NERRS Science Collaborative Progress Report for the Period 3/1/2013 through 8/31/2013

Project Title: A collaborative approach to address larval supplies and settlement as critical early life-history issues during restoration of native Olympia oysters (*Ostrea lurida*) in Coos Bay and the South Slough estuary

Principal Investigator(s): Dr. Steven Rumrill

Project start date: Nov 2010

Report compiled by: Steven Rumrill / John Bragg

Contributing team members and their role in the project:

Integration Leader: Frank Burris, Extension Watershed Educator
Oregon State University Extension Service
Gold Beach, OR
Role in project: Facilitation of interactions between the stakeholders (Olympia Oyster Restoration Advisory Committee) and project team members. Mr. Burris has expertise with community stakeholder discussions in rural environments, and will provide for integration and leadership through the joint fact-finding / structured decision-making process.

Co-Principal Investigators: Dr. Craig Young, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Director of OIMB and collaborating project scientist with particular expertise in the reproductive biology and larval ecology of marine and estuarine invertebrates. Dr. Young will serve as the primary graduate thesis advisor for one graduate student (module 1 / reproduction and reproductive output) supported by the project.

Dr. Alan Shanks, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Collaborating project scientist with particular expertise in larval behavior, dispersal, and tidally-driven transport in estuaries. Dr. Shanks will serve as the primary graduate thesis advisor for one graduate student (module 2 / larval supplies and dispersal) supported by the project.

Dr. Richard Emlet, Professor of Biology
University of Oregon / Oregon Institute of Marine Biology
Charleston, OR
Role in project: Collaborating project scientist with particular expertise in larval development, hydromechanics, larval settlement, and metamorphosis. Dr. Emlet will serve as the primary graduate thesis advisor for one graduate student (module 3 / larval settlement and metamorphosis) supported by the project.

Jamie Doyle, Marine Community Development Leader
Oregon Sea Grant Extension Program (Coos County)

Myrtle Point, OR
Role in project: Work with project team to develop a series of presentations, fact sheets, briefing materials to ensure that the stakeholders and scientists share a common level of understanding about the biology and ecology of Olympia oysters. Ms. Doyle has expertise with marine resource policy and management, community education, and outreach, and she will provide assistance to the Integration Leader with the SDM process.

John Bragg, Communications Leader
Coastal Training Program Coordinator
South Slough National Estuarine Research Reserve
Charleston, OR
Role in project: Work to conduct regular and routine communications among members of the project team and the NERRS Science Collaborative, to compile and summarize discussion notes generated during OORAC meetings, serve as co-author of the NSC Biannual reports, and assist with development of presentations, fact sheets, and briefing materials. Mr. Bragg has expertise with condensation of technical research materials into summary sheets, and will provide an interface for the project with the South Slough National Estuarine Research Reserve. John will also provide assistance to the Integration Leader with the SDM process.

A. Progress overview: State the overall goal of your project, and briefly summarize in one or two paragraphs, what you planned to accomplish during this period and your progress on tasks for this reporting period. This overview will be made public for all reports, including confidential submissions.

Project Goal: The overall goal of this project is to investigate the importance of reproductive timing and output, larval supplies, estuarine retention time, settlement, and recruitment as factors that potentially limit recovery of self-sustaining populations of *Ostrea lurida* in Coos Bay and the South Slough estuary. Our specific objectives are to: (A) bring together a diverse group of stakeholders and user-groups to form an Olympia Oyster Recovery Advisory Committee (OORAC); (B) determine the suite of intrinsic ecological, reproductive, and early life-history factors that contribute to the success of Olympia oyster restoration efforts in Coos Bay/South Slough; and (C) integrate the perspectives and collective knowledge from resource agencies, academic investigators, mariculture operators, restoration practitioners, and recreational stakeholders during development of an Olympia Oyster Conservation and Recovery Strategy for Coos Bay.

Accomplishments: The three graduate students at the University of Oregon / Oregon Institute of Marine Biology (OIMB) continued their thesis work focused on the reproductive biology and larval ecology of Olympia oysters (*Ostrea lurida*) in the Coos Bay estuary (Oregon). Mark Oates (MSC candidate; Dr. Craig Young thesis advisor) completed his investigation of gametogenesis, brooding, and brood release among populations of *O. lurida* in Coos Bay. Cate Pritchard (MSc candidate; Dr. Alan Shanks thesis advisor) is investigating the physical hydrodynamic characteristics of the greater Coos Bay estuary and how they influence the supplies, dispersion, export, and retention of *O. lurida* larvae. Rose Rimler (MSc candidate; Dr. Richard Emlet thesis advisor) is documenting the seasonal pattern of larval settlement, metamorphosis, survival, and growth at multiple locations throughout the Coos estuary. All three of the OIMB graduate students are supported by the NERRS Science Collaborative.

Over the period from Mar 2013 to Jun 2013, Mark Oates continued to analyze the histological process of gonad development and maturation (gametogenesis) and timing of reproductive events in two local populations of Olympia oysters in Coos Bay. Mark completed the analysis of the gonad tissues during the winter, and he successfully defended his M.Sc. thesis at the Oregon Institute of Marine Biology on 30 May 2013 (see Appendix I). His thesis is based on monthly collections of adult Olympia oysters along with bimonthly measurements of multiple ambient water quality parameters (*i.e.*, temperature, salinity, chlorophyll) gathered from two intertidal sites within Coos Bay (Haynes Inlet and Coalbank Slough) over a 12-month period from Jan to Dec 2012. The principal findings from his research were that gametogenesis and spawning occur seasonally from May through Sep, and brooding oysters were found from Jul through Sep. Gametogenesis was observed when water temperatures in the estuary exceeded 14.5^{o} C, and brooding oysters were found at temperatures from ~15-19° C. Oocyte diameters increased significantly from May to Jun in Haynes Inlet, and from Jun to Jul in Coalbank Slough. Spermatogenesis (maturation of the testicular component of the gonadal tissues) was initiated in May at Haynes Inlet and in Jun at Coalbank Slough. Dry meat condition values increased significantly during periods of reproduction and decreased significantly following the end of the reproductive season, with an unexplained decrease at both sites between the months of Mar and May. The body condition index values for Coalbank Slough were consistently lower than those at Haynes Inlet, suggesting poor nutrition and/or physiological stress. Low salinities (< 5 psu; below the reported physiological threshold) occurred in the winter months at the Coalbank Slough site and are believed to be an important factor that may influence decreased reproductive activity at this site. Assessments of embryo development stages suggest that spawning periods are linked to neap tide events in Coos Bay, and it is estimated that each brooding female oyster may release up to 250,000 veliger larvae, although it appears that many females release only partial broods at multiple times during the summer.

Cate Pritchard and Rose Rimler continued to work together over the period from Mar to Aug 2013 to routinely monitor and analyze a set of integrated field experiments to assess the supplies and settlement of *Ostrea lurida* larvae at multiple locations within Coos Bay. They deployed a series of replicated ceramic settlement plates (attached to PVC pipe) and replicated larval settlement tubes (five per site) into the soft sediments in the lower intertidal zone along the edges of the primary tidal channel at five locations: (A) Empire tideflats; (B) Haynes Inlet; (C) downtown Coos Bay; (D) Coalbank Slough; and (E) Catching Slough.

Over the last six months (Mar to Aug 2013) Cate completed the analysis of her earlier datasets, and she worked in collaboration with Rose to initiate the collection of new data on the abundance of larval oysters that settle into tube traps deployed in the lower intertidal zone of Coos Bay. These data are correlated with time-series measurements of ambient physical water parameters (*i.e.*, water level, salinity, temperature) in different hydrodynamic regions of the bay. They initiated sampling in mid-May 2013 to document the beginning of the spawning season and to ensure that any trends observed in 2012 were consistent with the measurements recorded in 2013. In addition, Cate and Rose added a sixth study site (Airport) during the reporting period to increase the spatial resolution of their datasets, and to lend further support to their hypothesis that larval retention in Coos Bay is determined by location of the hydrodynamic null point. In addition to using data from the larval traps to examine temporal and spatial variation in larval supplies of *Ostrea lurida*, Cate also worked to identify other bivalve larvae to the lowest taxonomic level and to interpret their local patterns of distribution in Coos Bay. In order to facilitate taxonomic identification of these planktonic larvae, Cate is currently working to process over 100 preserved larvae using morphological and DNA barcode techniques. She also completed a short literature review on recent scientific work focusing on *O. lurida*, with an emphasis on information which may be of interest to local managers, as well as anecdotal comments and statements of hypotheses which would benefit from future scientific examination or experimentation.

Finally, Cate deployed a series GPS drifters to characterize dispersal of water masses in the Coos Bay estuary. These observations will allow her to identify the location of the null point during ebb and flood events (*i.e.*, location where there is no net movement of water at the bed in either direction) and gain a new understanding about the potential role of the null point in the retention of *O. lurida* larvae in the tidal basin. While these data have just been collected and are currently being analyzed, preliminary data suggest that the null point could be a very strong mechanism of preventing larval wastage out of the estuary, but also preventing the intrusion of more marine (rather than estuarine) larval bivalves into the estuary. Cate will continue to work on these aspects of the larval biology of Olympia oysters until her thesis is completed in the winter.

During the spring (Mar to May 2013), Rose Rimler continued to analyze her new data on variability in larval settlement patterns collected during the 2012 field season, and she consulted with Dr. Brian Bingham (Western Washington University) for statistical advice to determine the significance of variability in larval settlement and growth among monitoring sites. Rose continued to monitor growth and survival of two size classes of sub-adult oysters deployed earlier into different regions of Coos Bay, and she measured the small oysters in the field (Apr through Jul 2013) and then brought them into the lab at the end of the deployment experiment. Rose completed the OIMB course on Invertebrate Embryology in the spring (1 Apr to 15 Jun 2013), and she acquired skills in microphotography required to obtain crisp digital photos of *Ostrea lurida* larvae. In May 2013, Rose and Cate Pritchard (see below) began a second field season to concurrently measure bi-weekly differences in larval abundance and settlement at several locations throughout Coos Bay. Heavy settlement of *O. lurida* spat was observed in early Jul 2013. Rose will continue to work on these aspects of the biology of settlement and early post-larval life in Olympia oysters until her thesis is completed in the spring of 2014.

In Apr 2013 Rose presented the results from the earlier collaborative work during the 36th Annual Meeting of the Pacific Estuarine Research Society (conference held in Delta, BC; 4-7 Apr 2013), and she received the PERS award for the best graduate student poster (see Appendix III). On 25 Jul 2013, Rose and Cate jointly delivered a joint presentation to a collection of coastal natural resource scientists and managers in the Coos Bay region (Coos Bay District / Bio Breakfast Quarterly Seminar Series).

B. Working with Intended Users:

- Describe the progress on tasks related to the integration of intended users into the project for this reporting period
- What did you learn? Have there been any unanticipated challenges or opportunities?
- Who has been involved?
- Has interaction with intended users brought about any changes to your methods for integration of intended users, the intended users involved, or your project objectives?
- How do you anticipate working with intended users in the next six months?

<u>Integration of input from intended users</u>: Steve Rumrill met individually and in small groups with several members of the Olympia Oyster Restoration Advisory Committee (OORAC) over the reporting period (Mar – Aug 2013) to discuss the progress made by the graduate students and the implications of their findings toward Olympia oyster restoration and other oyster recovery efforts in Oregon estuaries. Rumrill met again with the new Lead Scientist/Research Coordinator for South Slough NERR (Dr. L. Basch; 6 Mar 2013), with Dr. B. Dumbauld (USDA/ Agricultural Research Service; 8 May 2013) and with D. Landkammer (OR Sea Grant Aquaculture Extension Specialist; 13 May 2013) to provide an update on the work conducted by the three OIMB graduate students supported by the NERRS Science Collaborative project (M. Oates, R. Rimler, C. Pritchard), to discuss ecosystem services provided by Olympia oysters, and to further discuss the prospects for future research efforts that focus on restoration and recovery of Olympia oyster populations in Oregon bays and estuaries. During these

discussions, input was gained about the need to develop new information about the role of Olympia oyster beds to serve as habitat areas for estuarine fish and motile invertebrates that are important members of ecological communities in Oregon estuaries. In addition, there is a pressing need for new information about the ecological impacts of natural beds and mariculture plots of Olympia oysters on eelgrass beds (*Zostera marina*) in the lower intertidal zone. Although both of these topics are beyond the scope of the current graduate students supported by the NSC project, new data generated by the current students will provide fundamental information about the reproduction and larval ecology of Olympia oysters that will be relevant to future studies about potential mariculture impacts.

OORAC members Dr. L. Hoberecht (Regional Coordinator, NOAA Aquaculture Center), D. vander Schaaf (Coastal Conservation Leader, The Nature Conservancy), and members of the NOAA Restoration Center (L. Jennings, S. Morlock) worked with Steve Rumrill during Mar 2013 to respond to reviewer comments and other input received in response to their submission of a NOAA "tiger-team' technical-transfer proposal. The proposal titled "*West Coast Native Oyster Workshop #4 / 2013: Technical Transfer of New Information about Restoration and Recovery of Olympia oysters (Ostrea lurida) along the Pacific Coast*" was submitted on 25 Feb 2013, and sought $26,700 in federal grant funds to host the next Pacific coast regional workshop in Portland (Sep 2013). The goal of the WCNOW #4 is to renew contact among practitioners and produce tangible outcomes that would guide native oyster restoration efforts along the West Coast. The proposal outlined an agenda for the workshop participants to discuss current restoration practices and tools, monitoring methodologies, research priorities and natural aggregation, and to revisit the 10 year restoration goals set in 2010 for Oregon, California, Washington and British Columbia. Unfortunately, the project was not recommended for support in 2013, and the reviewers recommended that we postpone the WCNOW #4 until the fall of 2014 or 2015. During this process, we learned that the NOAA Aquaculture Center is keenly interested in continuation of the series of regional workshops that focus on recovery of Olympia oyster populations, but they are more supportive of holding the workshops on a 5-year basis rather than every 2-3 yrs.

<u>Unanticipated challenges and opportunities</u>: During the spring and summer months, several investigators from state universities and mariculture support groups in Oregon and Washington contacted the South Slough NERR and the Oregon Department of Fish and Wildlife / Shellfish Program to seek their assistance with development of new research proposals that focused on aspects of the biology, biogeochemistry, ecology, and mariculture of Olympia oysters. Staff members from South Slough NERR and the ODFW / Shellfish Program provided direct assistance with development of the new research proposals, with the logistics of their proposed sampling plans, and by providing letters of support. Some of the new proposals were rejected for financial support, and others are currently in the process of review. This high level of interest in new collaborative research was unanticipated, and presents a good opportunity to develop and initiate additional research that is focused on recovery of Olympia oyster populations in the future.

Recent attention on Olympia oysters in Oregon prompted the Oregon Department of Environmental Quality (ODEQ) to add this species to the list of bivalves that are routinely monitored at select locations for the analysis of tissue contaminants. Steve Rumrill provided technical assistance to Lori Pilsbury (ODEQ / Environmental Assessment Division) with identification of suitable populations of Olympia oysters in Coos Bay, Yaquina Bay, and Netarts Bay, and he participated in the collection of adult oysters from Coos Bay and the pre-processing of the tissue samples (6 Aug 2013). The tissue samples are currently undergoing further processing in the ODEQ laboratory (Portland, OR) for the analysis PAH, oil and grease, other hydrocarbons, and metals. In addition, Dr. Elise Granek (Assistant Professor of Environmental Sciences, Portland State University) recently developed an interest in the potential for the tissues of Olympia oysters to take up contaminants from personal care products released into Oregon's coastal watersheds through municipal wastewater treatment systems and the septic

systems of private residences. Dr. Granek contacted Steve Rumrill to seek advice and assistance with the location of suitable populations of Olympia oysters in Coos Bay for the investigation, and he helped with the collection of oysters for the project titled "*Impacts of watershed-based contaminants on marine species and coastal communities*" (supported by Oregon Sea Grant). Information generated by the analysis of potential tissue contaminants will be important in the future in the event that Olympia oysters become more popular for commercial mariculture operations and/or recreational harvests. Currently, the recreational collection of Olympia oysters is prohibited by the Oregon Department of Fish and Wildlife.

The Oregon Department of Agriculture (ODA) and Oregon Department of Fish and Wildlife (ODFW) recently signed a court-mediated agreement to allow the commercial cultivation of native Olympia oysters within a private lease area managed by ODA located in Netarts Bay, OR. ODFW currently prohibits the recreational harvest of Olympia oysters from public waters, but ODFW does not have regulatory authority for the cultivated oysters (including Olympia oysters), clams, and mussels that are grown for commercial purposes in leased plats. Steve Rumrill continued to work during the reporting period with OORAC members Ken Phippen and Michelle Mullin (NOAA / NMFS coastal ecologists) to help develop agency guidance on the establishment of commercial-scale Olympia oyster beds in the estuarine environment, and to discuss design options for the Olympia oyster mariculture area to minimize disturbance to established eelgrass (*Zostera marina*) and other estuarine organisms. Establishment of a commercial mariculture grow-out bed of Olympia oysters in Netarts Bay poses an unexpected opportunity to incorporate recent findings generated by the current NSC project into the ODA regulatory permit.

<u>Changes to methods of integration</u>: Members of the project team have held effective discussions with the stakeholders by meeting in small groups or on a one-on-one basis over the last several months (Mar to Aug 2013). The stakeholders continue to ask questions about the new science generated by the OIMB graduate students and to share their perspectives about recovery and restoration of Olympia oyster populations. For example, OIMB graduate students Rose Rimler and Cate Pritchard gave a joint presentation on their NSC-supported research to a group of coastal natural resource biologists and managers (including OORAC members Scott Groth, Pam Blake, Alicia Helms, Kate Groth) on 25 July 2013 during the quarterly "*Bio Breakfast*" seminar series (Coos Bay). In addition, the OORAC member from the US ARMY Corps of Engineers (Kate Groth; Oregon South Coast Navigational Channel Coordinator) has raised questions about the role of sedimentation on larval settlement by Olympia oysters in the lower intertidal and subtidal zones of Coos Bay. The new research conducted by OIMB graduate student Rose Rimler will address this question by making the comparison between larval settlement and rates of growth for different locations in Coos Bay that experience different levels of sedimentation. This issue is important because the primary navigational channel in Coos Bay is routinely dredged by the US Army Corps of Engineers for the purpose of maritime commerce, and the Oregon International Port of Coos Bay is interested in further deepening and widening of the channel and turning basin to support potential expansion of the port facilities and their dockside infrastructure for commercial shipping of cargo.

We have continued to hold one-on-one and small group discussions over the reporting period with OORAC members from the South Slough NERR (A. Helms), commercial mariculture industry (S. Cudd, Whiskey Creek Shellfish Hatchery), the NOAA Aquaculture Center (L. Hoberecht), The Nature Conservancy (D. vander Schaaf), the USDA-Agricultural Research Service (B. Dumbauld), Oregon Sea Grant (D. Landkammer) and others on development of new proposals for further research. Many of these proposals include components that build upon local information about the reproductive biology and larval ecology of Olympia oysters in Coos Bay/South Slough generated by the graduate students at OIMB. The Oregon Aquaculture Extension Advisory Council (including several OORAC members) is scheduled to meet in Newport, OR on 6 Sep 2013, and the future mariculture of Olympia oysters will be a topic for discussion on the meeting agenda.

During the next six months: During the next six months we will maintain periodic contact with intended users and stakeholders to: (1) provide updated NSC fact-sheet updates based on the further progress on the investigations of reproduction and larval ecology of Olympia oysters in Coos Bay; (2) work with an outside investigator to refine an existing numerical hydrodynamic model of the Coos Bay estuary, and conduct particle tracking scenarios to simulate the advective movement of Olympia oyster larvae within the estuarine tidal basin; (3) work with the members of the science team to conduct the shoreline survey of Olympia oyster populations along the shoreline of Coos Bay to identify the specific location of index sites that can be used to monitor recovery; (4) work with the project team to integrate the three components of the reproductive biology (Module 1 / reproduction and brooding; Module 2 / larval supplies and dispersal; Module 3 / larval settlement) into the framework for the local Olympia Oyster Conservation and Recovery Plan; (5) make arrangements with the South Slough NERR and the Whiskey Creek Shellfish Hatchery for the generation of 200-300 bags of Olympia oyster spat to be placed within the South Slough NERR or another location in Coos Bay; and (6) re-convene the OORAC to initiate discussions and gain their input about development of the local conservation plan for Olympia oysters in Coos Bay. The University of Oregon has submitted a request to the NSC for a no-cost 1-yr time extension to allow the team to meet the project objectives.

C. Progress on project objectives for this reporting period:

- Describe progress on tasks related to project objectives for this reporting period.
- What data did you collect?
- Has your progress in this period brought about any changes to your methods, the integration of intended users, or the project objectives?
- Have there been any unanticipated challenges, opportunities, or lessons learned?
- What are your plans for meeting project objectives for the next six months?

Progress and data collection: Over the past six months (Mar to Aug 2013) the three graduate students from the Oregon Institute of Marine Biology (Mark Oates, Cate Pritchard, Rose Rimler) continued their thesis work on the reproductive biology and larval ecology of Olympia oysters in the Coos Bay estuary. Early input received from the OORAC was incorporated into the objectives and design for the new science activities conducted by the students. Several different types of data were collected by members of the science team over the spring and summer months. Mark Oates (Module 1/ reproduction) analyzed the histological slides prepared from the gonadal tissues of adult oysters, and compiled bimonthly measurements of multiple ambient water quality parameters from two intertidal sites within Coos Bay (Haynes Inlet and Coalbank Slough). He characterized the process of gametogenesis, gender switching, and brooding in the local populations, and successfully defended his M.Sc. thesis in May 2013. Cate Pritchard (Module 2 / larval supplies and dispersal) continued to generate time-series data to describe seasonal variability in ambient water parameters in different regions of Coos Bay, and to deploy and recover a series of passive larval traps to characterize the abundance, supplies, and dispersal of Olympia oyster larvae at six strategic locations in Coos Bay. Cate also generated new information about the taxonomic identities of larval bivalves, to interpret their local patterns of distribution in Coos Bay, and to make progress on the taxonomic identification of over 100 larvae using morphological and DNA barcode techniques. Rose Rimler continued to conduct monthly assessments of the settlement, survival, and growth of Olympia oysters that recruit onto a series of paired ceramic plates deployed at six sites throughout Coos Bay estuary, and to measure bi-weekly differences in larval abundance and settlement at several locations throughout Coos Bay. Cate and Rose worked together to maintain a series of automated dataloggers to record ambient water parameters (*i.e.*, temperature, salinity, water level) at strategic points in Coos Bay, and the South Slough NERR continued to collect time-series measurements of estuarine water quality parameters (estuarine

water temp, sal, cond, pH, DO, Chl-a, turb) at several locations along the estuarine gradient of the South Slough.

Changes in methods and integration of intended users: Local natural resource managers (*i.e.*, NMFS, USACOE, ODFW, ODEQ) have raised questions about the role of sedimentation on larval settlement by Olympia oysters in the lower intertidal and subtidal zones of Coos Bay. New research conducted by OIMB graduate student Rose Rimler will address this question by making the comparison between larval settlement and rates of growth for different locations in Coos Bay that experience different levels of sedimentation. This issue is important because the primary navigational channel in Coos Bay is routinely dredged by the US Army Corps of Engineers for the purpose of maritime commerce, and the Oregon International Port of Coos Bay is interested in further deepening and widening of the channel and turning basin to support potential expansion of the port facilities and their dockside infrastructure for commercial shipping of cargo. In addition, the Oregon Aquaculture Extension Advisory Council is scheduled to meet in Newport, OR on 6 Sep 2013, and the mariculture of Olympia oysters will be a topic for discussion on the meeting agenda. This group provides an additional forum for discussion of the results generated by the OIMB graduate students, and another avenue for incorporation of the new scientific findings into possible management actions.

Unanticipated challenge, opportunities, and lessons learned: Recent research activities led by academic scientists from Oregon State University (including OORAC member Dr. Chris Langdon, Dr. Burke Hales, Dr. George Waldbusser, and Dr. Francis Chan) have placed an intense spotlight on the threats to native and cultivated shellfish due to elevated pCO2 concentrations in the nearshore ocean waters off of Oregon and northern California. Wind-driven upwelling of cold, often hypoxic, ocean waters, coupled with ocean acidification (OA) and shifts in the saturation state for the carbonate shells of larval bivalves, brings the coastal populations of adult oysters and their planktonic larval stages into contact with waters that can be corrosive to the formation of larval shells. Damage to oyster larvae from the combined effects of hypoxia and OA can be fatal, and several media articles have recently reported that larval oysters serve as a “canary in a coal mine” to forecast the detrimental impact of OA in Pacific northwest coastal waters. However, despite several years of very poor success with rearing the larvae planktonic larvae of Pacific oysters (*Crassostrea gigas*) in the hatcheries (attributed to OA), the planktonic larvae of *Ostrea lurida* have routinely survived and settled successfully in Coos Bay (near the upwelling center at Cape Arago). It appears that the larvae from the native Olympia oyster may be less susceptible to the combined effects of hypoxia and OA in comparison with larvae from the non-indigenous Pacific oyster.

The recent spotlight on OA as a contributing factor in the poor reproductive success of Pacific oysters raised within the Whiskey Creek Shellfish Hatchery poses important questions about the biogeochemical modification of nearshore ocean waters as they flood into Oregon’s estuaries, and about the potential impacts of OA on local populations of native Olympia oysters located in the mesohaline regions of the tidal basins. A recent article published by the World Newspaper (*Local Oysters OK with Acid*; T. Moriarty, 31 Jul 2013) described the problem presented to Oregon’s oyster populations by ocean acidification, ongoing research to characterize the potential extent of acidified ocean waters, and quotes about the possible effects of submerged aquatic vegetation in shallow estuarine waters to buffer OA impacts to Olympia oysters (http://theworldlink.com/news/local/local-oysters-ok-with-acid/article_7bc50c5e-f9f8-11e2-b610-0019bb2963f4.html#comments; see Appendix II).

Plan for the next six months: During the next six months we will maintain periodic contact with intended users and stakeholders to: (1) provide updated NSC fact-sheet updates based on the further progress on the investigations of reproduction and larval ecology of Olympia oysters in Coos Bay; (2) work with an outside investigator to refine an existing numerical hydrodynamic

model of the Coos Bay estuary, and conduct particle tracking scenarios to simulate the advective movement of Olympia oyster larvae within the estuarine tidal basin; (3) work with the members of the science team to conduct the shoreline survey of Olympia oyster populations along the shoreline of Coos Bay to identify the specific location of index sites that can be used to monitor recovery; (4) work with the project team to integrate the three components of the reproductive biology (Module 1 / reproduction and brooding; Module 2 / larval supplies and dispersal; Module 3 / larval settlement) into the framework for the local Olympia Oyster Conservation and Recovery Plan; (5) make arrangements with the South Slough NERR and the Whiskey Creek Shellfish hatchery for the generation of 200-300 bags of Olympia oyster spat to be placed within the South Slough NERR or another location in Coos Bay; and (6) re-convene the OORAC to initiate discussions and gain their input about development of the local conservation plan for Olympia oysters in Coos Bay. The University of Oregon has submitted a request to the NSC for a no-cost 1-yr time extension to allow the team to meet the project objectives.

D. Benefit to NERRS and NOAA: List any project-related products, accomplishments, or discoveries that may be of interest to scientists or managers working on similar issues, your peers in the NERRS, or to NOAA. These may include, but are not limited to, workshops, trainings, or webinars; expert speakers; new publications; and new partnerships or key findings related to collaboration or applied science.

- A graduate student supported by the NSC project successfully completed and defended his M.Sc. thesis at the University of Oregon – Oregon Institute of Marine Biology
    - Oates, M.S., 2013. Observations of Gonad Structure and Gametogenic Timing in a Recovering Population of *Ostrea lurida* (Carpenter 1864). M.Sc. Thesis, University of Oregon – Oregon Institute of Marine Biology, Eugene. 55 pp. (Charleston, OR; 30 May 2013)

- Graduate students supported by the NSC project delivered a joint presentation during the Coos Bay "Bio Breakfast" Seminar Series (Coos Bay, OR; 25 July 2013)
    - C. Pritchard / Variability in the larval supplies of Olympia oysters in the Coos Bay estuary
    - R. Rimler / Larval settlement and post-settlement mortality as determinants of spatial distribution of Olympia oyster populations in Coos Bay

- A graduate student supported by the NSC project delivered a poster presentation during the Pacific Estuarine Research Society conference (Delta, BC; 4-7 Apr 2013):
    - *Rose Rimler*, Cate Pritchard, Richard Emlet, Alan Shanks, and Steven Rumrill. Oregon Institute of Marine Biology, University of Oregon.* Settlement and post-settlement mortality as determinants of the spatial distribution of Olympia oysters (*Ostrea lurida*) in Coos Bay, Oregon.

- A member of the NSC science team delivered a Skype seminar/WebEx presentation during the SSNERR/GTMNERR EcoGeek Series: Reduce, Reuse, Recycle, and Restore:
    - S. Rumrill / Comparison of biofiltration services provided by Pacific and Olympia oysters, and development of a conservation and recovery plan for Olympia Oysters in Coos Bay (17 Apr 2013)

- An article was published by the World Newspaper that describes problems presented to Oregon's oyster populations by ocean acidification, ongoing research to characterize the potential extent of acidified ocean waters, and the possible effects of submerged aquatic vegetation in shallow estuarine waters to buffer OA impacts to Olympia oysters:

- *Local Oysters OK with Acid* (T. Moriarty; World Newspaper, 31 Jul 2013; http://theworldlink.com/news/local/local-oysters-ok-with-acid/article_7bc50c5e-f9f8-11e2-b610-0019bb2963f4.html#comments; see Appendix II)

- An article published by the Oregonian Newspaper focused on work completed by The Nature Conservancy, South Slough NERR, and the Oregon Department of Fish and Wildlife on recovery of Olympia oysters in Oregon bays, and emphasized potential aspects of the oysters as a mariculture species and culinary delicacy:
  - *Oregon's Only Native Oyster Makes a Comeback After Near Extinction* (K. Muldoon; Oregonian, 20 Jul 2013; http://www.oregonlive.com/environment/index.ssf/2013/07/oregons_only_native_oyster_the.html; see Appendix IV)

E. Describe any activities, products, accomplishments, or obstacles not addressed in other sections of this report that you feel are important for the Science Collaborative to know.

- The project PI (S. Rumrill) and several members of the OORAC (L. Hoberecht, D. Landkammer, C. Langdon, B. Dumbauld) continue to work with members from private industry (*i.e.*, Pacific Coast Shellfish Growers Association) on development of the Oregon Shellfish Initiative. This cooperative and collaborative initiative is designed to help meet many of the goals of the National Shellfish Initiative, and will likely include a component that is focused on enhancement, restoration, and recovery of Olympia oyster populations in Oregon estuaries.

- Two media articles were published in Jul 2013 that focused on the restoration and recovery of Olympia oysters in Oregon estuaries. The first article published by the World Newspaper (*Local Oysters OK with Acid*; T. Moriarty, 31 Jul 2013) described the problem presented to Oregon's oyster populations by ocean acidification, ongoing research to characterize the potential extent of acidified ocean waters, and quotes about the possible effects of submerged aquatic vegetation in shallow estuarine waters to buffer OA impacts to Olympia oysters (http://theworldlink.com/news/local/local-oysters-ok-with-acid/article_7bc50c5e-f9f8-11e2-b610-0019bb2963f4.html#comments; see Appendix II). The second article published by the Oregonian Newspaper (*Oregon's Only Native Oyster Makes a Comeback After Near Extinction*; K. Muldoon, 20 Jul 2013) focused on work completed by The Nature Conservancy, South Slough NERR, and the Oregon Department of Fish and Wildlife on recovery of Olympia oysters in Oregon bays, and emphasized potential aspects of the oysters as a mariculture species and culinary delicacy (http://www.oregonlive.com/environment/index.ssf/2013/07/oregons_only_native_oyster_the.html; see Appendix IV).

- The University of Oregon has submitted a request to the NSC for a no-cost 1-yr time extension (to Sep 2014) to allow the team to meet the project objectives. The request for a time extension is included below as Appendix V.

Appendix I. Oates, M.S. 2013. Observations of Gonad Structure and Gametogenic Timing in a Recovering Population of *Ostrea lurida* (Carpenter 1864). M.Sc. Thesis, University of Oregon – Oregon Institute of Marine Biology, Eugene. 55 pp.

Abstract: From January 2012 to December 2012 I collected adult oysters from two intertidal populations on a monthly basis in the Coos Bay estuary, Oregon for histological analysis of their gonads. Gametogenesis and spawning occur seasonally from May through September, with brooding oysters found from July through September. Gametogenesis was observed when water temperatures exceeded 14.5^{o} C, while brooding oysters were found at temperatures from ~15-19° C. Oocyte diameters increased significantly from May to June and June to July for Haynes Inlet and Coalbank Slough, respectively. Male gametogenesis initiated in May at Haynes Inlet and in June at Coalbank Slough. Dry meat condition values significantly increased during periods of reproduction and significant decreased following the end of the reproductive season, with an unexplained decrease at both sites between the months of March and May. Condition index values for Coalbank Slough were consistently lower than those at Haynes Inlet, suggesting poor nutrition or physiological stress. Salinities below recorded physiological thresholds are believed to be the primary environmental factor influencing the discrepancy in reproductive activity at Coalbank Slough, as temperature and food abundances followed similar patterns throughout the bay. Assessments of embryo developmental stages suggest that spawning periods are tied to neap tide events.

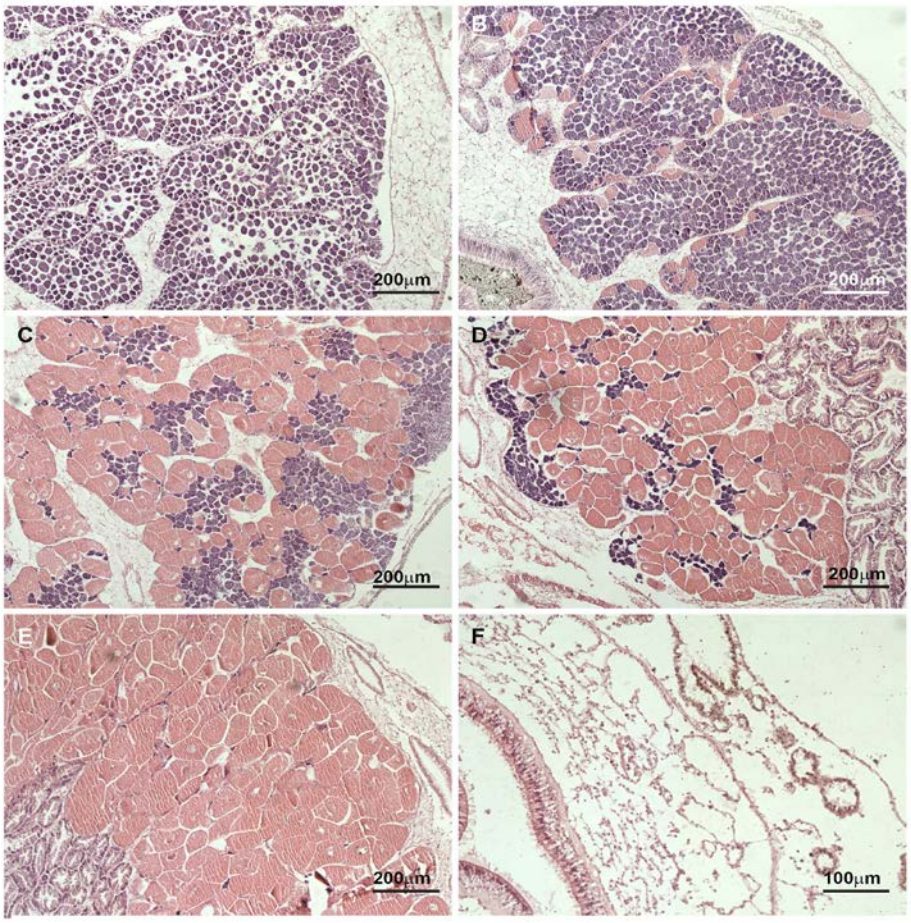

Figure 1. Histological micrograph illustrating six stages in the gametogenesis of male and female *Ostrea lurida* (from Oates, 2013).

Appendix II. World Newspaper article (T. Moriarty, 31 Jul 2013)
http://theworldlink.com/news/local/local-oysters-ok-with-acid/article_7bc50c5e-f9f8-11e2-b610-0019bb2963f4.html#comments

Local oysters OK with acid

Figure 2. Workers at Clausen Oysters in North Bend unload bags of seeded oyster shells gathered from Horsfall Beach on Tuesday. The oyster seed was taken back and spread out at Horsfall Wednesday morning (photo by A. Beck, The World).

July 31, 2013 8:48 am • By Thomas Moriarty, The World
(1) Comments

COOS BAY — As a federal research vessel heads out to study the impact of ocean acidification on Pacific marine life, Oregon biologists are reporting both benign and negative impacts on regional shellfish.

The National Oceanic and Atmospheric Administration dispatched the *R/V Fairweather* from Seattle on Monday for a month-long cruise to collect water, plankton and algae samples. The agency is concerned that increasing ocean acidity levels attributed to greenhouse gas emissions are threatening marine ecosystems the fisheries they support.

The Oregon coast oyster industry has firsthand experience with the problem.

Several years ago, Netarts Bay's Whiskey Creek Shellfish Hatchery — which produces much of the oyster seed used by commercial farms in the region — began experiencing a decline in production that Oregon State University researchers traced directly to ocean acidification.
But biologist Steve Rumrill said the future of the South Coast's native oyster isn't looking too bad.

"The short answer is that the native Olympia oysters may be doing OK and recovering in Coos Bay despite ocean acidification," he said. Rumrill, currently the director of Oregon Department of Fish and Wildlife shellfish monitoring program, was instrumental in Olympia oyster recovery efforts at the South Slough National Estuarine Research Reserve near Charleston.

"It may be that the shallow parts of Coos Bay may be able to act sort of as a buffer," he said.

Oregon State University Professor George Waldbusser said the difference in survivability likely lies in the species' reproductive practices.

"Olympias are brooders," he said, referring to the species' trait of carrying eggs in an internal chamber for several weeks after fertilization. Pacific oysters, on the other hand, are broadcast spawners, meaning their eggs are fertilized and develop in open water.

Waldbusser said the native species' reproductive period is on the edge of the coast's seasonal upwelling cycle, when deep ocean currents force cold water to the surface. Upwelling is believed to contribute to the acidification process by bringing oxygen-deprived, CO2-rich acidic water to the ocean's surface.

As far as Rumrill's buffer theory, the professor said one of his graduate students is also conducting research on increased production in seagrass habitat in Netarts Bay. Waldbusser said any findings are likely six months out, at the earliest.

Reporter Thomas Moriarty can be reached at 541-269-1222, ext. 240, or by email at thomas.moriarty@theworldlink.com. Follow him on Twitter: @ThomasDMoriarty.

Appendix III. Abstract for poster presented at the Pacific Estuarine Research Society Conference (Delta, BC; 4-7 Apr 2013). Settlement and post-settlement mortality as determinants of the spatial distribution of Olympia oysters (*Ostrea lurida*) in Coos Bay, Oregon.

R. Rimler, C. Pritchard, R. Emlet, A. Shanks, and S. Rumrill. Oregon Institute of Marine Biology, University of Oregon.*

The depleted west-coast oyster, *Ostrea lurida*, is the target of several restoration efforts along the west coast. Large oyster populations provide a number of ecosystem services including improving water quality and providing unique habitat for other estuarine species. Often, restoration efforts focus on laying down shell to encourage spat settlement. These efforts would be aided by a better understanding of the larval dispersal patterns, settlement behavior, and post-settlement mortality of oysters in the estuary of interest. In Coos Bay, Oregon, we are investigating all three of these components of the oyster life cycle at multiple sites throughout the estuary. We used time-integrative sampling techniques-- larval tube traps and settlement plates-- to sample larvae and settlers every two weeks from late July through late November, 2012. Larval abundance and settlement varied significantly throughout the bay, and larvae are apparently absent close to the mouth of the bay. Interestingly, the relationship between larvae and settlers also changed depending on location. We are currently monitoring the growth and survival rate of two size classes of field-collected oysters at most of these same sites. We hope that our results will help inform projects intent on revitalizing this struggling native species. See poster (Rimler Pritchard PERS 2013 poster.pdf).

Appendix IV. Oregon's only native oyster, the Olympia, makes a comeback after near extinction

Katy Muldoon, The Oregonian By Katy Muldoon, The Oregonian

Email the author | Follow on Twitter on July 20, 2013 at 10:00 AM, updated July 22, 2013 at 7:38 AM

NETARTS -- Stand at the edge of Netarts Bay as the tide ebbs and you might spot evidence of a comeback that's pleasing not only conservationists but also Oregon's passionate culinary crowd. There in the muck, the tiny, tangy Olympia oyster -- the only oyster native to the West Coast and a species harvested nearly to extinction more than a century ago -- is slowly repopulating.

Same goes in Yaquina and Coos bays, in Washington's Puget Sound and in a handful of California bays, where restoration efforts similar to that in Netarts make headway.

If those projects enjoy the sort of success ecologist Dick Vander Schaaf and his Nature Conservancy colleagues have in Tillamook County, many of the West's bays and estuaries could grow cleaner and healthier, thanks to the filtering work oysters perform and the habitat they provide other species. Plus, those who relish oysters' heady flavor but who seldom spot the Olympia variety on restaurant menus may have more opportunities to sample the rare, silver dollar-sized delicacy.

Ethan Powell, chef and partner in Northeast Portland's EaT: An Oyster Bar and The Parish in the Pearl District, understands one reason why Olys, as Olympias are nicknamed, were wiped out. He says they deliver the bliss factor some oyster aficionados seek -- an earthy flavor with hints of the wild mushrooms growing in coastal forests and finally, a coppery finish.

Native Americans ate Olys long before Europeans made their way west. But when miners struck gold in California in the mid-1800s, the oyster rush was on. As Vander Schaaf says, "They came to San Francisco, and it was all wine, women, song and oysters."

Forty-niners devoured the mollusks in soups, stews, pies, patties or wrapped in the omelet known as a Hangtown Fry. They ate them roasted, fried or bathed in cream. Of course, they slurped them down raw, too, chasing Olys with beer or bubbly.

It takes the meat of an estimated 2,000 Olympia oysters to fill a gallon jug, and during those frantic Gold Rush days suppliers couldn't pluck and shuck them fast enough. As San Francisco Bay's supply ran slim, industrious shellfishermen loaded schooners with hundreds of thousands of pounds of Olympias in the Northwest and sailed them down the coast.

Within a few decades, Oly beds in Oregon and Washington were wiped out, too. According to the Nature Conservancy, the annual harvest of Olys in Washington reached 130,000 bushels by the 1890s but by 1910, it declined to 16,000 bushels a year.

A study published last year in Proceedings of the Royal Society, a scientific journal, dubbed the species "functionally extinct." While Olympias persisted in some estuaries, the habitat they require to thrive -- the oyster beds and shell reefs that once covered thousands of acres in western waters -- was gone.

Restoration efforts, though, already were under way. And while most oysters commercially grown today in the Northwest are native to Japan, a few farmers had started growing and selling the lone native species, too.

That makes Powell, the Portland chef who espouses their virtues, a happy fellow. He buys around 500 dozen oysters a week, including about 20 dozen Olympias grown in Yaquina Bay. "They don't live long out of the water," he says, "so they're super fresh ... full of juice, just a fantastic oyster."

In his 30 years with the Nature Conservancy, Vander Schaaf, 61, has done everything from survey Oregon silverspot butterflies at Cascade Head to help the nonprofit identify terrestrial and marine natural areas worth preserving. "Estuaries," he says, "are forgotten habitats." He knew about efforts to bolster remnant Olympia oyster populations in Puget Sound. So, when Alan Trimble, a University of Washington biologist, suggested Netarts Bay was ripe for a similar project, Vander Schaaf jumped at the chance.

The bay, about five miles southwest of Tillamook, seemed the perfect spot. Long and shallow, it covers less than four square miles. No major rivers feed it, so it flushes nearly dry twice a day at low tide -- a bonus for oysters. It wasn't nearly as degraded by development or pollution as other estuaries that once held Olys. Eelgrass, which oysters like, grows in the bay. Toward the south end, more than 60 acres of tidal flats already were set aside by the state as a shellfish reserve off-limits to harvesting.

Plus, the conservancy could learn from about a dozen small commercial oyster farmers working outside the reserve; recreational oyster harvesting is prohibited in Oregon.

The operators of Whiskey Creek Shellfish Hatchery across the street from Netarts Bay volunteered to help, and in 2005 Vander Schaaf and others started lugging heavy mesh bags filled with empty, clean Pacific oyster shells onto the tidal flats, building a reef. The shells of the larger, non-native Pacifics would serve, essentially, as condominiums for Olys.

Using the hatchery's equipment and expertise, the Nature Conservancy started growing oysters.
Each spring, a few buckets full of mature oysters were dumped into huge tanks in the hatchery's humid, barn-like buildings, where roaring pumps keep water circulating around the clock. The adult Olys produce larvae, which hatchery workers collect and feed until they're about as big as a grain of sand and ready to settle, or attach themselves for life to some hard substrate -- Pacific oyster shells, in this case. Workers place bags of shell in the tanks and the larvae grab hold. A few days later, they deliver the bags to the bay, adding to the man-made shell reef.

Olys grow slowly. Unlike Pacifics, which reach market size of about 4 inches in 18 to 30 months, Olympias take at least three years to get to be the size of a quarter. At their biggest, the razor-sharp shells are only 1 1/2 to 2 inches across.

What Vander Schaaf and colleagues wanted to see was the Olys reproducing on their own in the bay, a process called natural recruitment. Last year, for the first time, they did, spotting many examples of young oysters about the size of a little fingernail, indicating they were maybe a year old. Some showed up on man-made materials in the bay and on Pacific oysters grown on leased land outside the shellfish reserve, so they knew they weren't hatchery-grown.

This year, the Nature Conservancy didn't seed the bay with any juvenile oysters. Vander Schaaf will continue to survey the more than 1.5 million Olympia oysters growing there and if they continue to reproduce on their own, he expects to let nature take its course.

Similar small success stories unfold farther down the coast.

Yaquina Bay once held such a bountiful Olympia supply it contributed to the establishment of Newport and the burg upriver, Oysterville. The species was sometimes referred to as the Yaquina oyster.
While huge harvests led to a steep decline, Olys never went extinct in Yaquina Bay. Newport-based Oregon Oyster Farms workers routinely find them attached to their cultured Pacific oyster shells.
In Coos Bay, shell deposits indicate Olys once were abundant. Scientists believe the species disappeared there before Europeans arrived; the oysters likely were buried in sediment resulting from wildfires, earthquakes or tsunamis.

Researchers aren't certain but believe Olys may have been reintroduced inadvertently as hitchhikers aboard the Pacific variety, which oystermen brought to Coos Bay in the 1940s.

During a salt marsh restoration project in Coos Bay's South Slough in the early 1990s, Steve Rumrill began thinking about the benefits of bolstering the population in the bay, much of which had been diked for agriculture by early settlers. Changing the landscape that way pushed out oysters, degrading the ecosystem.

He knew the damage done elsewhere when oysters were lost: Chesapeake Bay's oyster population, once legendary, is less than 1 percent of what it once was, according to the National Oceanic and Atmospheric Administration. That bay's water quality suffered dramatically as the bivalves were wiped out by overharvesting, pollution and other factors.

Oysters improve water quality by filtering their food -- phytoplankton, or free-swimming algae -- from the water. They process up to 25 gallons of ocean water each day, according to the Nature Conservancy. NOAA offered Rumrill, shellfish program leader for the Oregon Department of Fish and Wildlife, and others along the West Coast grants to get native oyster restoration efforts started. He says perhaps 80 to 100 people work on them now from Washington to California.

"We're being successful," Rumrill says. "Populations are establishing. Self-recruitment is beginning to happen. We feel good about that."

Success, though, is moderate.

Unlike in the old days, he says, "we don't have massive beds of native Olympias along the shoreline here."

Given their slow growth and small size, the species will likely never again be a big part of the commercial oyster market. For those who fancy them, though, they'll fill a niche.

James Beard, the late Portland-born king of the kitchen, wrote that an oyster lover could consume at least 250 Olys in a sitting, though shucking them was a tedious job. Apparently, he thought it worth the trouble, calling oysters "one of the supreme delights that nature has bestowed on man... Oysters lead to discussion, to contemplation, and to sensual delight. There is nothing quite like them."

Vander Schaaf, the ecologist who brought the little gems back to Netarts Bay agrees they're a treat.

"I eat them raw," he says, "but only for research purposes."

- Katy Muldoon
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Appendix V. Request for One-Year Time Extension (to Sep 2014):

We request a one-year time extension of the NSC grant titled "A Collaborative Approach to Address Larval Supplies and Settlement as Critical Life History Issues During Restoration of Olympia Oysters (*Ostrea lurida*) in Coos Bay and the South Slough Estuary." The rationale for the time-extension is presented below:

A. Project Implementation was delayed by Recruitment of Graduate Students:

Implementation of the NERRS – Science Collaborative (NSC) project was delayed at the beginning of the grant period (Nov 2010) by an unanticipated hold-up associated with recruitment and selection of the three MSc graduate students supported by the grant. Faculty members and co-PIs on the NSC project debated many options associated with the academic backgrounds and interests of the prospective students and their abilities to contribute to the specific objectives of the project and the ongoing scientific investigations undertaken by their major professors. The three students were formally admitted into the graduate program at the University of Oregon - Department of Biology in the fall of 2011, and this delay in recruitment and selection of the graduate students resulted in a slow start-up of the project. The graduate students recruited to complete the new science components of the project began their work at the University of Oregon – Oregon Institute of Marine Biology (OIMB) in Jun 2011 (Mark Oates / Module 1 – Reproductive Biology), Aug 2011 (Rose Rimler / Module 2 – Larval Settlement) and Sep 2011 (Module 3. Cate Pritchard / Module 3 – Larval Supplies).

B. New Science MSc Thesis Projects Not Yet Completed

The three graduate students supported by the NSC project have all made excellent progress with development of the new science components of the overall NSC project. In particular, their original work with Olympia oysters in Coos Bay has contributed substantial new information about: (1) the site-specific differences in the timing of gametogenesis, brood release, and reproductive output of Olympia oyster populations in different regions of the tidal basin; (2) about the intricacies of larval supplies, duration, and retention with regard to seasonal and spatial difference in the estuarine water column; and (3) site selection, survival and growth of post-larvae and early juveniles. Taken collectively, these advancements in our technical knowledge about the reproductive biology and larval ecology of local oyster populations have contributed a great deal to our understanding of the critical factors that are important to the recovery of Olympia oyster populations in the Coos Bay estuarine system. One of the students (Mark Oates / Module 1 – Reproductive Biology) completed his work on the gametogenic process and successfully completed his MSc thesis in Jun 2013. However, the two remaining students have not yet completed the field work, laboratory analyses, and statistical interpretations of their datasets, nor the writing of their graduate thesis documents. Additional time (through the end of 2013) is required to complete the second seasonal sampling of larval supplies, larval settlement, and survival/growth over the end of the 2013 reproductive season. A sub-set of the planktonic larvae captured in settlement tubes deployed by the graduate students have been difficult to identify by morphological traits alone. One of our colleagues at the OIMB (Dr. S. Maslakova) has developed the molecular techniques and probes required to identify these problematic samples of larvae, and it will be highly advantageous to gain molecular confirmation of the species of oysters captured by the settlement tubes. Additional time (through the end of 2013) is required to conduct the taxonomic identities of a sub-set of the larvae by molecular techniques. In addition, our team has not yet completed a quantitative shoreline survey to document the abundance and distribution of Olympia oysters along the shoreline of the Coos estuary. The shoreline survey was originally planned as a component of

Module 1 (Reproductive Biology) but was determined to be a low priority by the graduate thesis committee and not completed prior to defense of the MSc thesis. The shoreline survey is an essential component of the conservation and recovery plan for Coos Bay, and additional time is required to complete the surveys of index areas in the intertidal zone during the fall of 2013 and spring of 2014.

C. Redirection of sub-contract for Hydrodynamic Technical Assistance

In our original project proposal, we allocated a portion of the budget as a sub-contract to Oregon Health Science University (Dr. A. Baptista / Portland, OR) for the provision of technical assistance with generation of output and forecasts from a numerical hydrodynamic model. The purpose of the modeling work was to gain a better picture of the likelihood of export or retention of planktonic Olympia oyster larvae in the Coos Bay estuary. During the last two years, members of our science team have made observations of site-specific differences in reproductive output and regional differences in the abundance of larvae in the plankton. This new information has been coupled with ancillary information provided by local stakeholders about settlement patterns along the shore, and has helped refine the specific information required from the hydrodynamic modeling. In particular, we require particle tracking trajectories over periods of 8-12 days to simulate the release of planktonic oyster larvae during mid-late summer from three sites (Haynes Inlet, Downtown Coos Bay, Isthmus Slough), followed by estimation of the likelihood of export and retention from the estuarine tidal basin. A new faculty member at the University of Oregon (D. Sutherland) has initiated an independent project to develop and refine an improved numerical hydrodynamic circulation model that takes into account variability in local wind forcing, and he has made recent progress with advancement of a realistic model for the Coos Bay/South Slough system. In addition, Dr. Sutherland will be able to incorporate model parameters for the particles (*i.e.*, size, density, buoyancy, settling velocity, diel behavior) to better simulate the behavior of Olympia oyster larvae in the water column. We believe that it will be highly advantageous to work in close collaboration with Dr. Sutherland to conduct the larval/particle tracking work, and that the new collaboration will help improve the quality of the output and facilitate a productive academic environment in the future. Additional time is required (through the end of 2013) to redirect the sub-contract in support of the new hydrodynamic particle tracking work conducted by Dr. Sutherland at the University of Oregon.

D. Generation and Placement of Olympia Oyster Spat in 2014

In our original proposal, we allocated funds in the project budget for a sub-contract with the Whiskey Creek Shellfish Hatchery to generate larvae, early spat, and more fully developed cultch (living juvenile Olympia oysters attached to non-living shells) to help address questions and issues raised by the members of the OORAC, science team, and other stakeholders during implementation of the project. So far, as an interested stakeholder, the commercial shellfish hatchery has graciously provided small batches of larvae, expertise and technical assistance to our scientists over the past without cost. Consequently, we have not expended grant funds to pay for these essential services provided by a key stakeholder. The specific location for placement of additional Olympia oyster cultch has been identified in the South Slough NERR (*i.e.*, Long Island Point; pending further approval by DFW and the South Slough NERR Management Commission). However, the specific location for placement of Olympia oyster cultch has not yet been identified for Coos Bay, and the sites will be prioritized by consensus during development of the local Olympia oyster conservation and recovery plan (see below). Generation of the larvae and a substantial number of cultch bags (*i.e.*, 300-400 bags) by the Whiskey Creek Shellfish Hatchery will require payment, and additional time is required (through

the end of 2013) to obtain the cultch bags for placement in South Slough and Coos Bay during the summer of 2014.

E. Development of Olympia Oyster Conservation and Recovery for Coos Bay

Development of a local Olympia Oyster Conservation and Recovery Plan for Coos Bay (Conservation Plan) was identified as a specific output and deliverable at the conclusion of the NSC project. The conservation plan for Coos Bay will be generated by the stakeholder group during work sessions facilitated by the project integration leader (F. Burris), and will incorporate input of traditional knowledge, fundamental understandings contributed by the stakeholders, and new findings and local data about the reproductive biology and larval ecology of Olympia oyster populations generated by the three graduate students. Although one of the graduate students (Mark Oates / Module 1 – Reproductive Biology) recently completed his MSc thesis (Jun 2013), the remaining graduate students (Rose Rimler / Module 2 – Larval Settlement; Cate Pritchard / Module 3 – Larval Supplies) have not yet completed their thesis work. Additional time (through Sep 2014) is required for the integration leader to work with the science team and stakeholder group (OORAC) to incorporate the new science into the Olympia oyster conservation plan as a deliverable at the conclusion of the NSC project.