RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress
Glenn R. VanBlaricom
An ecosystem modeling approach to investigate direct and indirect effects of geoduck aquaculture expansion in Washington State
R/SFA-5
Submitted On: 05/11/2016 03:59:02 AM

METRICS & MEASURES

Metric/Measure	Value	Note
Acres of coastal habitat	0	No area of habitat was protected, enhanced, or restored as a result of these activities
Fishermen and seafood industry personnel	1	Taylor Shellfish is already making changes in bird monitoring; Results of this project will have bearing on the aquaculture activities of the three largest producers of geoduck clams in Washington State (Taylor Shellfish, Chelsea Farms, and Seattle Shellfish).
Communities - economic and environmental development	7	Managers in Mason, Thurston, Pierce, Clallam, Kitsap, Skagit, and Snohomish counties will be able to utilize this guidance to implement policy as part of Shoreline Master Program updates. Jurisdictions that have completed their SMP updates – King, Jefferson, and Whatcom counties - will apply findings in their scheduled updates.
Stakeholders - sustainable approaches	0	N/A
Informal education programs	0	N/A
Stakeholders who receive information	130	55 people attended P. Sean McDonald's presentation at the 107th Annual Meeting of the National Shellfisheries Association in Monterey, California, March 2015 75 people attended P. Sean McDonald's presentation at the Coastal & Estuarine Research Federation, 23rd Biennial Meeting in Portland, Oregon, November 2015
Volunteer hours	0	N/A
P-12 students reached	0	N/A
P-12 educators	0	N/A

REQUESTED INFORMATION

Publications

Evaluating trophic and non-trophic effects of shellfish aquaculture in a coastal estuarine foodweb
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015

Publication Authors:
Publisher Info:
Notes:
Related URLs:
Keywords: aquaculture, food web, model, non-trophic, shellfish
Publication URLs: http://icesjms.oxfordjournals.org/content/73/2/429.full
Abstract: Expansion of the shellfish aquaculture industry has the potential to affect the structure and dynamics of coastal estuarine foodwebs. To better understand foodweb trade-offs we incorporated both trophic and non-trophic interactions (e.g. habitat facilitation and predator refuge) into a foodweb model of central Puget Sound to predict the effects of an increase in geoduck (Panopea generosa) aquaculture. At a basin scale, the foodweb can support at least 120% increased geoduck aquaculture, above current production levels (landings of 10 546 kg in 2012), with only minor changes in individual species' biomass and/or metrics of ecosystem resilience. The non-trophic effects of increased geoduck aquaculture, related to the influence of anti-predator structure, had a stronger influence on the foodweb than the trophic role of cultured geoducks as filter-feeders and prey to other species. Increased geoduck culture caused substantial increases in biomass densities of surfperch, nearshore demersal fish, and small crabs, and decreases in seabirds, flatfish, and certain invertebrates (e.g. predatory gastropods and small crustaceans). This study identifies species that should be a priority for additional empirical research and monitoring related to bivalve aquaculture interactions, including demersal fish, small crustaceans, and seabirds. It also provides insights into the benefits and challenges of incorporating habitat-related data into a foodweb model. Understanding these relationships can inform management decisions by clarifying trade-offs in ecosystem functions and services in Puget Sound and facilitates estimation of direct and cumulative effects of bivalve aquaculture at a foodweb scale.
Citation: Ferriss, B.E., J.C. Reum, P.S. McDonald, D.M. Farrell, and C.J. Harvey. 2015. Evaluating trophic and non-trophic effects of shellfish aquaculture in a coastal estuarine food web. ICES J. Mar. Sci. 73 (2): 429-440.
Citation for Coverpage:
SG can post PDF online?: Yes
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Students Supported

No **Students Supported** information reported

Narratives

2015 annual progress report R/SFA-5
Uploaded File: VanBlaricom_WSG_PROGRESS_REPORT.pdf

Partners This Period

NOAA Northwest Fisheries Science Center
Types: Government
Scale: FEDERAL or NATIONAL
Notes:

Pacific Shellfish Institute
Types: NGO
Scale: REGIONAL
Notes:

Taylor Shellfish
Types: Industry/Business
Scale: INTERNATIONAL
Notes:

Washington Department of Ecology
Types: Government
Scale: STATE
Notes:

Washington Department of Natural Resources
Types: Government
Scale: STATE
Notes:

STANDARD QUESTIONS

Impacts and Accomplishments

(1)

Type	impact
Title	Washington Sea Grant research models the ecosystem effects of expanding geoduck aquaculture, informing resource management and regulation
Relevance	Geoduck aquaculture is a valuable, fast-growing, but controversial Puget Sound industry. From 2007 to 2013 Washington Sea Grant conducted the first comprehensive study of its environmental effects. But some stakeholders still expressed concern about broader impacts, particularly on iconic species such as salmon and eagles.
Response	Washington Sea Grant-funded researchers investigated the effects of expanding intertidal geoduck culture on the Central Puget Sound ecosystem. They incorporated key predator–prey relationships into a robust food-web model and worked with a comprehensive panel of stakeholders to identify important linkages for inclusion when assessing management scenarios.
Results	Initial modeling suggests that effects are most pronounced at farm sites but can ripple throughout the food web when farming expands dramatically. This may adversely affect flatfish, predatory snails and small crustaceans directly and more mobile species such as eagles, herons and salmon indirectly. Shorebirds, crabs, surf perch and some other organisms may benefit directly or indirectly from culture-driven habitat changes. Bottomfish, small crustaceans, and flatfish may be useful as indicator species. Regulators immediately began incorporating the model in their analyses: the U.S. Army Corps of Engineers cited it in its Programmatic Biological Assessment of Shellfish Activities in Washington State Inland Waters, and other agencies will do likewise. “We found it extremely helpful and informative,” said one Corps scientist. “It’s the first

	time someone has done this modeling.”
Recap	Washington Sea Grant-supported ecosystem modeling gauged the effects of expanding geoduck aquaculture on Puget Sound’s food web and found unexpected implications for many species.
Comments	
Primary Focus Area	Sustainable Fisheries and Aquaculture
Secondary Focus Areas	Healthy Coastal Ecosystems,Resilient Communities and Economies
Goals	Ocean and coastal resources are managed using ecosystem-based approaches.|Aquaculture operations and shellfish harvests are safe, environmentally sustainable and support economically prosperous businesses.|Coastal communities engage in comprehensive planning and sustainable development.
Partners	Northwest Fisheries Science Center (US DOC, NOAA, NMFS, NWFSC) Pacific Shellfish Institute Point No Point Treaty Council Shellfish Interagency Permitting Team Taylor Shellfish Company Washington State Department of Ecology Washington State Department of Natural Resources
PI Draft	* Type impact * Title Washington Sea Grant ecosystem modeling provides insight into the effects of geoduck aquaculture on the Puget Sound food web * Relevance From 2007 to 2013 Washington Sea Grant conducted a comprehensive state funded study of the effects of geoduck aquaculture on the Puget Sound environment. This research provided the first scientific assessment of the ecosystem impacts of geoduck culture practices from planting through harvest. While the study substantially increased understanding, some stakeholders continued to express concern about broader ecosystem effects, particularly on iconic Northwest wildlife such as salmon, bald eagles, seabirds, and marine mammals. * Response Partnering with the Northwest Fisheries Science Center, Washington Sea Grant funded researchers investigated the effects of expanding intertidal geoduck culture on the Central Puget Sound ecosystem. They incorporated key predator–prey relationships quantified in previous research into a robust food-web model. Together with an inclusive working group of stakeholders, they identified management scenarios to submit to the model. * Results Preliminary results suggest that culture practices that modify shoreline habitat can have consequences that are most pronounced at farm sites but ripple throughout the food web, and which may affect more mobile species such as eagles, herons, and shorebirds. Results also indicate that bottomfish, small crustaceans, and flatfish may

	be useful as indicator species. The model provides new information about the potential impacts of expanding geoduck aquaculture in Puget Sound and will help managers plan for future conditions. * Recap A Washington Sea Grant-supported ecosystem model examines the effects of continued and expanding geoduck aquaculture on the Puget Sound food web, with preliminary results suggesting some unexpected indirect implications for finfish, birds, and mammals. Comments Primary Focus Area Sustainable Fisheries and Aquaculture Secondary Focus Areas Healthy Coastal Ecosystems,Resilient Communities and Economies Goals Aquaculture operations and shellfish harests are safe, environmentally sustainable and support economically prosperous businesses. Partners NOAA Northwest Fisheries Science Center Pacific Shellfish Institute Point No Point Treaty Council Shellfish Interagency Permitting Team Taylor Shellfish Farms Washington State Department of Ecology Washington State Department of Natural Resources

Tools, Technologies, Information Services / Sea Grant Products

(1)

Description	Information on species sensitivity to cultured geoduck for use in shellfish management in Puget Sound, WA.
Developed (in the reporting period)?	Yes
Used (in the reporting period)?	Yes
Used for EBM?	Yes
ELWD product?	No
Number of managers	11
Description/Names of managers	state (Department of Ecology, Department of Natural Resources, Department of Fish and Wildlife) and Federal (US Army Corps of Engineers), as well as county planners (Managers in Mason, Thurston, Pierce, Clallam, Kitsap, Skagit, and Snohomish counties)

Economic Impacts

No **Economic Impacts** information reported

Community Hazard Resilience

No **Community Hazard Resilience** information reported

Meetings, Workshops, Presentations

(1)

Type of Event	Public or professional presentation
Description	McDonald, PS. A modeling approach to understand the effects of geoduck aquaculture on the puget sound food web. 107th Annual Meeting of the National Shellfisheries Association in Monterey, California, March 2015
Event Date	03-23-2015
Number of Attendees	55

(2)

Type of Event	Public or professional presentation
Description	McDonald, PS. Application of an ecosystem model to address stakeholder concerns about aquaculture expansion. Coastal & Estuarine Research Federation, 23rd Biennial Meeting in Portland, Oregon, November 2015
Event Date	11-11-2015
Number of Attendees	75

Leveraged Funds

No **Leveraged Funds** information reported

WASHINGTON SEA GRANT PROGRESS REPORT

for the period 2/1/2015 - 1/31/2016

Project Title: R/SFA-5 - *An ecosystem modeling approach to investigate direct and indirect effects of geoduck aquaculture expansion in Washington State*

Principal Investigator(s) and Affiliation:

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

1. PROJECT OBJECTIVES (from original proposal)

We will synthesize five years of data collected at geoduck aquaculture sites and reference beaches to guide model simulations (see below). Our objectives are as follows: (1) to evaluate direct and indirect ecosystem effects in scenarios involving future increases in the extent of geoduck aquaculture; (2) to identify appropriate indicator species that reflect the broader status of ecosystem health in response to geoduck aquaculture expansion; (3) to determine gaps in data to guide future research; and 4) to provide a tool for managers to aid in screening policy options.

2. PROJECT PROGRESS

This project involves incorporating results from the Sea Grant-sponsored Geoduck Aquaculture Research Program and other studies into an ecosystem model for central Puget Sound. We have made substantial progress to date, including integrating empirical field data into a vetted, published food web model of central Puget Sound developed in the Ecopath with Ecosim (EwE) software by co-investigator, Chris Harvey (2010, 2012b). EwE simulates production, mortality, predator-prey interactions, habitat effects, and fishery effects in aquatic food webs (Christensen and Walters 2004).

We perturbed the system in the dynamic Ecosim module once the initial conditions had achieved mass balance (in the static Ecopath module of the program). Perturbations are simulations of changes in environmental conditions or human activities. Because functional groups are linked by predator-prey relationships, a perturbation in one group will ripple throughout the entire food web. The magnitudes of ripples depend on the strength of direct and indirect interactions, as determined in large part by the core parameters listed above.

In a management context, system perturbations allow the user to conduct experiments in which different policies can be applied; the outcomes of multiple model runs can then be compared to determine which policies best achieve desired goals and objectives, as well as the tradeoffs involved. For example, one scenario may result in increased yield in a fishery but also lead to reduction in some other ecosystem service, such as the capacity for a species of concern to recover. This capability for strategy comparisons and tradeoff analysis is why ecosystem models like EwE are often employed as part of management strategy evaluation (Sainsbury et al. 2000) and integrated ecosystem management (Levin et al. 2009).

The original EwE model developed by Harvey et al (2010a, 2012b) has been modified in the following ways:

- We added a new geoduck group representing "cultured geoducks" whose biomass, harvest rates, and spatial distribution are based on aquaculture practices. Thus, the simulated interactions and management activities are focused on cultured geoducks, rather than on the diffuse population of wild geoducks that occur at a much broader range of depths and experience quite different management practices.
- We integrated the findings from field studies conducted by McDonald et al. (2015), McPeek et al. (2014), and VanBlaricom et al (2015). These data provide direct and indirect links between cultured geoducks (or geoduck aquaculture activity) and other functional groups in the nearshore community. Linkages include: direct consumption of phytoplankton by cultured geoducks; transition of available habitat from soft sediment tideflats to farmed plots; and shifts in diet due to "mediation functions" in Ecosim, as described by Espinosa-Romero et al. (2011). In essence, the biomass of a mediating group—here, cultured geoducks—indirectly facilitates or constrains ecological processes of other biota, in a manner consistent with the empirical data.

We integrated cultured geoducks into the model and conducted two series of model runs. First, we tested the sensitivity of the model to parameter inputs, so that we could include estimates of uncertainty in subsequent scenario exercises (Fig. 1). Second, we built scenarios that address potential geoduck aquaculture futures in central Puget Sound, based on discussions with stakeholder groups such as shellfish growers and managers (Table 1). Findings to date indicate that a number of taxa are sensitive; for example, nearshore demersal fish (poachers, eelpouts, sculpins), surfperch, and crabs tend to increase, while various birds (eagles, cormorants, grebes), flatfish, and small crustaceans (amphipods, mysids, isopods) tend to decrease in the model (Ferriss et al. 2015; doi:10.1093/icesjms/fsv173).

As part of our recent publication in ICES Journal of Marine Science (Ferriss et al. 2015), we have made substantial progress completing project objectives listed above. We have evaluated direct and indirect ecosystem effects and identified appropriate indicator species. We continue to make steady progress on the remaining objectives (i.e., determining gaps in data to guide future research and providing management tools). Our findings when complete will facilitate a more holistic view of the impacts of geoduck aquaculture and policy decisions regarding future expansion.

Our modeling work is contributing results as bases for making informed decisions and allow managers to move beyond the delicate matter of responding to public demands based solely on postulated aesthetic values and anticipated ecological effects. Previous funding by Washington State Legislature, DNR, and ECY, and our current NOAA NMAI grant has allowed us to establish study sites, foster working relationships with state regulatory agencies, tribal organizations, and private companies involved in geoduck aquaculture activities, and develop an infrastructure and data set necessary to evaluate ecological impacts of aquaculture activity. While earlier work focused on characterizing communities and trophic dynamics directly associated with geoduck operations (McDonald et al. 2105, McPeek et al. 2014, VanBlaricom et al. 2015), this present project greatly expands our understanding of ecosystem responses in the region and provides a useful framework to evaluate policy options.

The present work also coordinates with other shellfish aquaculture research programs. Collaborator Dr. Dan Cheney of Pacific Shellfish Institute (PSI) received a 2012 NMAI award to address ecological carrying capacity of South Puget Sound, in part, using a similar modeling approach (*Planning for sustainable shellfish aquaculture in complex multiple use environments: Determining social and ecological carrying capacity for south Puget Sound, Washington*); that project is both regionally specific (i.e., focused on Mason, Pierce, and Thurston Counties) and generalized (i.e., lacks specific data for geoduck aquaculture). Co-investigator McDonald participated in a workshop on these modeling results in January 2016 (*Visualizing Ecological Interactions of South Puget Sound*). We are now making efforts to coordinate analyses among projects in the hopes of comparing and contrasting model architecture and parameters, as well as extending the spatial extent of the modeled area to other counties where geoduck aquaculture is occurring.

More recently, we have been coordinating with industry and regulators on ways to use the model for planning purposes. We see this as an exciting prospect since we can use the model output to develop hypotheses that may be tested during farm development through targeted monitoring. For instance, species showing higher sensitivity to geoduck aquaculture in the model could be evaluated before and after new farming operations have been initiated. Moreover, we are exploring the sensitivity of the model itself to the shape and magnitude of the mediation functions described above in response to questions from stakeholders. We see this work as critical for contextualizing model results to make them more useful for management.

This work contributes to Sea Grant's National Strategic Plan Focus Area of Safe and Sustainable Seafood Supply by supporting aquaculture with acceptable environmental impacts. Moreover, the work addresses goals of the Puget Sound Partnership's (PSP) Puget Sound Action Agenda (A.4.4.1 Implement best management practices for shellfish production; continue the work of the SARC and implement its recommendations). Building on previous efforts, including work funded by Washington Sea Grant and NOAA National marine Aquaculture Initiative, we have identified and engaged target audiences for outreach. In addition to the recent publication by Ferriss et al. (2015), we anticipate at least one addition peer-reviewed publication, as well as presentations at relevant scientific conferences.

References:

Christensen V., and C.J. Walters. 2004. Ecopath with Ecosim: methods, capabilities and limitations. Ecological Modelling 172:109-139.

Espinosa-Romero M.J., E.J. Gregr, C. Walters, V. Christensen, and K.M.A. Chan. 2011. Representing mediating effects and species reintroductions in Ecopath with Ecosim. Ecological Modelling 222:1569-1579.

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Harvey C.J., K.K. Bartz, J.R. Davies, T.B. Francis, T.P. Good, A.D. Guerry, M.B. Hanson, K.K Holsman, J. Miller, M. Plummer, J.C.P. Reum, L.D. Rhodes, C.A. Rice, J.F. Samhouri, G.D.

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Harvey C.J., T.P. Good, and S.F. Pearson. 2012a. Top-down influence of resident and overwintering bald eagles (*Haliaeetus leucocephalus*) in a model marine ecosystem. Canadian Journal of Zoology 90: 903-914.

Harvey C.J., G.D. Williams, and P.S. Levin. 2012b. Food web structure and trophic control in central Puget Sound. Estuaries and Coasts 35:821-838.

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McDonald, P.S., A.W.E. Galloway, K.C. McPeek, and G.R. VanBlaricom. 2015. Effects of geoduck (*Panopea generosa* Gould, 1850) aquaculture gear on resident and transient macrofauna communities of Puget Sound, Washington. Journal of Shellfish Research 34(1): 189-202.

McPeek, KC, PS McDonald, and GR VanBlaricom. 2014. Aquaculture Disturbance Impacts the Diet but not Ecological Linkages of a Ubiquitous Predatory Fish. Estuaries and Coasts 10.1007/s12237-014-9909-z

Sainsbury K.J., A.E. Punt, and A.D.M. Smith. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. ICES Journal of Marine Science 57:731-741.

VanBlaricom, GR, J Price, J Olden, and PS McDonald. 2015. Ecological effects of the harvest phase of geoduck clam (*Panopea generosa* Gould, 1850) 1 aquaculture on infaunal communities in southern Puget Sound, Washington USA. Journal of Shellfish Research 34(1):171-187.

Table 1. Changes in biomass of functional groups due to increases in cultured geoduck biomass and landings (from 70% to 120%). Bold values represent biomass changes greater than 10% and gray highlight represents biomass changes greater than 20%. Biomass values are estimated in Ecosim, running the time series for each geoduck stanza and landings over 50 years.

		Increase in Cultured Geoduck Biomass and Landings					
Functional Group	**Start Biomass ($t \cdot km^{-2}$)**	**70%**	**80%**	**90%**	**100%**	**110%**	**120%**
Birds							
Resident birds	0.011	-9.9%	**-11.3%**	**-12.8%**	**-14.2%**	**-15.6%**	**-16.9%**
Great blue herons	0.003	**-11.8%**	**-13.5%**	**-15.2%**	**-16.8%**	**-18.5%**	**-20.1%**
Resident eagles	0.001	-9.3%	**-10.8%**	**-12.2%**	**-13.5%**	**-14.9%**	**-16.2%**
Migratory eagles	0.002	-8.8%	**-10.3%**	**-11.8%**	**-13.2%**	**-14.7%**	**-16.1%**
Pelagic fish							
S/a wild salmon	16.367	-5.5%	-6.4%	-7.3%	-8.3%	-9.2%	**-10.1%**
Surf perch	3.490	**18.3%**	**20.2%**	**22.0%**	**23.7%**	**25.2%**	**26.7%**
Demersal fish							
Walleye pollock	3.237	-5.8%	-6.9%	-7.9%	-8.9%	-9.9%	**-10.9%**
Pisc flatfish	1.155	-7.9%	-9.0%	**-10.1%**	**-11.3%**	**-12.4%**	**-13.5%**
Small mouth flatfish	7.962	**-18.5%**	**-20.8%**	**-23.1%**	**-25.4%**	**-27.5%**	**-29.6%**
Demersal fish	5.816	8.3%	9.0%	9.8%	**10.4%**	**11.0%**	**11.5%**
Demersal invertebrates							
Urchins	0.455	9.1%	**10.3%**	**11.4%**	**12.5%**	**13.6%**	**14.6%**
Small crustaceans	20.143	-8.1%	-9.6%	**-11.1%**	**-12.6%**	**-14.2%**	**-15.8%**
Small crabs	15.921	**11.1%**	**12.5%**	**13.9%**	**15.2%**	**16.4%**	**17.6%**
Pred gastropods	0.988	**-26.0%**	**-29.4%**	**-32.6%**	**-35.7%**	**-38.8%**	**-41.7%**
Suspension feeders	2.526	9.3%	**10.5%**	**11.6%**	**12.7%**	**13.7%**	**14.7%**

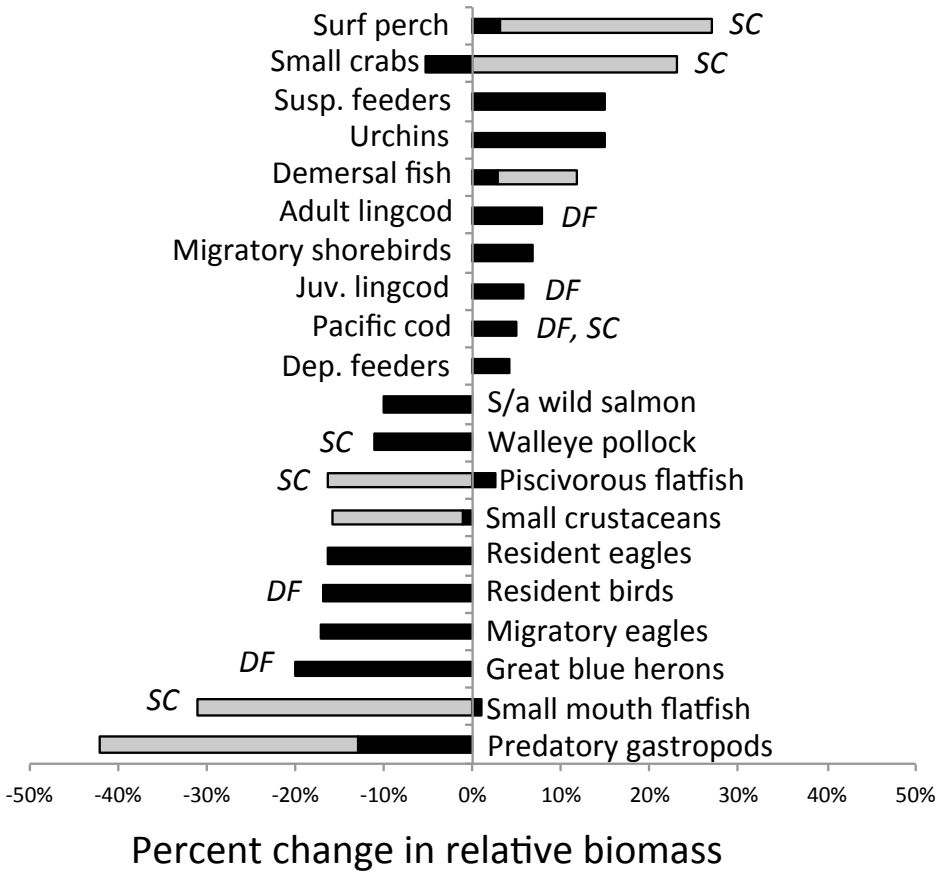

Figure 1. The functional groups whose biomasses are most affected (10 most positive and negative) due to the addition of geoduck mediation effects in the model. The changes in biomass due to indirect effects (black) and direct effects (gray) are additive (except for small crabs). A list of changes in biomass for all groups is in Table 3. Groups are assigned the label *DF* (Demersal fish) or *SC* (small crustaceans) if those represent their top three prey (as defined by Ecosim). The biomass estimates are generated by increasing cultured geoduck biomass by 120% over 50 years. The magnitude of change in biomass estimates is relative to the biomass of cultured geoducks in the model and is less relevant than the general trends (positive or negative) and which species are most sensitive to these mediation effects.