Sitka Sound Kelp Wet Weights

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Project
» CAREER: Energy fluxes and community stability in a dynamic, high-latitude kelp ecosystem (High latitude kelp dynamics)

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Abstract
While the recently decimated predatory sea star, Pycnopodia helianthoides, may support kelp forests by consuming herbivorous sea urchins, less is known about their non-consumptive effects. We conducted a field experiment in three replicate sea urchin barrens in Sitka Sound, AK in February of 2023, where we deployed pre-weighed Macrocystis pyrifera blades at discrete distances on four metre radial cables from caged adult P. helianthoides and control cages and reweighed after 24 hours. Our results suggest the chemical cue of P. helianthoides elicits a localised, species-specific landscape of fear of approximately 15m2 that suppresses grazing, and that the non-consumptive effects of P. helianthoides on sea urchin behaviour may be important for kelp restoration.

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Coverage

Location: Sitka Sound, Alaska, USA (57.033762 N, 135.264282 W) depth 6-9m
Spatial Extent: **N**:57.036 **E**:-135.255 **S**:57.033 **W**:-135.28
Temporal Extent: 2023-02-13 - 2023-02-20

Methods & Sampling

Experiment

To test whether and at what distance the presence of *Pycnopodia* can reduce prey densities or suppress grazing on kelp, we performed an underwater caging experiment at three urchin barren sites approximately six km east of Sitka in February 2023: Ellsworth Cut (57.036, -135.280), Harris Island (57.033, -135.277), and Whale Park (57.033, -135.255). Each experimental array consisted of a central cage with four 4 m long radial transect lines (Figure 1). We constructed cages (30 x 30 x 15 cm; l x w x h) using a PVC frame covered in ~1cm Vexar mesh fastened with zip ties that could be opened underwater to add a *Pycnopodia*. We attached a 4m long lead line to each corner of the cage, forming a plus pattern (Figure 1). We simultaneously deployed four of these arrays at each site in two blocks. In each block, one cage served as an experimental treatment (with a *Pycnopodia*) and the second cage served as a control (an empty cage). We placed all arrays in areas with high sea urchin density, hard rocky substrate, and low rugosity, and the cages within a block were ~20-30 m apart.

The experiment began when we sealed a *Pycnopodia* (9.5-19.5 cm radius, lab acclimated for >2 weeks) into the experimental treatment cage and the control cage was sealed with a dive weight. To each lead line of all cages, we attached a yellow nylon "kelp line" with 1 m distances demarcated by tape (Figure 1). Kelp lines consisted of pre-weighed, individually labeled *Macrocystis pyrifera* blades at regular intervals (metre marks: 0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.75, 3.75) woven into the nylon line. *M. pyrifera* blades were harvested from surface canopies over 1 mile away from closest experimental urchin barren sites and held in recirculating seawater for no more than a week before deployment. After the 24 hours, we removed the arrays and kelp lines and re-weighed each individual kelp blade in the lab to calculate any change in wet mass.

Analyses

We assessed the main and interactive effects of *Pycnopodia* treatment and continuous distance from the cage on the percent of kelp biomass lost over 24 hours using a mixed effects hierarchical linear model, fit using the lmer() function in the lme4 package in R. We included site, block (nested within site), and array (nested within site, and block, and treatment), and transect (nested within site and array) as random factors.

We then calculated the net effect of the sea star at 24 hours on kelp abundance as the difference in the average percent of kelp remaining, respectively, in the sea star treatment minus its paired control treatment (i.e., the differences between treatments in each block). In other words, for each block and at a given distance from the cage at 24 hours we calculated: [avg. percent remaining in sea star treatments at each distance - avg. percent remaining in paired control treatments at each distance]. We tested the main and interactive effects of continuous distance from the cage and kelp on the net sea star effect using a linear model (lm()) in base R. We originally performed a model that included site, block and array as random factors matching the model construction as above, but were forced to simplify the model to avoid singularity errors. We then ran follow-up, individual linear fits (lm()) for each species separately to obtain the equation for each line (i.e., net effect = intercept + (slope * distance from cage)). Finally, we calculated the radius of the 'halo of influence' of the sea star by setting the net effect to zero and solving for the distance to the cage (i.e., the distance at which the sea star effect was no longer detectable). We calculated the area of influence using pie*(radius2), with the radius being defined as the distance from the cage statistic solved from the previous equation. This gives us an approximate measure of how far from an inactive sea star we can expect grazing to be suppressed for at least 24 hours, even when kelp is present in an urchin barren.

BCO-DMO Processing Description

- Spaces in column/parameter names in data file replaced with underscores ("_")

Problem Description

Some kelp weights unexpectedly increased after 24 hours, likely due to mucus development from handling. Reasonable mass increases between 3-20% labeled with a QC flag of 2, increases >20% labeled with a QC flag of 3. These quality flags correspond with the Geotraces Quality Flag Policy.

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Parameters

Parameter	Description	Units

RayID	Identity of individual ray: Site_treatment_replicate_ray, Pyc=Pycnopodia, Con=control.	unitless
Site	Urchin barren site name.	unitless
Lat	Latitude in decimal degrees; a positive value indicates a Northern coordinate.	decimal degrees
Long	Longitude in decimal degrees; a negative value indicates a Western coordinate.	decimal degrees
Treatment	Treatment (Pycnopodia in cage) or control (empty cage).	unitless
RepID	Block within a site where there is one treatment (P) and one control (c) paired.	unitless
Replicate	Paired spatial blocks either 1 or 2.	unitless
TreatRep	Treatment (P=Pycnopodia, C=control) and RepID (block #).	unitless
Date	YYYY-MM-DD, AKST (Alaska Standard Time), UTC -9.	unitless
TimeElapsed_hr	Time between deployment and retrieval of kelp blades.	hours
Ray	Direction of 4m transect line with attached kelp running off of cage (1-4).	unitless
Track	Identity of each individual ray or line: site_treatmentblock_ray#.	unitless
Color	Marker of distance at each kelp attachment site.	unitless
Dist_m	Fixed distance of kelp blade from the cage.	meters (m)
KelpStartWt_g	Initial wet weight of kelp blade before deployment around cages.	grams (g)
AttachedKelpEndWt_g	Wet weight after 24 hours of blade still attached to kelp line.	grams (g)
DriftKelpEndWt_g	Wet weight of drift kelp that was observed disconnecting from an individual, identifiable blade.	grams (g)
Total_KelpEndWt_g	Final wet weight after 24 hours, including attached and drift kelp.	grams (g)

KelpChgWt_g	Change in wet weight over 24 hours, [Total KelpEndWt_g - KelpStartWt_g].	grams (g)
KelpGrazed_g	Kelp lost or grazed in experiment, negative values show an increase of weight likely due to mucus development.	grams (g)
PercentKelpGrazed	Percent of initial kelp wet weight grazed or lost, [(KelpGrazed_g/KelpStartWt_g)*100].	unitless
Flags	Quality flags, see definitions within Geotraces quality flag policy documentation.	unitless

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Project Information

CAREER: Energy fluxes and community stability in a dynamic, high-latitude kelp ecosystem (High latitude kelp dynamics)

Coverage: SE Alaskan coastal waters

NSF Award Abstract:
High latitude kelp forests support a wealth of ecologically and economically important species, buffer coastlines from high-energy storms, and play a critical role in the marine carbon cycle by sequestering and storing large amounts of carbon. Understanding how energy fluxes and consumer-resource interactions vary in these kelp communities is critical for defining robust management strategies that help maintain these valuable ecosystem services. In this integrated research and education program, the project team will investigate how consumer populations respond to variability in temperature, carbonate chemistry and resource quality to influence the food webs and ecosystem stability of kelp forests. A comprehensive suite of studies conducted at the northern range limit for giant kelp (Macrocystis pyrifera) in SE Alaska will examine how kelp communities respond to variable environmental conditions arising from seasonal variability and changing ocean temperature and acidification conditions. As part of this project, undergraduate and high school students will receive comprehensive training through (1) an immersive field-based class in Sitka Sound, Alaska, (2) intensive, mentored research internships, and (3) experiential training in science communication and public outreach that will include a variety of opportunities to disseminate research findings through podcasts, public lectures and radio broadcasts.

Consumer-resource interactions structure food webs and govern ecosystem stability, yet our understanding of how these important interactions may change under future climatic conditions is hampered by the complexity of direct and indirect effects of multiple stressors within and between trophic levels. For example, environmentally mediated changes in nutritional quality and chemical deterrence of primary producers have the potential to alter herbivory rates and energy fluxes between primary producers and consumers, with implications for ecosystem stability. Moreover, the effects of global change on primary producers are likely to depend on other limiting resources, such as light and nutrients, which vary seasonally in dynamic, temperate and high latitude ecosystems. In marine ecosystems at high latitude, climate models predict that ocean acidification will be most pronounced during the winter months, when primary production is limited by light. This project is built around the hypothesis that there could be a mismatch in the energetic demands of primary consumers caused by warming and ocean acidification and resource availability and quality during winter months, with cascading effects on trophic structure and ecosystem stability in the future. Through complementary lab and field experiments, the project team will determine 1) how temperature and carbonate chemistry combine to affect primary consumer bioenergetics across a diversity of species and 2) the indirect effects of ocean acidification and warming on primary consumers via environmentally mediated changes in the availability, nutritional quality and palatability of primary producers across seasons. Using the data from the laboratory and field experiments, the project team will 3) construct a model of the emergent effects of warming and ocean acidification on trophic structure and ecosystem stability in seasonally dynamic, high latitude environments.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1752600

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