Ascidian coverage change from removal experiments in rocky intertidal Marine Protected Areas in the San Juan Islands from 2008-2011

Website: https://www.bco-dmo.org/dataset/472901
Version: 2013-12-10

Project
» Effects of Marine Preserves on Rocky Subtidal Communities (Subtidal Preserves)

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Coverage

Spatial Extent: **N**:48.60458 **E**:-122.98844 **S**:48.55235 **W**:-123.09283
Temporal Extent: 2008 - 2011

Dataset Description

In this study, we tested the hypothesis that red urchins (Strongylocentrotus franciscanus) and lined chitons (Tonicella spp.) are redundant in the maintenance of available space, defined here as encrusting algae and bare rock. In a factorial field experiment replicated at three sites, we reduced the densities of urchins and chitons for nine months. The effects of grazers were interpreted in the context of natural temporal variation by monitoring the benthic community one year before, during, and after grazer removal.

These data were published in Elahi & Sebens (2013).

Physical data - temperature, salinity, conductivity - can also be viewed online at http://nvs.nanoos.org/Explorer and http://depts.washington.edu/fhl/wx.html

Associated physical underwater and weather data:

See http://140.142.199.7/vdv/VV_Frame.php

Methods & Sampling

Field Experiment

In December 2007 (prior to the removal of grazers), permanent transects (2.5 m long, 2 m wide, n =6 site21) and quadrats (0.09 m2, n =4 transect21) were established on subtidal rock walls (12–18 m depth) at three sites in the San Juan Islands, Washington, United States of America [12]. Using a split-plot factorial design, we removed urchins from transects (whole-plot factor), and removed chitons from quadrats (within-plot factor). The two grazers were manipulated at different scales because red urchins are larger, less abundant, and more mobile, than lined chitons. Consequently, the split-plot design allowed a test of the effects of urchin removal on chiton abundance, but not chiton removal on urchin abundance.

At each of three sites, urchins were removed from three transects, and three other transects served as controls. The six permanent transects at each site were arranged linearly and parallel to shore, and for the purposes of urchin removal, adjacent transects were paired (to stratify the removal treatments throughout the site). For each pair of transects, the removal treatment was assigned to the transect with higher urchin density (quantified from six surveys between December 2007 and March 2009). Within each transect, the quadrats with the highest and third highest density of chitons (quantified from three surveys between December 2007 and March 2009) were assigned to removal treatments. The remaining two quadrats were not manipulated. The systematic method by which we targeted higher densities of grazers ensured that the treatments were meaningful (i.e., so that removal treatments were, on average, actually removing grazers), but not completely biased (i.e., control treatments did experience some grazing pressure). We acknowledge that our removal methods were unconventional, but they were meant to achieve a middle ground, between random and targeted entirely towards the highest densities. In principle, our methods are similar to removal (or addition) experiments that purposefully target areas of high grazer density for comparison with areas that lack grazers. Consequently, inferences drawn from the latter design (and our design) must be limited to situations in which there are high densities of grazers. Initial field experiments are often designed to determine if there is any potential effect at high (but relevant) population densities, before designing experiments that test the more subtle effects of lower densities. In the following paragraphs (see Analysis), we will highlight potential biases in our response variables that may have arisen due to our design.

Grazer removals began on 18 April 2009 and continued every two weeks until 24 January 2010. The density of urchins within two meters of the 2.5 m transects was quantified prior to their removal. Chiton density was quantified from photographs of quadrats (n= 10 during the experimental period) taken prior to their removal; quadrats were not photographed after each removal. Logistical difficulties associated with winter SCUBA diving in the San Juan Islands prevented the removal treatments from continuing through March, one year after the initial photographs. However, urchin densities were quantified in February 2010. Although experimental treatments were maintained actively for nine months, we considered the experimental period to be one year, from March 2009 to March 2010, and the recovery period to be from March 2010 to March 2011. We deemed this appropriate because these communities exhibit strong seasonality, and furthermore, we expected there to be a lag in the response of the sessile community to the experimental treatments. All of the fieldwork described in this study was conducted within the San Juan County and Cypress Island Marine Biological Preserve, Washington State with permission from the Director of the University of Washington Friday Harbor Laboratories.

Data Processing Description

Analysis

To quantify temporal variation in sessile community composition, we analyzed the percent cover in eleven photographs of each permanent quadrat taken between 29 March 2008 and 14 March 2011. The percent cover of sessile organisms was estimated visually from photographs, using a method developed by [29] and modified by [12]. Taxa were scored only if they were attached to rock or encrusting algae, i.e., epibiotic taxa do not occupy primary space and thus were not quantified. We defined available space as the substratum available for the recruitment and growth of macroalgae and sessile invertebrates [30], which included bare rock, calcified encrusting algae, and non-calcified encrusting algae. Encrusting algae are included in the definition of available space because there is very little bare rock in shallow hard-bottom subtidal habitats, and most invertebrates can overgrow coralline and non-calcified algal crusts [31]. In so doing we assumed that these algal crusts are functionally equivalent, in part for simplicity, but also because the extent to which various species of encrusting algae facilitate [32] or inhibit [33] the settlement of other sessile taxa is poorly understood in this community.

Linear mixed effects models and a model selection approach were used to address the effectiveness of experimental treatments and the primary hypotheses. First, we tested the effects of removal treatment on grazer densities (log-transformed) during the experimental period (March 2009 - March 2010). Second, we tested the effects of grazer removal on temporal variation in invertebrate and macroalgal cover during the experimental period. Third, we hypothesized that grazer removal would result in an increase in clonal ascidians and a concurrent decrease in the cover of available space.

We studied temporal variation in the sessile community before the experiment (28 March 2008-20 March 2009), during the experiment (21 March 2009 - 22 March 2010), and during one year of recovery after the experiment (23 March 2010 - 14 March 2011). Specifically, we quantified the percent cover of sessile invertebrates and macroalgae in quadrats. The comparison of sessile epifauna and macroalgae was of interest because urchins and chitons are studied most often in a macroalgal context [18,19], and because the abundance of these two sessile functional groups is strongly dependent on the orientation of the rock surface [36]. By targeting higher densities of grazers for removal, it could be argued that our approach led to a reduced chance of detecting a treatment effect in the absolute cover of invertebrates or macroalgae, and was thus a conservative design. This is because control quadrats and transects harbored fewer grazers to begin with, and thus the average difference in grazing pressure between control and removal treatments was lower than if replicates for removal had been selected at random. We compared the set of 19 nested, ecologically relevant models for the data collected during the experiment (March 2009-March 2010). All models included site, transect and quadrat as random effects; quadrat at a specific time point was the unit of replication in this analysis. The fixed effects varied between the models, and these details are listed for each model description (Tables 1, 2, S1 and S2). In all models, time was treated as a categorical factor because the dependent variables (e.g., grazer density, percent cover) were not expected to vary linearly through time (for example, due to seasonality). The percent cover of sessile invertebrates was not transformed, but we used a logit transformation for algal cover to correct the nonlinearity observed in a diagnostic plot of residuals against fitted values.

To address the hypothesis that the removal of grazers would change the cover of clonal ascidians and concurrently affect the amount of available space, we quantified annual changes in these functional groups during (March 2009 - March 2010; experiment) and after (March 2010 - March 2011; recovery) the experimental treatment. By targeting higher densities of grazers for removal, we would expect a larger relative change in the benthic community and in this case our experimental approach is biased towards the detection of an effect. All statistical models included site and transect as random effects; quadrat was the unit of replication in this analysis.

Model fit based on maximum likelihood scores was compared using the small sample unbiased Akaike information criteria (AICc), a metric that considers both model fit and complexity (i.e., number of parameters, K). The difference in AICc (Di) between each model and the best model (i.e., lowest AICc) was calculated to emphasize the most plausible models given the data (Di ,2). Finally, Akaike weight (wi), or the relative likelihood of each model, was obtained by normalizing the likelihood across the entire set of candidate models. Details on model selection are provided in Burnham and Anderson [34] and Johnson and Omland [35]. Residuals were inspected visually for normality and homoscedasticity. When necessary, dependent variables were log or logit transformed. Maximum likelihood was used to estimate parameters in all mixed effects models. Statistical analyses were conducted using the packages 'lme4' [37] and 'vegan' [38] in R 2.14 [39]. Data used in this manuscript are publicly available as Dataset S1.

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Data Files

File
ascid_space.csv (Comma Separated Values (.csv), 5.21 KB) MD5:b404f139346bfe30e047efdb0bfd7aa3 Primary data file for dataset ID 472901

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Related Publications

Bates, D., Maechler, M., & Bolker, B. (2013). lme4: Linear mixed-effects models using S4 classes. R package version 0.999999-2.
Software

Elahi, R., & Sebens, K. P. (2013). Experimental Removal and Recovery of Subtidal Grazers Highlights the Importance of Functional Redundancy and Temporal Context. PLoS ONE, 8(11), e78969.

https://doi.org/10.1371/journal.pone.0078969
Results

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Parameters

Parameter	Description	Units
site	site names	unitless
transect	transect names	unitless
quadrat	quadrat name	unitless
tmt_urchin	urchin removal treatment	unitless
tmt_chitin	chitin removal treatment	unitless
cover_space_dur	the change in percent cover of available space during the experiment (March 2009 - March 2010)	percent
cover_space_aft	the change in percent cover of available space during the recovery (March 2010- March 2011)	percent
cover_ascid_dur	the change in percent cover of ascidians during the experiment (March 2009 - March 2010)	percent
cover_ascid_aft	the change in percent cover of ascidians during the recovery (March 2010- March 2011)	percent

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Deployments

Sebens_lab

Website	https://www.bco-dmo.org/deployment/472912
Platform	Friday_Harbor
Start Date	2008-03-27
End Date	2011-03-14
Description	Predator removal from Marine Protected Areas in Puget Soudn, by SCUBA.

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Project Information

Effects of Marine Preserves on Rocky Subtidal Communities (Subtidal Preserves)

Website: http://depts.washington.edu/fhl/wx.html

Coverage: San Juan Island, Washington. Rocky subtidal habitats

Subtidal communities in temperate geographic zones of the world are faced with changes caused by fishing, climate change, habitat alteration and invasive species, yet we know fairly little about their community dynamics. The loss of large predators (species removals), and the introduction of nonindigenous species (species additions), are likely to have immediate and large consequences for the structure, resilience and function of subtidal communities. Marine preserves have recently been established in many coastal locations, including the San Juan Archipelago of Washington State. While they are demonstrated to have positive effects on certain fish populations, effects on the rest of the subtidal community are generally not known. The benefit of marine preserves to fisheries remains to be determined on a case-by-case basis. Regardless of the benefit to fisheries, they can serve effectively as conservation zones, similar to terrestrial parks, where original species assemblages can recover in the absence of human extraction. They also provide excellent venues to study the effects of large predators in relatively intact communities, in comparison to nearby non-preserve locations.

With goals such as maintaining or increasing biodiversity, it is important to understand how the protection of large predators influences small prey and non-prey species. Determining the ecological effects of fish extraction is of prime interest in the growing body of marine protected area science. Higher level predators can decrease the abundance of their prey, but can also indirectly increase the abundance of organisms two trophic levels beneath them through a trophic cascade. Additionally, non-trophic interactions may cause species abundances to change in unpredicted ways after the recovery of large predators. The investigators in this project will explore the interaction of invasive ascidian species in the Puget Sound region, including sites where they have invaded successfully and sites where they have not. Much of this research will be conducted in (and out of) a regional network of MPAs in San Juan Co., WA, with a focus on the rocky subtidal community on these shores.

The significance of this research applies to any nearshore temperate ecosystem with rocky substrate; thus it has broad ecological relevance, particularly with regard to management of coastal ecosystems. Coastal communities are changing due to extraction, invasive species, and climate change, yet we know little about these effects in the shallow rocky subtidal zone.

The FHL Research Apprenticeship Program is a successful vehicle to provide intensive research experiences to undergraduates, and it motivates many to pursue graduate and professional training. There will also be an opportunity for summer FHL Blinks Fellows (undergraduate researchers of diverse background) and REU students to work on this project. FHL research, including that done by students, also supports citizen-driven conservation priorities. A primary connection is through the San Juan County Marine Resources Committee (MRC). This research will also provide training for several graduate and undergraduate students in current techniques in subtidal ecological research and advanced SCUBA based research and operations. They will also be encouraged to take part in FHL K-12 Outreach activities, and the new GK-12 Program at FHL (and Seattle).

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0850809

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