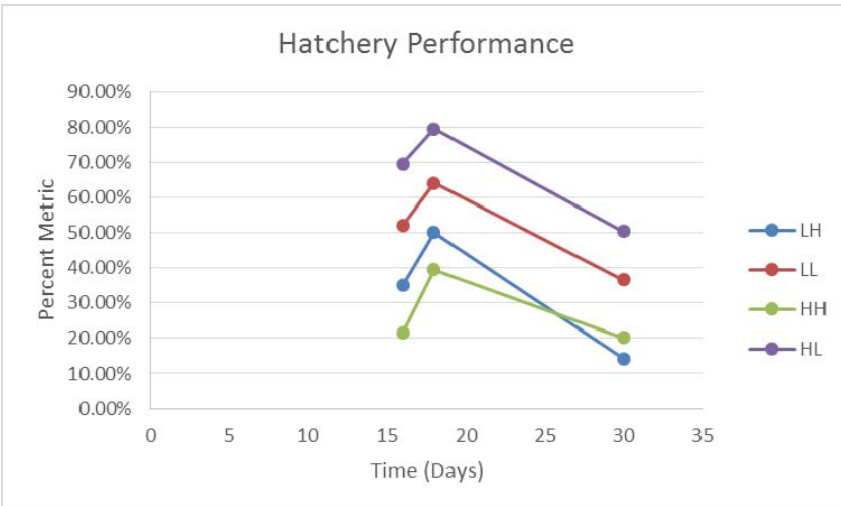


Figure 11. Hatchery performance of larvae among treatments.

Table 3. Correlation of performance among days.

	Row ID	Day 18	Day 30	Day 85	Day 282	Day 647
Day16	1	**1**	0.915	0.564	**0.972**	**0.957**
	2	**0.000392**	0.0852	0.436	**0.0285**	**0.043**
	3	4	4	4	4	4
Day18	1		0.922	0.542	**0.965**	*0.949*
	2		0.0783	0.458	**0.0348**	*0.0513*
	3		4	4	4	4
Day30	1			0.234	0.801	0.782
	2			0.766	0.199	0.218
	3			4	4	4
Day85	1				0.742	0.778
	2				0.258	0.222
	3				4	4
Day282	1					**0.997**
	2					**0.00338**
	3					4

1= Correlation coefficient; 2 = p value; 3 = number; bold red indicate a significant correlation; italics indicates a near significant correlation

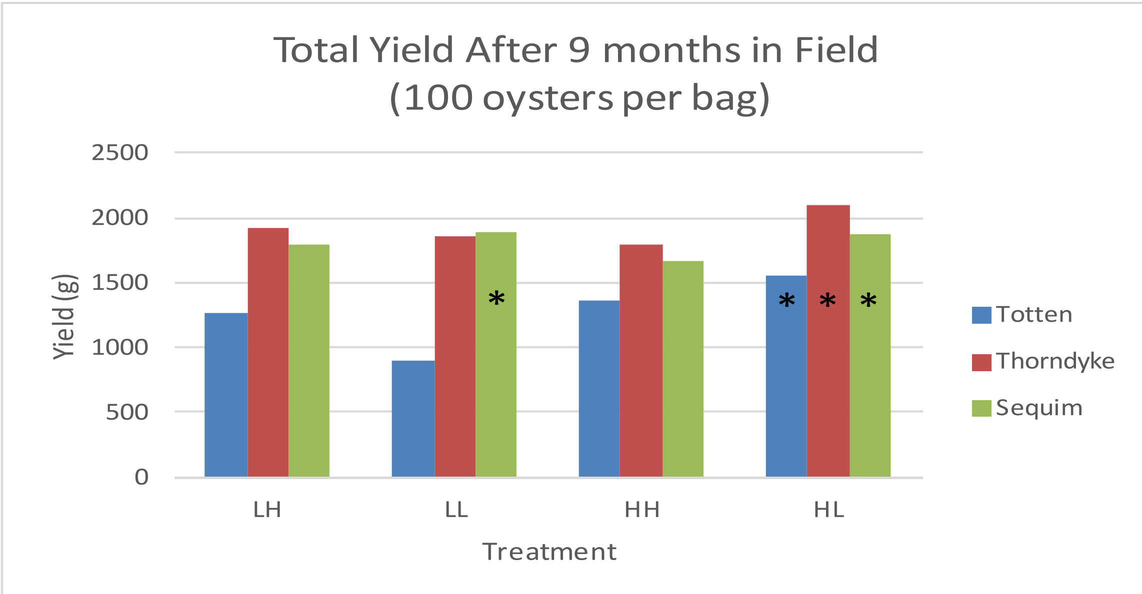


Figure 12. Yield of oysters from each treatment (all families combined) after 9 mo of growth in the field, of which 2 months oysters were held in a common nursery (Thorndyke Bay) followed by deployment at the three field sites for 6 months.

Both site and treatment impacted total weight of oysters. Those in Totten Inlet were larger than those in the other two sites ($p<0.05$). When all data was combined, treatment affected weight: oysters from the HL treatment weighed more than those from the other three treatments ($p<0.001$), which were similar to one another ($p>0.05$). In December 2014, day 647, we observed similar trends of a site effect on survival (Totten = 43% and Thorndyke = 87%; $p<0.0001$) but no effect from treatment ($p>0.05$). When all data was combined for treatments, treatment effects on total weight were marginally significant: LL > HH = HL > LH ($p=0.06$). Yield measurements, a combination of survival and live weight from hatch through 9 months in the field was estimated and preliminary analysis suggests that the HL treatment may provide increased yield at both Totten Inlet and Thorndyke Bay (Figure 4). Oysters from both the HL and LL treatments that were reared in Sequim Bay had similar yields. Highest yields for treatment groups as highlighted with an asterisk.

3. ACCOMPLISHMENTS AND IMPACTS

Follow the Relevance, Response, Results and Recap format as detailed in the Accomplishments and Impacts guidance at: http://wsg.washington.edu/research/pdfs/Impact_Accomps_Guidance.pdf

a. **ACCOMPLISHMENT** Ocean acidification is an increasing threat to our oceans. The NE Pacific is particularly vulnerable to its impacts and our inland marine waters are already experiencing conditions worse than end of century predictions. Via Washington Sea Grant funding, we are learning that transgenerational effects of ocean acidification are apparent and studies are needed that cross multiple generations to fully understand the impacts of OA on our shellfish species.
b. **IMPACTS** Our biggest impact to date is the identification of rearing methods that appear to improve survival under stressful field conditions. The Taylor Shellfish Farm is interested in using some of our oysters as broodstock to further assess their utility.

4. PUBLICATIONS

Timmins-Schiffman, E, O'Donnell, MJ, **Friedman, CS**, Roberts, SB. 2013. Elevated pCO_2 causes developmental delay in early larval Pacific oysters, *Crassostrea gigas*. Mar. Biol. 160(8):1973-1982.

Two additional manuscripts are in progress. One paper details the information provided herein and a second paper deals with proper reporting of OA chemistry.

Presentations:

Oral:

Ocean Acidification: Influence on marine calcifiers: Transgenerational and potential for population level impacts. C. Friedman, J. Bouma, S. Brombacker, E. Carrington, L. Crosson, R. Darmawan, J. Davis, B. Dumbauld, B. Eudeline, M. George, J. Havenhand, D. Mercer, M. O'Donnell, M. Roberts, S. Roberts, K. Schaffnit, S. White. Invited Seminar: Gulf Coast Research Lab, University of Southern Mississippi, Nov 2013.

Ocean Acidification: Influence on marine calcifiers. C. Friedman, M. Roberts, E. Dorfmeier, L. Crosson, S. Brombacker, B. Eudeline, K. Schafnet, S. White, D. Mercer, R. Darmawan, E. Timmins-Schiffman, D. Metzger, M. O'Donnell, E. Carrington, S. Roberts, B. Dumbauld, J. Davis. Invited Speaker, Think Evolution workshop, Forks, WA, August 2013.

Ocean Acidification: Influence on marine calcifiers. C. Friedman, E. Timmins-Schiffman, E. Dorfmeier, S. White, D. Metzger, S. Brombacker, M. O'Donnel, J. Bouma, E. Carrington, S. Roberts. Invited Speaker, Marine managers Workshop, Friday Harbor, WA. Feb 2013.

Ocean Acidification: Influence on the Pacific oyster: Transgenerational effects. C. Friedman, R. Darmawan, J. Davis, B. Dumbauld, B. Eudeline, M. George, D. Mercer, K. Schaffnit,. Invited Seminar: Friday Harbor Marine Lab, August 2014.

Effects of ocean acidification on marine molluscs. C. Friedman. Bio 533, Friday Harbor Labs August 2014.

Effects of ocean acidification on oysters. C. Friedman. Fish 250, University of Washington, December 2014.

Poster:

Ocean Acidification: Are our shellfish in peril? C. Friedman, J. Bouma, S. Brombacker, E. Carrington, L. Crosson, R. Darmawan, J. Davis, B. Dumbauld, B. Eudeline, J. Havenhand, D. Mercer, M. O'Donnel, M. Roberts, K. Schaffnit, E. Timmins-Schiffman. UW College of the Environment Donor Event 2013.

5. STUDENTS

Please provide the following information for every student that worked with you during the reporting period.

____ Please indicate with a check mark here if no students were involved in the project.

Student Name: Bryanda Wippel
Degree track: BS
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): New
Department: Environmental Studies
Major/Degree field: Environmental Studies
Major Professor: Undergraduate student
Dissertation title (actual or anticipated): N/A
Date of graduation: 2014

Student Name: Nathan Berry
Degree track: BS
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): New
Department: Microbiology
Major/Degree field: Microbiology
Major Professor: Friedman
Dissertation title (actual or anticipated): Transgenerational effects of ocean acidification on the Pacific oyster larvae.
Date of graduation: anticipated 2015

Student Name: Rizky Darmawan
Degree track: BS
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): No SG support capstone student
Department: SAFS
Major/Degree field: SAFS
Major Professor: Friedman
Dissertation title (actual or anticipated): Transgenerational effects of ocean acidification on the Pacific oyster larvae and early juveniles.
Date of graduation: anticipated 2013

Student Name: Eric Harris
Degree track: BS
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): No SG support: Capstone
Department: SAFS
Major/Degree field: SAFS
Major Professor: Friedman
Dissertation title (actual or anticipated): Transgenerational effects of ocean acidification on the pacific oyster: effect on morphometrics after 9 months under field conditions.
Date of graduation: anticipated 2013

Student Name: Marina Krasnovid
Degree track: BS
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): No SG support: volunteer
Department: SAFS
Major/Degree field: SAFS
Major Professor: Friedman
Dissertation title (actual or anticipated): Transgenerational effects of ocean acidification on the pacific oyster.
Date of graduation: anticipated 2013

Student Name: Jacob Gregg
Degree track: PhD
Whether degree was **completed** during the reporting window (NO):   Yes
New or continuing student on WSG support (NEW): No SG support: volunteer
Department: SAFS
Major/Degree field: SAFS
Major Professor: Friedman
Dissertation title (actual or anticipated): N/A
Date of graduation: anticipated 2015

Student Name: Matt George
Degree track: PhD
Whether degree was **completed** during the reporting window (NO):   No
New or continuing student on WSG support (NEW): No SG support but collaborating on the chemistry paper
Department: Biology
Major/Degree field: Biology
Major Professor: Carringtom
Dissertation title (actual or anticipated): Biochemical effects of ocean acidification on mussel byssus.
Date of graduation: anticipated 2016

Student Name: Lisa Crosson
Degree track: Ph.D.
Whether degree was **completed** during the reporting window (NO):
New or continuing student on WSG support (NEW):
Department: School of Aquatic and Fishery Sciences
Major/Degree field: Fisheries
Major Professor: Friedman
Dissertation title (actual or anticipated): Withering Syndrome Dynamics in California Abalone
Date of graduation: anticipated June 2015

Student Name: Emma Timmins-Schiffman
Degree track: Ph.D
Whether degree was **completed** during the reporting window (YES):
New or continuing student on WSG support (CONTINUING):

Department: School of Aquatic and Fishery Sciences
Major/Degree field: Fisheries
Major professor/Capstone advisor, if relevant: Roberts
Dissertation/Thesis/Capstone project title, if relevant (actual or anticipated): The Physiological Effects of Ocean Acidification on Multiple Life History Stages of the Pacific Oyster, Crassostrea gigas
Date of graduation (actual or anticipated): December 2013
If student has graduated, please provide any known information about their future plans (name and location of anticipated/current employer, graduate program they are entering, etc):

6. PARTNERSHIPS

Please list any partners that you work with on your project. Please specify the partner type and level and describe the nature of the partnership.

Partner	**Specify Type** (Academic, Government, Industry/Business, NGO, SG Program, Other)	**Specify level** (International, Federal, Regional, State, Local)	**Nature of Partnership**
Taylor Shellfish	*Industry*	*Local*	*Full collaboration: they provide animals for experiments and outreach, participate in studies*
USDA Agricultural Research Station	*Government*	*Federal*	*Full collaboration: participating in experiments and genotyping oysters*
Baywater Inc	*Industry*	*Local*	*Provide animals for experiments and participate in study design*
Friday Harbor Marine Lab	*Academic*	*State*	*Provide lab space for longer term trials and use of ocean chemistry laboratory*

7. OUTREACH AND INFORMATION/TECHNOLOGY TRANSFER
See presentations above.

8. LEVERAGED FUNDS
USDA-ARS lab is providing thousands of dollars in genotyping at no charge to the grant.

SEE BELOW FOR PERFORMANCE METRICS REPORTING REQUIREMENTS

9. PERFORMANCE METRICS

We are required to report on a suite of national performance metrics, provided in table format below. Performance metrics are one of the most scrutinized sections of program reports and we appreciate your attention and creativity in considering how these metrics may relate to your research. Please keep in mind your engagement plan as you consider the various measures. To complete this section of your report, fill in all relevant fields of the table. Note that some metrics require your estimate of actual contributions during the reporting window (2/1/2011-1/31/2012) and your estimate of anticipated contributions during 2/1/2012-1/31/2013. Other metrics require information for only the current reporting window.

A. Economic (market and non-market) benefits derived from Sea Grant activities.

Explanation: Society benefits from Sea Grant's assistance in developing new businesses/jobs and retaining existing businesses/jobs. This measure should also include dollars that communities or businesses save due to Sea Grant assistance (i.e., providing information to help businesses make better decisions and avoid mistakes). This measure also tracks economic benefits from the development of new ocean, coastal and Great Lakes resources and technology. (Please do not include economic benefit from volunteer hours).

Enter the category, describe the activity, and enter the actual and anticipated values (dollar amount, number of jobs, etc). If a particular activity yields multiple types of benefits, enter a new category in a new row, repeat the activity description, and enter the values associated with the new category. CATEGORIES: economic benefit ($ - this can include dollars saved due to Sea Grant assistance), businesses created, businesses retained, jobs created, jobs retained, patents/licenses.

Economic benefit category (limited to list above)	Description	Actual (2/1/2011-1/31/2012)	Anticipated (2/1/2012-1/31/2013)

B. Number of tools, technologies and information services **that are developed, provided or facilitated by Washington Sea Grant research, outreach, communications or education to improve ocean and coastal management or sustainable practices.**

Step 1. WSG has tracked this measure since 2006 and has defined it broadly to include any audiences. Please enter tools, technologies and information services (including datasets, standards and indicators) for your project. Fill in the "Developed" and "Used" column with "Y" or "N" as appropriate for 2011 Actual and 2012 Anticipated.

Step 2. The national office tracks a similar measure; however, they have a much more narrow definition to track success in translating information into tools, technologies and information services that improve the use and management of coastal, ocean and Great Lakes ecosystems. *The key here is to account for tools and services utilized and applied by managers*. Indicate in the "# of managers" column the **number of managers that used** a tool, technology or information service listed below (please enter 0 if necessary). For all entries >0, identify who the managers are (which agency, council, etc). If you are **only anticipating** manager use in 2012, you do not need to provide manager details.

	2012 Actual (2/1/2013-1/31/2014)		**2013 Anticipated (2/1/2014-1/31/2015)**		**NSGO restricted definition = used by managers**	
Tool, technology or information service	**Developed**	**Used**	**Developed**	**Used**	**# of managers**	**Who are the managers?**

C. Number of coastal communities (including cities, municipalities, small towns, and neighborhoods that have a cohesive identity) that have adopted or implemented hazard resiliency practices to prepare for and respond to/minimize coastal hazardous events.

		Number of resiliency trainings/technical assistance services *provided*		**Community hazard resiliency improved (e.g., changes in zoning ordinances)? Y/N**	
Name of coastal community	**County of coastal community**	**Actual (2/1/2011-1/31/2012)**	**Anticipated (2/1/2012-1/31/2013)**	**Actual (2/1/2011-1/31/2012)**	**Anticipated (2/1/2012-1/31/2013)**
[EXAMPLE] Port Angeles, WA	*Clallam*	*1*	*4*	*N*	*Y*

D. Additional national performance measures - *NOTE: As relevant, the measures below should correlate with tools, technologies and information services listed above (e.g., fishermen using a new SG-developed technique should match a tool/technology listed above).*

Performance measure		**Actual (2/1/2011-1/31/2012)**	**Anticipated (2/1/2012-1/31/2013)**
Number of fishers, consumers and seafood industry stakeholders who modify their practices using knowledge gained in fisheries sustainability, seafood safety, and the health benefits of seafood.	Number of stakeholders modifying practices		
	Number of fishers using new techniques		
Number of coastal communities that have adopted or implemented sustainable (economic and environmental) development practices and policies (e.g., land-use planning, working waterfronts, energy efficiency, climate change planning, smart growth measures, green infrastructure) as a result of Sea Grant activities.			
Number of coastal communities that have restored degraded ecosystems as a result of Sea Grant activities.			
Number of acres of degraded ecosystems restored as a result of Sea Grant activities.			

E. Focus area metrics – please estimate your contribution to these metrics for the reporting period (2/1/2011-1/31/2012).

Metric	Contribution
Volunteer hours (estimated number of hours that citizens volunteer without payment for their time and services to help a state Sea Grant program accomplish the goals and objectives of its four-year plan)	~1200+75
K-12 students reached (estimated number of K-12 students who attend a Sea-Grant sponsored event as well as the number of students reached by teachers who have utilized information from a Sea Grant project)	~14+30
Curricula developed (number of curricula developed with Sea Grant support, assistance or influence, including formal education courses, school or university instructional materials, lesson plans, audio-visual materials, teacher guides and textbooks.	
Sea Grant-sponsored/organized meetings, workshops and conferences (number of events for which Sea Grant support was integral – planning, financial, personnel contributions)	
Attendees at Sea Grant-sponsored/organized meetings (estimated number of attendees at the events counted in the preceding metric)	
Number of Public or Professional Presentations	4+3
Approximate number of attendees at Public or Professional Presentations	175+235