Completion Report

Period 2/1/2013 - 1/31/2014

Project R/LME/N-1 - Community and multi-trophic implications of structure additions associated with intertidal geoduck aquaculture

STUDENTS SUPPORTED

McPeek, Kathleen, mcpeek@uw.edu, University of Washington, School of Aquatic and Fishery Sciences, status cont, field of study Fisheries and aquaculture, advisor G.R. VanBlaricom, degree type MS, degree date 2013-12-01, degree completed this period Yes
Student Project Title Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington

Involvement with Sea Grant This Period masters student

Post-Graduation Plans environmental consulting

Oyafuso, Zack, oyafusoz@hawaii.edu, University of Washington, School of Oceanography, status cont, field of study Fisheries and oceanography, advisor P.S. McDonald, degree type BS, degree date 2013-06-01, degree completed this period Yes
Student Project Title Investigating the Effects of Geoduck Aquaculture on the Benthic Community During the Planting Stage.

Involvement with Sea Grant This Period intern, independent study

Post-Graduation Plans Zack now attends the University of Hawaii (HIMB) in Erik Franklin's lab.

CONFERENCES / PRESENTATIONS

VanBlaricom GR., McDonald PS, Price JL, McPeek KC, Galloway AWE, Cordell JR, Dethier MN, Armstrong DA (2013) Ecological consequences of geoduck clam Panopea generosa Gould 1850 aquaculture for benthic communities of intertidal sand flats in southern Puget Sound, Washington USA A summary of findings, 2008-2012. Oral presentation at the 105th Annual Meeting, National Shellfisheries Association, and Aquaculture 2013 Triennial Meeting, Nashville, TN, 21-25 February 21-25, public/profession presentation, 30 attendees, 2013-02-25
VanBlaricom GR, Price JL, McDonald PS, Cordell JR, Essington TA, Galloway AWE, Dethier MN, Armstrong DA (2013) Evaluations of the Ecological Effects of Geoduck (Panopea generosa) Aquaculture Harvest Practices on Benthic Organisms in southern Puget Sound, 2008-2012. Oral presentation of testimony in the matter of Environmental Appeal SHB 13-006c, at the Washington State Shorelines Hearings Board, Tumwater, WA, August 13 2013, public/profession presentation, 40 attendees, 2013-08-13
McDonald PS, Holsman KK, VanBlaricom GR (2013) Evaluating spillover effects of

geoduck aquaculture practices on selected resident invertebrates of southern Puget Sound. Oral presentation at the Pacific Coast Shellfish Growers Association Annual Conference, Sunriver, OR, September 30-October 2, public/profession presentation, 150 attendees, 2013-10-01
Kathleen C. McPeek. Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. WDFW and UW Brown Bag Seminar Series, Olympia, WA, November 13 2013, public/profession presentation, 50 attendees, 2013-11-13
McPeek KC. Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. MS defense, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, November 19 2013, public/profession presentation, 15 attendees, 2013-11-19
McDonald PS, Holsman KK, VanBlaricom GR (2014) Ecological effects of clam (Panopea generosa) aquaculture on resident and transiet macrofauna in an urban estuary. Poster presentation at the Ocean Sciences Meeting, Honolulu, HI, February 23-28, public/profession presentation, 150 attendees, 2013-02-26

ADDITIONAL METRICS

K-12 Students Reached	Acres of degraded ecosystems restored as a result of Sea Grant activities
Curricula Developed	Resource Managers who use Ecosystem-Based Approaches to Management
Volunteer Hours	HACCP - Number of people with new certifications
Cumulative Clean Marina Program - certifications	

PATENTS AND ECONOMIC BENEFITS

No Benefits Reported This Period

TOOLS, TECH, AND INFORMATION SERVICES

Description		Developed	Used	Names of Managers	Number of Managers
Expert testimony in the matter of Environmental Appeal SHB 13-006c, at the	Actual (2/1/2013 - 1/31/2014)	1	1	Shorelines Hearings Board, Tumwater, WA; Kathleen D. Mix, Joan Marchioro, Tom McDonald, Rob Gelder, Pamela Krueger, Mary Alyce	6
	Anticipated (2/1/2014 - 1/31/2015)	0	0		

Washington State Shorelines Hearings Board, Tumwater, WA, August 13 2013. R/LME/N-1				Burleigh,	
Dataset of predator-prey relationships in geoduck aquaculture areas. R/LME/N-1	Actual (2/1/2013 - 1/31/2014) Anticipated (2/1/2014 - 1/31/2015)	1 0	0 0		0

HAZARD RESILIENCE IN COASTAL COMMUNITIES

No Communities Reported This Period

ADDITIONAL MEASURES

Safe and sustainable seafood

Number of stakeholders modifying practices
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Number of fishers using new techniques
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Sustainable Coastal Development
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Coastal Ecosystems
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

PARTNERS

Partner Name Agriculture Research Service (USDA

Partner Name Aquatic Resources Division, Washington State Department of Natural Resources

Partner Name Chelsea Farms

Partner Name Pacific Shellfish Institute

Partner Name People for Puget Sound

Partner Name Puget Sound Restoration Fund

Partner Name Seattle Shellfish LLC

Partner Name Taylor Shellfish Company
Partner Name University of Washington
Partner Name University of Washington, Program on the Environment, College of the Environment (UW)
Partner Name Washington Cooperative Fish and Wildlife Research Unit, School of Aquatic and Fishery Sciences, College of the Environment (UW)

IMPACTS AND ACCOMPLISHMENTS

Title Washington Sea Grant research illuminates the effects of geoduck aquaculture on intertidal predator-prey relationships

Type impact

Relevance, Response, Results Relevance The expansion of geoduck aquaculture in Puget Sound has raised concern among resource managers, conservation organizations, and the public regarding its environmental impacts. Aquaculture structures may affect a number of ecological functions and processes, including predator and prey distribution. Response Sea Grant national strategic investment funds enabled university researchers to investigate the effects of the intertidal culture of Pacific geoduck clams on community dynamics and trophic interactions. Building on the results of previous Washington State-funded research, investigators identified key prey for fish and crab associated with geoduck farm sites. Working with the industry and shoreline property owners, they conducted studies of the site fidelity, growth and stable isotope signatures of Pacific staghorn sculpin, a ubiquitous local predator and useful indicator of ecosystem changes, and modeled the energetics of sculpin and their prey. Results A mark-recapture study found that staghorn sculpin show fidelity to their initial capture sites. Analysis of diet samples and comparison to previous data demonstrated that sculpin consume different types of prey in different habitats. But despite some minor differences in prey-chemistry composition, the sculpin evinced similar carbon and nitrogen stable isotope ratios at farm and reference areas across the summer months, indicating that that their trophic position and general food web function were unchanged. These findings have important implications for geoduck aquaculture management and will inform regulatory decisions related to it.

Recap Washington Sea Grant-supported research used traditional food-habit measuring techniques, chemical analyses, and energetic models to examine the effects of geoduck aquaculture operations on trophic relationships in Puget Sound.

Comments Primary Focus Area LME (SSSS) Secondary Focus Areas LME (HCE), COCC (SCD) State Goals Support conservation and sustainable use of living marine resources through effective and responsible approaches, tools, models and information for harvesting wild and cultured stocks and preserving protected species (SSSS, Industry). Strengthen ecosystem approaches to management of living marine resources through improved understanding of marine biodiversity, marine and coastal ecosystem function, climate change and other sources of variability (HCE, Science). Improve capacity to manage ocean and coastal ecosystems and resources for societal benefit under changing climatic and demographic conditions (SCD, Inter-relation).

Related Partners Agriculture Research Service (USDA, Aquatic Resources Division, Washington State Department of Natural Resources, Chelsea Farms, Pacific Shellfish Institute, People for Puget Sound, Puget Sound Restoration Fund, Seattle Shellfish LLC, Taylor Shellfish Company, University of Washington, Program on the Environment, College of the Environment (UW), Washington Cooperative Fish and Wildlife Research Unit, School of Aquatic and Fishery Sciences, College of the Environment (UW)

PUBLICATIONS

Title Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington

Type Full theses / Dissertations Publication Year 2013 Uploaded File McPeek_MS_Autumn_2013.pdf URL none

Abstract Aquaculture operations are a frequent and prominent cause of anthropogenic disturbance to marine and estuarine communities. In Puget Sound, Washington, aquaculture of the Pacific geoduck clam (Panopea generosa) is on the rise, however little is currently known about impacts of the industry on ecological communities. The study took place during the initial, structured phase of intertidal geoduck aquaculture, when nets and PVC tubes were in place to protect immature geoducks from predators. The food web of a local ubiquitous consumer, Pacific staghorn sculpin (Leptocottus armatus), was compared between geoduck aquaculture sites and nearby reference areas without aquaculture. A variety of research techniques, including stomach content analysis, stable isotope analysis and bioenergetics modeling, were utilized to examine the ecological impacts of geoduck aquaculture at its current scale. Overall, the results showed that the structured phase of geoduck aquaculture initiated some changes to staghorn sculpin ecology, but the general function of sculpin within the food web remained unchanged.

Citation McPeek KC (2013) Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. MS thesis, University of Washington, Seattle, WA

Copyright Restrictions + Other Notes

Journal Title none

Title McPeek KC, McDonald PS, VanBlaricom GR (in review) Impact of aquaculture disturbance on ecological linkages and the diet of a ubiquitous predatory fish. Estuaries and Coasts

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 0 Uploaded File none URL none

Abstract Aquaculture operations are a frequent and prominent cause of anthropogenic disturbance to marine and estuarine communities, and may alter species composition and abundance. However, little is known about how such disturbances affect linkages or ecosystem functions. In Puget Sound, Washington, aquaculture of the Pacific geoduck clam (Panopea generosa) is on the rise and involves placing nets and PVC tubes in intertidal areas to protect juvenile geoducks from predators. Initial studies of the structured phase of the farming cycle have documented limited impacts on the abundance of some species. To examine the effect of geoduck aquaculture on ecological linkages, the trophic relationships of a local ubiquitous consumer, Pacific staghorn sculpin (Leptocottus armatus), to its invertebrate prey were compared between geoduck aquaculture sites and nearby reference areas with no aquaculture. Mark-recapture indicated that sculpin exhibit fidelity to cultured and reference areas. The stomach contents of sculpin and stable isotope signatures of sculpin and their prey were examined to study the trophic ecology of cultured and reference areas. The results showed that the structured phase of geoduck aquaculture initiated some changes to staghorn sculpin ecology, as reflected in sculpin diet through stomach content analysis. However, carbon and nitrogen stable isotopes revealed that the general food web function of sculpin remained unchanged. The source of carbon at the base of the food web and the trophic position of sculpin were not impacted by geoduck aquaculture. The study has important implications for geoduck aquaculture management and will inform regulatory decisions related to shellfish aquaculture policy.

Citation McPeek KC, McDonald PS, VanBlaricom GR (in review) Impact of aquaculture disturbance on ecological linkages and the diet of a ubiquitous predatory fish. Estuaries and Coasts

Copyright Restrictions + Other Notes

Journal Title none

OTHER DOCUMENTS

No Documents Reported This Period

LEVERAGED FUNDS

Type influenced Period 2013-09-25 2013-12-13Amount $13349

Purpose 1-quarter tuition/stipend scholarship to Kathleen McPeek

Source Richard T. Whiteleather Scholarship administered by School of Aquatic and Fishery Sciences, Recruitment, Admissions, and Scholarship Committee (RASC)

COMPLETION NARRATIVE

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WASHINGTON SEA GRANT FINAL REPORT

Project Title: Sea Grant Aquaculture Research Program 2010: Community and multi-trophic implications of structure additions associated with intertidal geoduck aquaculture

Principal Investigator(s) and Affiliation:

Glenn R. VanBlaricom
School of Aquatic & Fishery Sciences, University of Washington

NARRATIVE

PROJECT OBJECTIVES

We investigated the effects of intertidal culture operations for Pacific geoduck clams (*Panopea generosa*) on community dynamics and trophic interactions in South Puget Sound, Washington. The work contributes to NOAA Sea Grant program priorities by involving multiple partners, and leveraging resources by utilizing infrastructure and data of an existing Washington State program. We coordinated these efforts with similar regional investigations on the effects of shellfish aquaculture conducted elsewhere to extend the relevance and applicability of our results. We compared areas containing cultured geoducks (+ structure, + geoducks) and reference beaches (– structure, – geoducks), with a primary focus on an abundant predator, staghorn sculpin (*Leptocottus armatus*). Our objectives were to: (1) characterize changes in benthic communities associated with the planting of geoducks and the placement of aquaculture structures; (2) explore differences in fish abundance and site fidelity among cultured areas and reference beaches; (3) evaluate differences in fish diets in relation to prey abundance and availability using physical and chemical methods; and (4) determine the energetic consequences of diet shifts for growth and survival of fishes. We also trained undergraduate students in the use of field and laboratory techniques, dietary models based on isotope ratios, and bioenergetics models through in-depth internships and independent research projects.

METHODOLGY

Over three years, we investigated the effects of intertidal culture operations for Pacific geoduck clams (*Panopea generosa*; hereinafter "geoduck") on community dynamics and trophic interactions in southern Puget Sound, Washington. The project contributes to NOAA Sea Grant program priorities by involving multiple partners and by leveraging resources through utilization of infrastructure and data associated with an existing Washington State program. We also coordinated these efforts with similar regional investigations on the effects of shellfish aquaculture conducted elsewhere to extend the relevance and applicability of our results. We focused on comparisons of areas containing cultured geoducks (+ predator exclusion structure, + geoducks) and reference beaches (– structure, – geoducks). During the early part of our study we identified Pacific staghorn sculpin (*Leptocottus armatus*), as an indicator predator with which to assess trophic dynamics at three field research sites (Table 1). In addition to characterizing the predator and prey communities, we also modeled and analyzed data from hundreds of samples, including gut contents and tissue of staghorn sculpin, as well as prey organisms that constitute infauna and epifauna.

During each monthly sampling interval, we used beach seines to assess the fish community at our sites. Captured fish were identified and enumerated to characterize seasonal and spatial patterns of abundance associated with geoduck aquaculture. All staghorn sculpin were measured (total length, TL), and individuals larger than 65 mm TL were weighed and tagged with uniquely numbered anchor tags (Floy Tag, Seattle, WA). Tagged sculpin were released after a recovery period as part of our mark-recapture study. A subsample of fish from each location and habitat type was retained for laboratory analyses of stable isotope ratios or gut content studies. We used coring methods and pumps, developed in our previous work and refined in this study, to characterize changes in infaunal and epifaunal communities associated with the presence of geoducks and aquaculture structures in April, June, and August, 2012. Infaunal and epifaunal samples allowed us to quantify the abundance of organisms, and tissues were used for carbon and nitrogen stable isotope analysis of important prey groups. Standardized photo-quadrats were used to develop a record of changes in algal cover throughout the study period.

As part of our laboratory activities, we identified and enumerated more than 50 infaunal and epifaunal taxa in nearly 360 core and pump samples. We also processed and analyzed over 300 gut content samples to describe general patterns in the food habits of staghorn sculpin and identified infaunal and epifaunal taxa that constitute important prey for fish associated with our project sites. Eight prey categories were identified for subsequent chemical characterization from the physical diet evidence, and we analyzed nearly 250 samples, including fish and prey tissues, for carbon and nitrogen stable isotopes. In addition, approximately 270 photos were evaluated to determine changes in percent algal cover (%).

A continuous record of temperature was collected in both habitat types at the three study sites using submersible data recorders. Data on recaptured sculpin were used to determine growth rates at liberty. These data, and the diet information referenced above, informed bioenergetics modeling efforts to estimate prey consumption and growth of two size classes of staghorn sculpin.

RATIONALE

Expansion of intertidal geoduck aquaculture operations has raised concern among managers, conservation organizations, and the public regarding industry practices that may alter resident ecological communities. The addition of aquaculture structure constitutes a “press” disturbance that affects a number of ecological functions and processes over several years. In particular, organisms that are absent from adjacent unstructured areas colonize newly available surfaces and interstices, dramatically altering species diversity. These changes attract some mobile predators that feed on attached or associated biota but exclude others that rely on soft-bottom benthic prey. Such disturbances modify predation pressure and, in the case of staghorn sculpin and their prey, minimally alter trophic dynamics within culture sites and adjacent habitats. Our research group studied the effects of aquaculture structures on invertebrate communities as part of a WA legislature-mandated investigation. We leveraged resources by utilizing existing geoduck program infrastructure to investigate the trophic consequences of geoduck aquaculture operations. Our work expanded on the previous study by examining linkages within these communities and evaluating the consequences of structure additions to the food web. The results presented here have important implications for management, science, and conservation because these data are necessary to determine the overall impact of expanding aquaculture practices.

MAJOR FINDINGS

Abundance and site fidelity:

Staghorn sculpin were the most abundant fish captured during beach seining events in all months and in both plot types (Figure 1). From 2011-2012, a total of 2,681 sculpin were tagged at all sites and plots (Table 2). Recapture rates were slightly higher on the reference plots and ranged from 1.0-3.6%, while rates on the cultured plots were 0.0-2.7%. The consistently low percentage of recaptures did not allow for calculation of disappearance rates of staghorn sculpin. There were 71 total recaptures, of which 70 were sculpin caught on the same plot as originally captured. The results were consistent with site fidelity, and it was concluded that staghorn sculpin exhibited fidelity to cultured or reference plots at the study sites and did not move between plots to forage.

Stomach Content Analysis:

Analysis of similarity (ANOSIM) was used to test for differences in prey groups among months and between cultured and reference plots. Ecological importance was interpreted as follows: low to none when R is less than 0.2, moderate when R is between 0.2-0.45 and high when R is above 0.45. Non-metric multidimensional scaling (NMDS; Kruskal and Wish 1978) was employed to explore visual representations of diet at cultured and reference plots. NMDS is an ordination technique that is complementary to ANOSIM and reduces the dimensionality of a dataset based on the rank order of distances between objects (Digby and Kempton 1987). Statistical significance of prey groups was based on a permutation test. Significant prey groups were overlaid as vectors on the NMDS plots to facilitate interpretation of the position of each fish's stomach contents in ordination space.

Among the sculpin collected for laboratory analysis, we observed differences in the average mass-based proportions of all prey groups for each plot and month (Figure 2). Prey groups were created based on broad taxonomic group and frequency of occurrence, resulting in the following eight categories: amphipods excluding *Americorophium salmonis* (Stimpson, 1857) and *Monocorophium spp.* (AMPH), bivalves (BIV), the amphipod species *Americorophium salmonis* and Monocorophium spp. (CORO), crabs (CRAB), isopods (ISO), other crustaceans including ostracods, cumaceans and tanaidaceans (OCRUST), polychaetes (POLY), shrimp (SHRI) and other identifiable prey items not belonging to any of the previous eight groups (OTH). In general, the most dominant prey groups found in the gut contents were AMPH and CRAB, with CORO, ISO, POLY and SHRI showing higher proportions during specific month-plot combinations (Figure 2). Overall, BIV, OCRUST and OTH presented low proportions in the diets. POLY and AMPH were disproportionately consumed earlier in the season (May-July), while CRAB generally increased in proportion with each subsequent month and dominated the stomach contents during the months of July-September at both plots. CRAB and SHRI had higher proportions on the cultured plots, while the CORO and ISO groups were commonly associated with the reference plots.

ANOSIM detected significant differences in sculpin gut contents between plots in the months of June, July, August and September (Table 3). There was no statistically significant difference between plots in the month of May. To aid in visualization of the data, two dimensional NMDS plots were created for each of the five months (McPeek 2013). Vector overlays of significant prey groups ($p < 0.05$) showed associations of different food items with the two plot types. Representative of the strength of statistically significant differences between plots, NMDS displayed strong intermixing of sculpin gut contents between plots for May (Figure 3), moderate to low intermixing for June and August and clear separation of plots in July and September (Figure 4). The reference plots were generally more associated with CORO, ISO and OCRUST, while the cultured plots were more often linked to BIV and CRAB (see Figure 4).

Diet comparisons between each month pairing were conducted for cultured and reference plots, resulting in ten ANOSIM tests per plot (as detailed in Table 4). For the cultured plots, ANOSIM detected significant differences in seven of the ten month pairings, and for reference plots in six of the ten (Table 4). NMDS plots for May and September at both habitat types demonstrate the variability in sculpin diets between the beginning and the end of the study period. Overall, NMDS of cultured and reference plots show increased consumption of AMPH and ISO in the month of May, while CRAB were more commonly eaten in September.

Stable Isotope Analysis:

Carbon and nitrogen stable isotope data for staghorn sculpin and sculpin prey groups are summarized in Table 5. An information-theoretic approach using Akaike's information criterion (AIC; Akaike 1973) was employed to analyze sculpin carbon and nitrogen stable isotope data. A list of candidate linear mixed effects models was created based on plot (P), month of sampling (M) and sculpin length (L) for the response variables δ13C and δ15N. Since the effect of site was minimized in the experimental design, site was included as a random effect on the intercept of each model. Plot, month and fish length were fixed effects. A modified version of AIC (AICc) that adjusts for small sample sizes was used: $AICc = -2*\ln(L) + 2*K + (2*K*(K+1))/(n-K-1)$, where L is the maximum likelihood estimate for the model, K equals the number of parameters including the intercept and n is the number of data points. Delta AICc (ΔAICc) is the difference between each candidate model and the model with the lowest AICc value. Models with ΔAICc values less than 2 are considered to be equivalent in quality of fit to the top model (Richards 2005). The strength of each candidate model (i) was compared using an Akaike weight (Wi) and an evidence ratio (ER; the weight of the best model divided by the weight of another candidate model). Akaike weights were calculated from ΔAICc values and represented the probability that a specific model was the model of best fit (Burnham and Anderson 2002).

After generating AICc values, the original list of candidate models was narrowed to generate a 95% confidence set of models with cumulative Akaike weight ≤0.95 (Symonds and Moussalli 2011). The resulting models were used to calculate the average weight, standard error and 95% confidence interval for each model parameter (plot, month, sculpin length and the interaction terms) to assess the effect of each variable on the response variable. Categorical parameters were compared to a base model such that cultured was compared to reference for plot and the months of July and September were compared to May. If zero was included in the confidence interval, the estimate was considered to be no different from zero and, thus, it was assumed that there was no effect of the variable tested (Mazerolle 2006).

AIC values for linear mixed effects models and Akaike parameter weights for stable isotope data from staghorn sculpin for δ13C and δ15N are summarized in McPeek 2013. Carbon and nitrogen analyses each resulted in ten top models, with cumulative Akaike weights of 0.95 or less, which were used to calculate parameter weights for length, month, plot and applicable interaction terms.

The strongest candidate model for carbon was the month only model, followed by five other models with ΔAICc values <2: plot x length, plot x month, length only, plot x length + month and plot + month. There was a 21% chance that the month only model was the model of best fit, a 14% chance that model 2 was best, and so on. Parameter weights for carbon showed no effect of length, month, plot or the interaction terms. For nitrogen, the strongest candidate model was month + length, followed by the models for length only and month only. The top three models had 59% probability of including the best model. Parameter weights suggested no effect of length, month, plot or the interaction terms.

Differences between cultured and reference plots in sculpin diet were not clearly seen on a chemical level in sculpin stable isotope signatures. For carbon and nitrogen, there were ten top statistical models, from an original list of 26. The large group of top models with cumulative Akaike weights <0.95 suggest no overwhelming effect of any single factor. Any one of the top ten models could provide reasonable explanatory power to the dataset (Symonds and Moussalli 2011). Plot was included in over half of the top models for carbon and nitrogen, suggesting that plot explained some of the variability in the stable isotope data. However, the effect of plot was low since the model-averaged weight of plot showed no effect for carbon or nitrogen. The parameter weights also showed no effect of length, month or applicable interaction terms. Based on the model-averaged parameter weight, there was a near effect of length on nitrogen, suggesting that sculpin length may explain more of the variability for nitrogen than plot or month. Length and month were included in the top three models for nitrogen. The two factors are tightly correlated since sculpin were larger later in the season.

Fitness Metrics Analyses:

The following metrics analyzed from the gut content data were used to assess the overall fitness of sculpin at cultured and reference plots: 1) ratio of sculpin mass (total prior to gut removal) to the mass of the gut contents as a metric of gut fullness and 2) ratio of sculpin total length to sculpin mass as a metric of body condition. Analysis of variance (ANOVA) was used to test for significant differences between plots and months. To meet the assumptions of ANOVA, the data were log transformed prior to analysis.

To prevent a bias related to allometric scaling between plots in the ratio of sculpin length to sculpin mass, only fish within specified 20 mm length ranges were analyzed for each month. The aquaculture structures likely caused a sampling bias since sculpin at the cultured plots had more opportunity to escape the seine than at the reference plots. Smaller sculpin at the cultured plots could fit through the mesh of the aquaculture netting, allowing them use the nets and tubes as refuge, and fish of any size could escape if the seine was briefly snagged on the aquaculture structures. Only sculpin of lengths represented at both plot types were used in the data analysis. Sculpin size ranges were based on total lengths of all fish captured and designated for each month: May (45-65 mm), June (60-80 mm), July (80-100 mm), August (95-115 mm) and September (105-125 mm). Tests between months were not conducted for this metric due to differences in lengths as the season progressed.

The fitness metrics were similar among the groups tested. There were no significant differences between plots or months in the ratio of sculpin mass to the mass of the stomach contents. The plot to month interaction term was also non-significant. Thus, gut fullness was similar between cultured and reference plots throughout the field season. For the ratio of sculpin length to sculpin mass, there were no significant differences between plots within any month. For this metric, a lower ratio corresponds to an improvement in body condition. The lower ratio later in the season was not necessarily indicative of improved body condition since sculpin in September were larger than those in May.

Bioenergetics Modeling:

The Wisconsin bioenergetics model was initially run for 54 staghorn sculpin recaptures for which specific growth data were available. The 54 individuals were chosen based on the time interval between tagging and recapture (June to early September) and because they represented both years (2011 and 2012), plot types (cultured and reference) and size classes (<100 mm and ≥100 mm). Size classes were determined from scatter plots of sculpin length compared to the relative mass contribution of the five most common prey groups (AMPH, CORO, CRAB, ISO and SHRI) at cultured and references plots for each site. The scatter plots indicated a general shift in diet for several prey groups at fish lengths of ~100 mm, so this length was used to demarcate the two size classes. Diet composition for every site was averaged for each plot, month and size class to create the proportions of each prey group that were entered into the model.

Feeding rates (P-values) generated for the 54 sculpin recaptures were averaged for each year, site and plot combination. The remaining recaptured fish (N=17) were not included in the recapture subset to generate P-values because they occurred during months with insufficient data to be included in the modeling period. Mean P-values from the sculpin recaptures were used to project the model forward two weeks from capture dates and within each sampling month of May through August. Projections were for sculpin captured during each modeled month for which no growth data were available (fish measured in the field but not recaptured at a later date) such that sculpin captured in May were modeled for May, sculpin captured in June were modeled for June, and so on. The two-week modeling period was chosen to conservatively estimate growth and consumption for the month in which each fish was captured, based on the most site and plot specific data available. For sculpin with mass and length data, weight was calculated as a function of length and the resulting regression equation was used to convert lengths of sculpin with unknown weights to a starting weight used in the model projection. Resulting simulations were averaged based on year, site, simulation day, plot and sculpin size class and used to compare total growth, total consumption and growth efficiency (a proportion of specific growth to specific consumption and a metric of grams of growth per gram of food consumed) between plots, across the simulation period for each year and site.

An information-theoretic approach using AIC was employed to analyze P-values from the recaptured staghorn sculpin. A list of candidate linear models was created for each year based on the main effects of site (S; 2012 only), plot (P) and sculpin length (L) for the response variable of P-value. After generating AICc values, the original list of candidate models was narrowed to generate a 95% confidence set of models with cumulative Akaike weight ≤0.95 (Symonds and Moussalli 2011). The resulting models were used to calculate the average weight, standard error and 95% confidence interval for each model parameter (site in 2012, plot, sculpin length and the interaction terms) to assess the effect of each variable on P-value. Categorical parameters were compared to a base model such that Foss was compared to Manke for site (there were no data for Rolfs) and cultured was compared to reference for plot.

Feeding rates (P-values) generated for the 54 sculpin recaptures ranged from ~0.7-1.9 and were averaged for each year, site and plot. Data for 2011 were available only for the Foss site. P-values used for the Rolfs site in 2012 were averaged from Foss and Manke. AIC values for linear models and Akaike parameter weights for the P-values of staghorn sculpin recaptures are summarized for 2011 (Foss) and 2012 (Foss and Manke) in McPeek (2013). The top model set, with cumulative Akaike weights of 0.95 or less, was used to calculate parameter weights for site (2012 only), plot, length and applicable interaction terms. In 2011 at Foss, plot was included in all three top models, suggesting at least a moderate effect of plot on the feeding rate of recaptured sculpin. The plot only model was the best model, followed by the model for plot x length. There was a 79% probability that the model of best fit was one of the top two models. Feeding rate was higher on the cultured plot. However, the parameter weights showed no effect of plot, sculpin length or the interaction term.

Analysis of the feeding rates for recaptured sculpin in 2012 showed an effect of site. There were 18 candidate models and nine models in the top subset with cumulative Akaike weights <0.95. Site was included in all of the top models. The best model was the site only model, with a 43% chance of being the model of best fit. Plot was in over half of the top models, suggesting some effect of plot on feeding rate. However, the model-averaged parameter weights did not indicate an effect of plot. Site was the only parameter to show a strong effect on feeding rate for 2012, with higher P-values at Manke on both plots. Thus, geoduck aquaculture initiated some changes in the feeding rates of sculpin but the differences between cultured and reference plots were generally weak.

Bioenergetics modeling did not show that geoduck aquaculture explicitly altered the growth or consumption of small or large staghorn sculpin. Differences between cultured and reference plots were generally small and resulted in frequent pattern reversal within sites for the two size classes and several of the months modeled. In many cases, growth and consumption were indistinguishable between plots due to overlapping 95% confidence intervals.

The biggest differences in sculpin bioenergetics were between sites. While the three study sites had similar habitat characteristics (tidal range, sediment size, beach slope), site differences were not surprising since the model was run with temperature data specific to each site (and plot) and temperature directly impacts metabolism and feeding rate (Kitchell et al. 1977). Analysis of the feeding rates for recaptured sculpin showed an effect of site in 2012. In 2011 and 2012, there was some effect of plot, as indicated by the top candidate models. However, parameter weights showed no effect of plot in either year, indicating that geoduck aquaculture resulted in overall minor changes to sculpin bioenergetics.

When extrapolated to the population level, the weak effect of geoduck aquaculture on sculpin consumption is more obvious. Sculpin population consumption levels were similar between plots, while differences in prey biomass were more apparent. Biomass was higher overall on the reference plots, where larger populations of sculpin were supported. Both habitat types at all sites had more than enough prey biomass to support the total consumption of a hypothetical population of 1,000 staghorn sculpin (Table 6). Population consumption was generally less than 25% of the total biomass. There were a few year, site, month and plot combinations in which total population consumption exceeded half of the total available biomass. Consumption was lower at all sites in the month of May, when large sculpin were not present. Based on the biomass estimates, each 5,000 m^2 cultured plot could support ~1,300 – 12,700 sculpin, while the reference plots could support ~2,700 – 36,400 sculpin, depending on the site and month. Clearly, reference plots were generally capable of supporting larger population sizes.

The results suggest that structural complexity does not have a strong effect on staghorn sculpin consumption and growth, however the actual foraging efficiency of sculpin could differ between habitat types. Sculpin may use more energy to forage on cultured plots to grow at similar rates, as indicated by the slightly higher feeding rates of sculpin recaptures on the cultured plot at Foss in 2011. In several cases, the diets of sculpin were of higher energy content at the cultured plots, which suggests that there could be an energetic trade-off to foraging in the more complex habitat if diet is of higher quality, but growth and the amount of prey consumed remain approximately the same.

While sculpin prey biomass differed between cultured and reference plots, overall sculpin growth and consumption were not dramatically altered, suggesting that geoduck aquaculture initiated changes in some aspects of the food web but the overall function of sculpin population dynamics within the ecosystem remained unchanged. The reference habitat has the ability to support larger populations of sculpin, an outcome that should be investigated further in future studies on the ecological impacts of geoduck aquaculture.

SIGNIFICANCE

The present study and concurrent work by McDonald et al. (in press) and VanBlaricom et al. (in press) provide data to better balance economic interests with those of maintaining natural ecosystems and are critical for geoduck aquaculture management. Taken together, these studies will inform best management practices for the industry and aid management agencies in making regulatory decisions related to permitting by providing data regarding types of disturbance. McDonald et al. (in press) showed that the structured phase of geoduck aquaculture impacts the abundances of some resident prey groups and mobile fauna. At the current scale, geoduck aquaculture also initiated some changes to trophic dynamics in the present study, however the impacts detected were not significant enough to alter energy flow or the overall structure of the food web of staghorn sculpin. The community structure of demersal fishes in Puget Sound is known to change seasonally, with summer being the season of greatest prey availability and diet overlap (Reum and Essington 2008). Summer also corresponds to the peak period when geoduck aquaculture areas are used by staghorn sculpin and many other fish and invertebrates (McDonald et al. in press). Impacts from the structured phase of geoduck aquaculture could be minimized by outplanting larger geoducks and removing gear as early in the farming cycle as possible, thereby reducing the total time nets and tubes are in place during ecologically productive summer months. Furthermore, lower-impact farming techniques could be adopted, such as using mesh tubes instead of PVC tubes. Baseline monitoring of resident and transient fauna should be prioritized if operations expand or are modified. It is imperative that research keep pace with aquaculture operations and continued focus is placed on balancing human needs with preserving nearshore marine ecosystems.

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***Table 1*. Description of local conditions and biota at geoduck aquaculture research sites in Puget Sound.**

Site/Status	Description	Resident Biota
Rolf site – planted 07/2011		
5,100 m^2 cultured; 2,500 m^2 each plot	The site is North of Wilson Pt on Hartstine Island (47° 19.181'N, 122°50'28.21"W). Sandy substrate. (~ 500 μm grain size); slope moderate from +0.61 m to -0.61 m MLLW; reference plot is on county property adjacent to state park.	Horse clams and oysters present; Sand dollars patchy.
Foss/Joemma Beach site – planted 08/2010		
4,450 m^2 cultured; 4,450 m^2 each plot	The site is West of Joemma Beach State Park on Case Inlet (47°13'23.36"N, 122°49'4.36"W). Sandy substrate. (~ 500 μm grain size); slope moderate from +0.61 m to -0.61 m MLLW; Reference plot is adjacent to state park property.	Horse clams and cockles present; sand dollars in some areas.
Manke site – planted 07/2010		
10,600 m^2 cultured; 2,500 m^2 each plot	The site is South of Wilson Pt on Hartstine Island (47°11'55.33"N, 122°50'28.21"W). Sandy with some fines (~ 250-500 μm grain size). Freshwater seepage from uplands occurs. The reference plot is nearby on private tidelands.	Horse clams and cockles are present; Sand dollars patchy.

***Table 2.* Numbers of captured/tagged (≥65 mm) and recaptured staghorn sculpin by year, site and plot. * Indicates location of one fish that was not recaptured on the same plot as original capture.**

Site	Plot	Year	# Sculpin Captured/Tagged	# Recaptures	Recapture %
Foss	CULT	2011	296	8	2.7
Foss	REF	2011	290	10	3.4
Foss	CULT	2012	132	2*	0.7
Foss	REF	2012	459	16	3.5
Manke	CULT	2012	395	10	2.5
Manke	REF	2012	581	21	3.6
Rolfs	CULT	2012	116	0	0.0
Rolfs	REF	2012	412	4	1.0
Total			2681	71	

Table 3. **ANOSIM summary statistics for tests conducted on stomach content data between cultured and reference plots for each month. Bold indicates statistically significant difference with p<0.05.**

Test Between Plots	ANOSIM R	p-value
May	-0.005	0.504
June	0.042	**0.034**
July	0.177	**0.001**
Aug	0.055	**0.034**
Sep	0.283	**0.001**

Table 4. **ANOSIM summary statistics for tests conducted on stomach content data between each month pairing for cultured and reference plots. Bold indicates statistically significant difference with p<0.05.**

Test Months	Plot	ANOSIM R	p-value
May and June	CULT	0.033	0.111
May and June	REF	0.014	0.215
May and July	CULT	0.083	**0.011**
May and July	REF	0.110	**0.001**
May and Aug	CULT	0.186	**0.001**
May and Aug	REF	0.145	**0.001**
May and Sep	CULT	0.443	**0.001**
May and Sep	REF	0.105	**0.001**
June and July	CULT	0.000	0.438
June and July	REF	0.043	0.055
June and Aug	CULT	0.069	**0.014**
June and Aug	REF	0.047	**0.046**
June and Sep	CULT	0.245	**0.001**
June and Sep	REF	0.056	**0.026**
July and Aug	CULT	0.028	0.123
July and Aug	REF	0.083	**0.003**
July and Sep	CULT	0.132	**0.001**
July and Sep	REF	0.027	0.093
August and Sep	CULT	0.048	**0.045**
August and Sep	REF	0.024	0.129

***Table 5.* Mean $\delta^{13}C$ and $\delta^{15}N$ values and standard error (SE) for all organisms. AMPH: non-corophium amphipods, CORO: corophium amphipods, CRAB: crabs, FPOLY: filter-feeding polychaetes, PPOLY: predatory polychaetes, SHRI: shrimp, SCULP: staghorn sculpin.**

Group	Month	Plot	N	Mean $\delta^{13}C$	SE $\delta^{13}C$	Mean $\delta^{15}N$	SE $\delta^{15}N$
AMPH	April	CULT	5	-13.798	0.450	7.905	0.302
AMPH	April	REF	5	-10.372	0.666	8.037	0.327
AMPH	June	CULT	5	-12.560	0.343	7.905	0.085
AMPH	June	REF	2	-13.266	0.568	9.535	0.102
AMPH	Aug	CULT	5	-11.622	0.483	9.206	0.215
AMPH	Aug	REF	5	-11.917	0.147	9.357	0.312
CORO	April	CULT	5	-15.706	0.713	9.300	0.196
CORO	April	REF	5	-13.152	0.219	8.730	0.216
CORO	June	CULT	4	-15.559	0.421	9.085	0.159
CORO	June	REF	5	-14.880	0.311	8.874	0.159
CORO	Aug	CULT	2	-16.199	0.755	9.454	0.308
CORO	Aug	REF	5	-15.182	0.418	9.330	0.165
CRAB	April	CULT	5	-10.047	1.050	8.593	0.884
CRAB	April	REF	2	-8.679	1.909	9.091	0.142
CRAB	June	CULT	5	-14.158	0.481	10.049	0.085
CRAB	June	REF	2	-15.115	0.159	9.678	0.197
CRAB	Aug	CULT	5	-10.533	0.224	10.594	0.180
CRAB	Aug	REF	5	-12.950	0.258	10.487	0.186
FPOLY	April	CULT	5	-13.610	0.321	11.095	0.442
FPOLY	April	REF	5	-11.457	0.387	12.628	0.512
FPOLY	June	CULT	5	-13.446	0.554	11.200	0.910
FPOLY	June	REF	5	-14.093	1.223	10.950	0.849
FPOLY	Aug	CULT	5	-13.318	0.846	12.486	0.506
FPOLY	Aug	REF	5	-12.363	0.728	12.311	0.738
PPOLY	April	CULT	5	-12.978	0.540	13.078	0.419
PPOLY	April	REF	5	-12.418	0.474	14.812	0.707
PPOLY	June	CULT	5	-13.057	0.301	12.637	0.567
PPOLY	June	REF	5	-11.606	0.643	12.919	0.362
PPOLY	Aug	CULT	5	-11.258	0.607	13.129	0.364
PPOLY	Aug	REF	5	-11.673	0.779	13.563	0.631
SHRI	April	CULT	5	-12.378	0.184	10.923	0.360
SHRI	June	CULT	5	-12.715	0.381	11.598	0.199
SHRI	Aug	CULT	5	-12.610	0.437	11.183	0.137
SHRI	Aug	REF	2	-15.479	0.681	10.765	0.021
SCULP	May	CULT	15	-13.608	0.277	13.572	0.103
SCULP	May	REF	15	-12.989	0.240	13.801	0.166
SCULP	July	CULT	15	-14.174	0.270	14.501	0.132
SCULP	July	REF	15	-13.884	0.247	14.260	0.157
SCULP	Sep	CULT	15	-13.810	0.222	14.776	0.119
SCULP	Sep	REF	15	-14.346	0.242	14.702	0.125

***Table 6*. Total biomass of prey compared to sculpin population consumption at each site and plot in 2011 and 2012. Pop. Cons.: consumption of a population of 1000 staghorn sculpin.**

Month	Site	Plot	Year	Total Pop. Cons. (g)	Total Biomass for 5000 m^2 Plot (g)	Total Biomass-Total Pop. Cons.	Total Biomass /Total Pop. Cons.	# Sculpin Supported
July	Foss	CULT	2011	22515	28441	5926	1	1263
July	Foss	REF	2011	18713	182797	164085	10	9769
Aug	Foss	CULT	2011	25649	138794	113145	5	5411
Aug	Foss	REF	2011	21068	130808	109740	6	6209
May	Foss	CULT	2012	3904	47782	43877	12	12238
May	Foss	REF	2012	5173	188248	183075	36	36389
June	Foss	CULT	2012	11254	47782	36528	4	4246
June	Foss	REF	2012	9852	188248	178396	19	19107
July	Foss	CULT	2012	14009	38670	24660	3	2760
July	Foss	REF	2012	14674	122101	107428	8	8321
Aug	Foss	CULT	2012	16020	29558	13538	2	1845
Aug	Foss	REF	2012	17293	55954	38661	3	3236
May	Manke	CULT	2012	9012	114814	105802	13	12740
May	Manke	REF	2012	7581	154380	146799	20	20364
June	Manke	CULT	2012	17182	114814	97632	7	6682
June	Manke	REF	2012	15884	154380	138496	10	9719
July	Manke	CULT	2012	22477	80958	58481	4	3602
July	Manke	REF	2012	21084	108551	87467	5	5148
Aug	Manke	CULT	2012	27480	47102	19622	2	1714
Aug	Manke	REF	2012	23262	62721	39459	3	2696
May	Rolfs	CULT	2012	7321	54731	47410	7	7476
May	Rolfs	REF	2012	5587	63629	58042	11	11388
June	Rolfs	CULT	2012	14614	54731	40117	4	3745
June	Rolfs	REF	2012	12760	63629	50869	5	4986
July	Rolfs	CULT	2012	18612	62961	44350	3	3383
July	Rolfs	REF	2012	17702	87015	69313	5	4916
Aug	Rolfs	CULT	2012	23017	71192	48174	3	3093
Aug	Rolfs	REF	2012	21958	111069	89111	5	5058

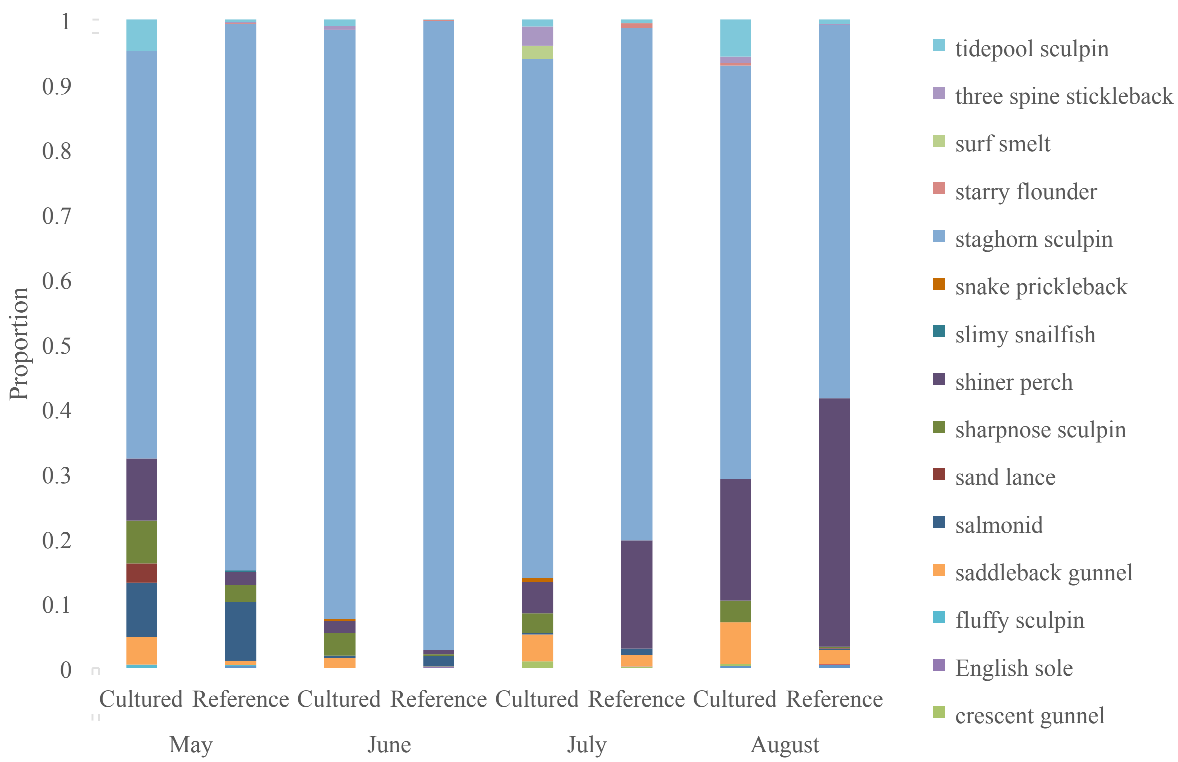

Figure 1. **Relative abundances of all fish captured in beach seines at cultured and reference plots in May-August, 2012.**

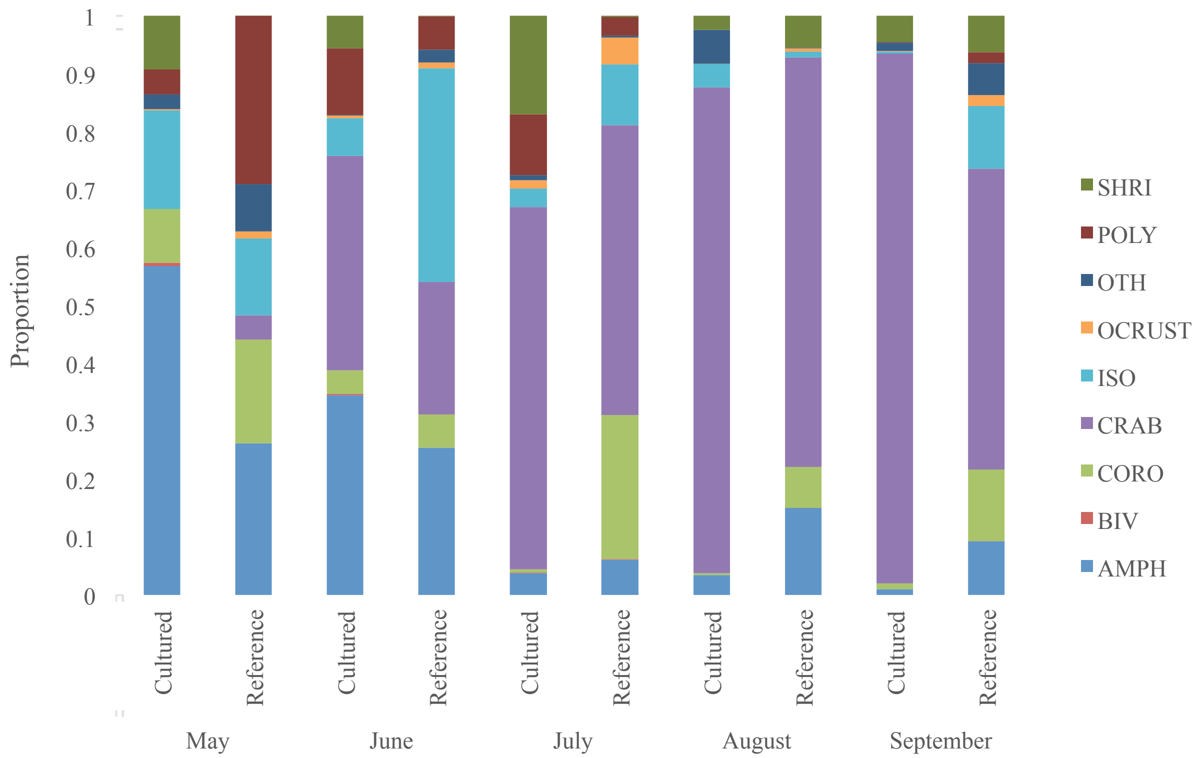

Figure 2. **Average mass-based proportion of each prey group by month and plot from staghorn sculpin stomach contents. AMPH: non-corophium amphipods, BIV: bivalves, CORO: corophium amphipods, CRAB: crabs, ISO: isopods, OCRUST: other crustaceans, OTH: other, POLY: polychaetes, SHRI: shrimp.**

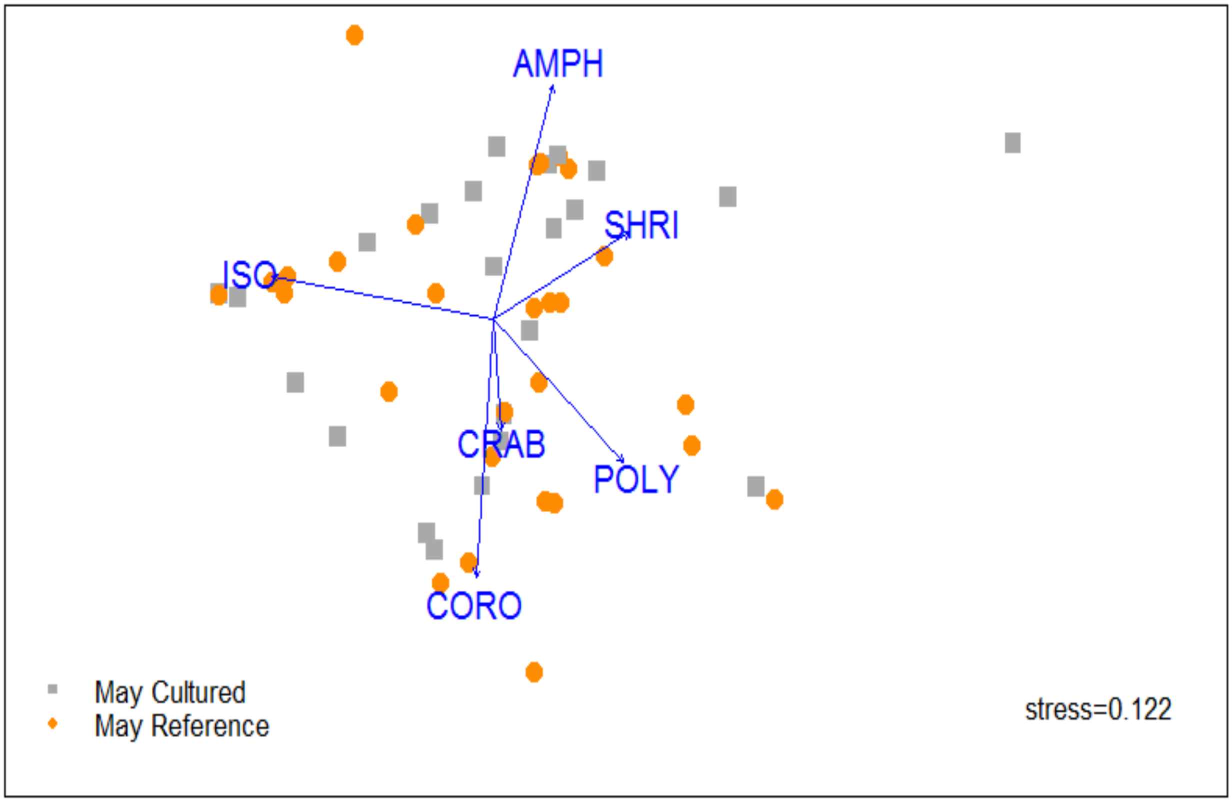

Figure 3. **NMDS plot of staghorn sculpin stomach contents at cultured and reference plots in May. Significant prey groups (p<0.05) overlaid as blue vectors. AMPH: non-corophium amphipods, CORO: corophium amphipods, CRAB: crabs, ISO: isopods, POLY: polychaetes, SHRI: shrimp.**

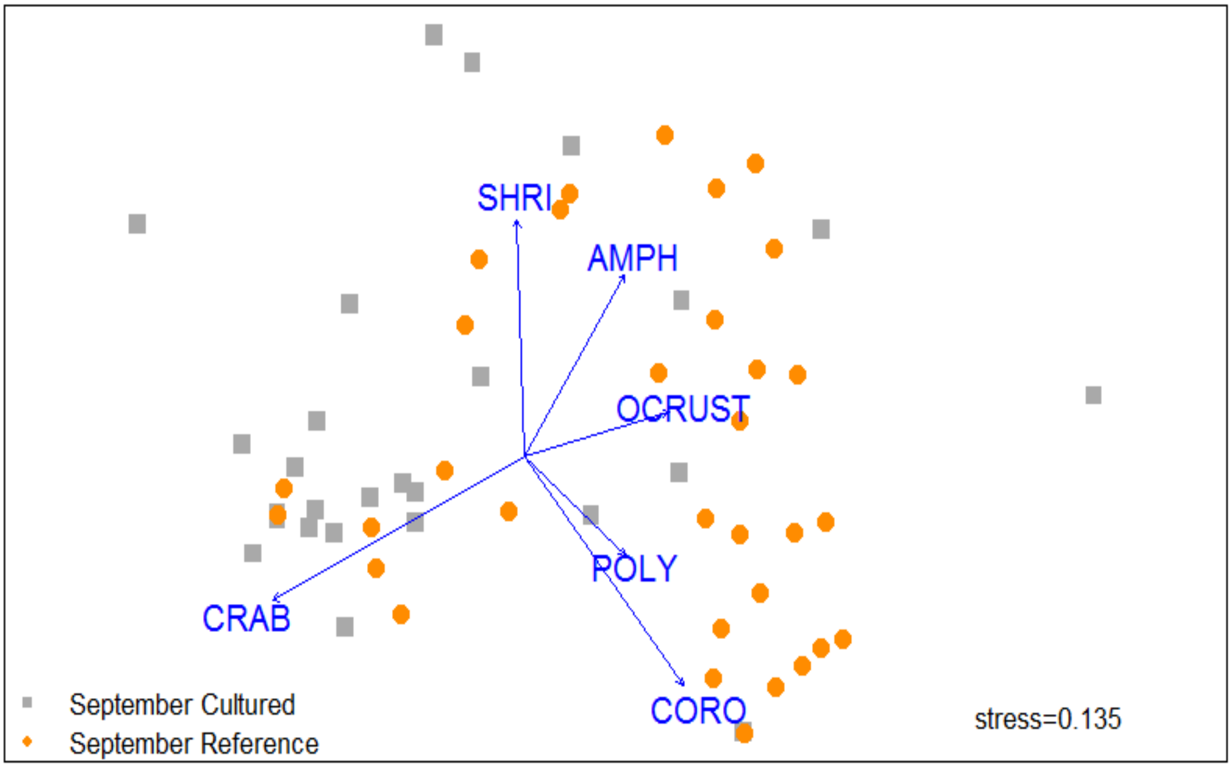

Figure 4. **NMDS plot of staghorn sculpin stomach contents at cultured and reference plots in September. Significant prey groups (p<0.05) overlaid as blue vectors. AMPH: non corophium amphipods, CORO: corophium amphipods, CRAB: crabs, OCRUST: other crustaceans, POLY: polychaetes, SHRI: shrimp.**

3. ACCOMPLISHMENTS AND IMPACTS

Accomplishment Statement

Title: **Sea Grant-supported research helps elucidate the impact of aquaculture on predator-prey relationships**

Relevance: Expansion of geoduck aquaculture operations in Puget Sound has raised concern among managers, conservation organizations and the public regarding their environmental impacts. Addition of aquaculture structures may affect a number of ecological functions and processes over several years, such as predator distribution.

Response: Sea Grant National Strategic Investment funding has enabled university researchers to investigate the effects of intertidal culture operations for Pacific geoduck clams (*Panopea generosa*) on community dynamics and trophic interactions. Building on results of previous Washington state-funded research, investigators identified key prey for fish and crab associated with geoduck farm sites. Working with the industry, they identified three research sites and conducted studies of the site fidelity, growth and stable isotope signatures of a local ubiquitous predator, Pacific staghorn sculpin (*Leptocottus armatus*) within three geoduck farms and associated nearby reference areas. This species is useful as an indicator of potential changes in the ecosystem associated with aquaculture impacts.

Results: The mark-recapture study indicated that staghorn sculpin show fidelity to their site of initial capture. Analysis of diet samples and comparison to previous data demonstrated that sculpin consume different types of prey within each habitat; yet results from carbon and nitrogen stable isotopes suggest that sculpin are chemically similar at farm and reference areas across summer months, despite some differences in prey composition. These data were used to model energetics of sculpin and their prey. Project results provide new insights into the way geoduck aquaculture may modify prey availability and alter predator-prey relationships.

Recap: A Washington Sea Grant-supported researcher has used traditional food habits techniques, chemical analyses, and energetic models to examine the effects of geoduck aquaculture operations on trophic relationships in Puget Sound

4. PUBLICATIONS

Peer-reviewed journal articles:

McPeek KC, McDonald PS, VanBlaricom GR (in review) Impact of aquaculture disturbance on ecological linkages and the diet of a ubiquitous predatory fish. Estuaries and Coasts

Theses and dissertations:

McPeek KC (2013) Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. MS thesis, University of Washington, Seattle, WA

Proceedings, Symposia (entire publication): **none.**
Peer-reviewed book chapters: **none.**
Paper in Proceedings: **none.**
Handbooks, Manuals and Guides: **none.**
Newsletters and Periodicals: **none.**
Technical reports: **none.**
Brochures, Fact sheets, etc. **none.**

Media Placements (print, radio, TV and internet coverage): **none.**
Web site: **none.**
Videos, DVDs, Software and other non print formats: **none.**
Books or Monographs: **none.**
Theses and dissertations: **1.**

Conference/Workshop activity, Presentation or Seminar: **12.**
Conference poster presentation: McDonald PS, Holsman KK, VanBlaricom GR (2014) Ecological effects of clam (Panopea generosa) aquaculture on resident and transiet macrofauna in an urban estuary. Poster presentation at the Ocean Sciences Meeting, Honolulu, HI, February 23-28

Presentation: McPeek KC. Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. MS defense, School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, November 19 2013

Seminar: Kathleen C. McPeek. Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington. WDFW and UW Brown Bag Seminar Series, Olympia, WA, November 13 2013

Conference oral presentation: McDonald PS, Holsman KK, VanBlaricom GR (2013) Evaluating spillover effects of geoduck aquaculture practices on selected resident invertebrates of southern Puget Sound. Oral presentation at the Pacific Coast Shellfish Growers Association Annual Conference, Sunriver, OR, September 30-October 2

Presentation: VanBlaricom GR, Price JL, McDonald PS, Cordell JR, Essington TA, Galloway AWE, Dethier MN, Armstrong DA (2013) Evaluations of the Ecological Effects of Geoduck (*Panopea generosa*) Aquaculture Harvest Practices on Benthic Organisms in southern Puget Sound, 2008-2012. Oral presentation of testimony in the matter of Environmental Appeal SHB 13-006c, at the Washington State Shorelines Hearings Board, Tumwater, WA, August 13 2013

Conference oral presentation: VanBlaricom GR., McDonald PS, Price JL, McPeek KC, Galloway AWE, Cordell JR, Dethier MN, Armstrong DA (2013) Ecological consequences of geoduck clam *Panopea generosa* Gould 1850 aquaculture for benthic communities of intertidal sand flats in southern Puget Sound, Washington USA: A summary of findings, 2008-2012. Oral presentation at the 105th Annual Meeting, National Shellfisheries Association, and Aquaculture 2013 Triennial Meeting, Nashville, TN, 21-25 February 21-25

Conference oral presentation: McPeek KC, VanBlaricom GR, McDonald PS, Beauchamp D (2012) Effects of geoduck aquaculture on the growth and stable isotope signatures of staghorn sculpin. Oral presentation at the National Shellfish Association Annual Meeting, Seattle, WA, March 25-29

Conference oral presentation: McDonald PS, Stevick PF, Galloway AE, McPeek KC, Armstrong DA, VanBlaricom GR (2012) Nekton, nets, and tubes: macrofauna response to intertidal geoduck aquaculture operations in Puget Sound, Washington. Oral presentation at the National Shellfish Association Annual Meeting, Seattle, WA, March 25-29

Conference oral presentation: McPeek KC, VanBlaricom GR, Beauchamp D, McDonald PS (2012) Patterns of utilization of geoduck aquaculture plots by Pacific staghorn sculpin in Puget Sound, WA: Results from mark-recapture and stable isotope studies. Oral presentation at the Pacific Coast Shellfish Growers Association Annual Conference, Tulalip, WA, September 25-27

Conference oral presentation: McDonald PS, Galloway, AE, Price, JL, McPeek KC, VanBlaricom GR (2012) Macrofauna associated with geoduck aquaculture: SCUBA and seining results. Oral presentation at the Pacific Coast Shellfish Growers Association Annual Conference, Tulalip, WA, September 25-27

Presentation: McPeek KC. Patterns of utilization of geoduck aquaculture plots by Pacific staghorn sculpin in Puget Sound, WA: Results from mark-recapture and stable isotope studies. Presentation to the Washington Cooperative Fish and Wildlife Research Unit Annual Meeting, Seattle, WA, September 27, 2012

Conference oral presentation: McPeek KC, VanBlaricom GR, Beauchamp D, McDonald PS (2012) Patterns of utilization of geoduck aquaculture plots by Pacific staghorn sculpin in Puget Sound, WA. Oral presentation at the Western Society of Naturalists Annual Meeting, Seaside, CA, November 8-11

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: Lynda Le.
Involvement with WSG: undergraduate intern and Capstone student.
Degree track: B.S.
Whether degree was **completed** during the reporting window: YES.
New or continuing student on WSG support: CONTINUING.
Department: University of Washington, School of Aquatic and Fishery Sciences.
Major/Degree field: Aquatic and Fishery Sciences.
Major Professor: Patrick Sean McDonald.
Dissertation/Thesis title (actual): Effects of Algae Cover on the Growth and Survivorship of Commercial Geoducks (*Panopea generosa*).
Date of graduation (actual): December 2012.
If student has graduated, please provide name of current employer, if known: N/A

Student Name: Kathleen McPeek.
Involvement with WSG: M.S. student supported on project.

Degree track: M.S.
Whether degree was **completed** during the reporting window: YES.
New or continuing student on WSG support: CONTINUING.
Department: University of Washington, School of Aquatic and Fishery Sciences.
Major/Degree field: Aquatic and Fishery Sciences.
Major Professor: Glenn R. VanBlaricom.
Dissertation/Thesis title: Food web impacts of geoduck clam aquaculture practices in Puget Sound, Washington.
Date of graduation (actual or actual): December 2013.
If student has graduated, please provide name of current employer, if known: University of Washington.

Student Name: Katherine Armintrout
Involvement with WSG: undergraduate intern.
Degree track: B.S.
Whether degree was **completed** during the reporting window: YES.
New or continuing student on WSG support: CONTINUING.
Department: University of Washington, School of Aquatic and Fishery Sciences.
Major/Degree field: Aquatic and Fishery Sciences.
Major Professor: Patrick Sean McDonald.
Project title (actual): A bioenergetics model for staghorn sculpin utilizing geoduck.
Date of graduation (actual): August 2011.
If student has graduated, please provide name of current employer, if known: N/A

Student Name: Zack Oyafuso.
Involvement with WSG: undergraduate intern.
Degree track: B.S.
Whether degree was **completed** during the reporting window: YES.
New or continuing student on WSG support: CONTINUING.
Department: University of Washington, School of Aquatic and Fishery Sciences.
Major/Degree field: Aquatic and Fishery Sciences.
Major Professor: Patrick Sean McDonald.
Project title (actual): Investigating the Effects of Geoduck Aquaculture on the Benthic Community During the Planting Stage.
Date of graduation (actual): June 2013.
If student has graduated, please provide name of current employer, if known: N/A

Student Name: Kaitlin Soto.
Involvement with WSG: undergraduate intern and Capstone student.
Degree track: B.S.
Whether degree was **completed** during the reporting window: YES.
New or continuing student on WSG support: CONTINUING.
Department: University of Washington, School of Aquatic and Fishery Sciences.
Major/Degree field: Aquatic and Fishery Sciences.
Major Professor: Patrick Sean McDonald.

Dissertation/Thesis title (actual): The influence of algal cover on biodiversity around geoduck (*Panopea generosa*) farms.
Date of graduation (actual): August 2012.
If student has graduated, please provide name of current employer, if known: N/A

Other students receiving internship credit at University of Washington: Jessica Blanchette, Lise Ferguson, Joshua Fuller, Katrina Herlambang, Sylvia Howard, Loan Huynh, Jordan Lee, Felicia Muncaster-Jones, Marion Richards, Kaitlyn Robbins, Sarah Schooler, Julie Stewart

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/Business*	*State/Local*	*Managers consulted on site selection and scheduling of maintenance activities at study sites.*
Seattle Shellfish	*Industry/Business*	*State/Local*	*Owner consulted on site selection and project logistics.*
Chelsea farms	*Industry/Business*	*State/Local*	*Owner & managers consulted on site selection and scheduling of maintenance activities at study sites.*
People for Puget Sound	*NGO*	*State*	*Scientists and outreach specialists consulted on project activities, preliminary results, and volunteer requests.*
Pacific Shellfish Institute	*NGO*	*Regional*	*Scientists consulted on project activities and provided temperature data for ongoing modeling work.*
Puget Sound Restoration Fund	*NGO*	*State*	*Scientists consulted on project activities and coordination of data collection and processing techniques.*
School of Aquatic and	*Academic*	*State*	*Undergraduate program*

Fishery Sciences, University of Washington			*coordinator consulted on internship opportunities and volunteer requests.*
Program on the Environment, University of Washington	*Academic*	*State*	*Undergraduate program coordinator consulted on internship opportunities and volunteer requests.*

7. OUTREACH AND INFORMATION/TECHNOLOGY TRANSFER

Please describe any specific outreach or information/technology transfer activities that **have taken place** relative to your work that are not captured in the performance metrics tables below. What follow-up activities (by you, WSG or other partners) **would** ensure that the results of this project are fully applied?

8. LEVERAGED FUNDS

Travel award to Kate McPeek for conference attendance, Western Society of Naturalists ($500)

Travel award to Kate McPeek for conference attendance, Western Society of Naturalists ($1000)

Richard T. Whiteleather Scholarship (2012-2013) to Kate McPeek for tuition and stipend, School of Aquatic and Fishery Sciences ($13,349)

Richard T. Whiteleather Scholarship (2013-2014) to Kate McPeek for tuition and stipend, School of Aquatic and Fishery Sciences ($13,349)

Source Entity/Partner and Description (limit to ONE source/partner per line)	**Amount**
Western Society of Naturalists - Travel award to Kate McPeek for conference attendance, NSA-PCS best student paper award	$500
Western Society of Naturalists - Travel award to Kate McPeek for conference attendance, Gilbert B. Pauley Award for best lecture	$1000
Richard T. Whiteleather Scholarship (2012-2013) administered by School of Aquatic and Fishery Sciences, Recruitment, Admissions, and Scholarship Committee (RASC), 1-quarter tuition/stipend scholarship to Kate McPeek	$13,349
Richard T. Whiteleather Scholarship (2013-2014) administered by School of Aquatic and Fishery Sciences, Recruitment, Admissions, and Scholarship Committee (RASC), 1-quarter tuition/stipend scholarship to Kate McPeek	$13,349

SEE BELOW FOR PERFORMANCE METRICS REPORTING REQUIREMENTS