Water column nutrient data from a 4 year experiment (2018-2022) manipulating consumer pressure and nutrient availability on a coral reef in Moorea, French Polynesia

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Data Type: Other Field Results, experimental
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Project
» Collaborative Research: Tipping points in coral reefs and their associated microbiomes: interactive effects of herbivory, nutrient enrichment, and temperature (RECHARGE)

Contributors	Affiliation	Role
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Abstract
Here we experimentally test the relative importance of alterations to top-down and bottom-up processes in driving community development and variability after a simulated disturbance on a coral reef. We use a factorial experiment manipulating consumer pressure and nutrient enrichment for four years on a coral reef in Moorea, French Polynesia. Our experiment consisted of plots (~1.25 m2 each) that manipulated access by consumers via different size openings that allowed different size fishes access to the benthos, creating four levels of consumer pressure (Very Low, Low, Medium, High). These four levels of consumer pressure were crossed with manipulations of nutrient availability with either ambient or nutrient enriched conditions. At the start of the experiment, we removed all live corals and fleshy macroalgae from the plots to mimic the effects of a severe cyclone. We quantified the abundance of benthic organisms (e.g., corals, macroalgae, etc.) for four years to assess how experimental treatments affected community development. At three time points each year (April, July/August, November - except for two time points missed due to the COVID-19 pandemic, April 2020 and November 2020), we quantified benthic cover in each exclosure via point contacts on orthorectified photomosaics.   To evaluate the effectiveness of our nutrient treatment, we collected water samples using 50-ml syringes ~3cm above the benthos in each of our High consumer pressure exclosures (i.e., our open 1.25m2 exclosures). We collected water samples in 2021 and 2022 across a range of days after we swapped the nutrient diffusers (4-158 days). We filtered samples (GF/F) into falcon tubes, placed on ice and once back in the lab frozen until analysis. We analyzed inorganic nitrogen (nitrite + nitrate) and soluble reactive phosphorus concentrations using an autoanalyzer at the Marine Science Institute Analytical Laboratory at the University of California, Santa Barbara. For both nitrite + nitrate and phosphate, we averaged across time and our High consumer pressure exclosures to evaluate the average nutrient conditions in our experimental treatments.

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Coverage

Location: Moorea, French Polynesia 17.47° S, 149.82° W

Spatial Extent: **Lat**:-17.47 **Lon**:-149.82
Temporal Extent: 2018-08-01 - 2022-08-01

Methods & Sampling

Experimental Setup

In June 2018, we established a factorial experiment manipulating consumer pressure and nutrient availability in areas that mimicked disturbance from a cyclone. At 12m depth on the north shore forereef of Moorea, French Polynesia (17.47° S, 149.82° W) we established 16 ~30m^2 plots. Within each plot, we then nested 4 different consumer exclosures (~1.25 m^2 each) with different size openings that allowed different size fishes (herbivores and corallivores, hereafter referred to as 'consumers') access to the benthos . The exclosure frames consisted of 0.5cm stainless steel all-thread drilled into the reef matrix and epoxied into place. These frames were then wrapped with plastic-coated, galvanized wire to create the following levels of consumer pressure: 1) Very Low (2.5cm × 2.5cm openings); 2) Low (5cm × 5cm openings); 3) Medium (7.5cm × 7.5cm openings); 4) High (4 sides of 2.5cm × 2.5cm openings but no top). Others have used a similar design to create a gradient of consumer pressure to mimic the effects of different levels of fishing (Holbrook et al. 2016, Schmitt et al. 2019). We included sides, but not tops, on the High consumer pressure treatment to control for potential artifacts on water flow, although we have shown these are minimal (Zaneveld et al. 2016). Exclosures were scrubbed every 12-16 weeks to remove fouling organisms.

We also included a second treatment of Ambient or Enriched nutrient conditons with each plot (which included four nested consumer exclosures) was then assigned to either Ambient or Enriched nutrient conditions. Thus, each combination of consumer pressure (Very Low, Low, Medium, High) and nutrients (Ambient or Enriched) had n=4 for replication. For the enrichment we placed 175 g of Osmocote® (19-6-12, N-P-K) slow-release garden fertilizer into 5 cm diameter PVC tubes with 10, 1 cm holes drilled into them. These tubes were wrapped in fine plastic mesh to retain the fertilizer. This method is similar to our previous work (e.g., Zaneveld et al. 2016). PVC enrichment tubes were attached to the corners of each exclosure and onto a piece of stainless steel all-thread in the center of each plot (5 enrichment tubes per exclosure). We replaced enrichment tubes every 12-16 weeks except for two periods during the COVID-19 pandemic when travel to Moorea was not possible and enrichment tubes were deployed for longer than usual before replacement (deployed from 01-30-2020 to 08-31-2020, and from 08-31-2020 to 02-08-2021). We analyzed water samples from the experimental plots to evaluate the effect of nutrient enrichment.

Data Collection

To evaluate the effectiveness of our nutrient treatment, we collected water samples using 50-ml syringes ~3cm above the benthos in each of our High consumer pressure exclosures only (i.e., our open 1.25m^2 exclosures). We collected water samples in 2021 and 2022 across a range of days after we swapped the nutrient diffusers (4-158 days). We filtered samples (GF/F) into falcon tubes, placed on ice and once back in the lab frozen until analysis. We analyzed inorganic nitrogen (nitrite + nitrate) and soluble reactive phosphorus concentrations using an autoanalyzer at the Marine Science Institute Analytical Laboratory at the University of California, Santa Barbara.

Data Processing Description

For both nitrite + nitrate and phosphate, we averaged across time and our High consumer pressure exclosures to evaluate the average nutrient conditions in our experimental treatments. For comparisions, it is most useful to compare Ambient vs. Enriched values within a date of sampling as this allows you to address the effectiveness of the nutrient enrichment treatment. The concentration of dissolved inorganic nitrogen was calculated (nitrate+nitrite+ammonium).

BCO-DMO Processing Description

- Loaded water_nutrients.csv as table "water_nutrients", treating empty strings and "nd" as missing values
- Converted Date_taken from M/D/YY format (e.g., 2/7/21) to ISO 8601 date format (%Y-%m-%d)
- Output written to 1000890_v1_water_nutrients.csv

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Related Publications

Holbrook, S. J., Schmitt, R. J., Adam, T. C., & Brooks, A. J. (2016). Coral Reef Resilience, Tipping Points and the Strength of Herbivory. Scientific Reports, 6(1). https://doi.org/10.1038/srep35817
Methods

Schmitt, R. J., Holbrook, S. J., Davis, S. L., Brooks, A. J., & Adam, T. C. (2019). Experimental support for alternative attractors on coral reefs. Proceedings of the National Academy of Sciences, 116(10), 4372–4381. https://doi.org/10.1073/pnas.1812412116
Methods

Zaneveld, J. R., Burkepile, D. E., Shantz, A. A., Pritchard, C. E., McMinds, R., Payet, J. P., ... Thurber, R. V. (2016). Overfishing and nutrient pollution interact with temperature to disrupt coral reefs down to microbial scales. Nature Communications, 7(1). doi:10.1038/ncomms11833
Methods

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Parameters

Parameter	Description	Units
Block_plot	Experiment was arranged in 4 blocks - A, B, C, D with four plots 1, 2, 3, or 4 within each block; Block_plot is a combination of block and plot - e.g. Block A plot 1 would be 'A1'	unitless
Nutrient_TRT	Plots with either ambient or enriched nutrients	unitless
Date_taken	Date on which sample was taken	unitless
Days_since_nutrient_swap	Days since the previous nutrients had been replaced	Days
Sample_period	Period of the experiment when samples were taken	unitless
Phosphate	Concentration of soluble reactive phosphorus	micromolar (uM)
Nitrite_plus_Nitrate	Concentration of nitrate+nitrite	micromolar (uM)
Ammonium	Concentration of ammonium	micromolar (uM)
DIN	Concentration of dissolved inorganic nitrogen (nitrate+nitrite+ammonium)	micromolar (uM)

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Manual Biota Sampler
Dataset-specific Description	To evaluate the effectiveness of our nutrient treatment, we collected water samples using 50-ml syringes ~3cm above the benthos in each of our High consumer pressure exclosures only (i.e., our open 1.25m2 exclosures).
Generic Instrument Description	"Manual Biota Sampler" indicates that a sample was collected in situ by a person, possibly using a hand-held collection device such as a jar, a net, or their hands. This term could also refer to a simple tool like a hammer, saw, or other hand-held tool.

Dataset-specific Instrument Name	Seal Analytical AA500
Generic Instrument Name	Nutrient Autoanalyzer
Dataset-specific Description	We analyzed inorganic nitrogen (nitrite + nitrate) and soluble reactive phosphorus concentrations using an autoanalyzer at the Marine Science Institute Analytical Laboratory at the University of California, Santa Barbara. Seal Analytical AA500 is a high-throughput, automated segmented flow analyzer (SFA) designed for environmental, industrial, and agricultural testing, running over 700 documented EPA, ISO, and ASTM methods.
Generic Instrument Description	Nutrient Autoanalyzer is a generic term used when specific type, make and model were not specified. In general, a Nutrient Autoanalyzer is an automated flow-thru system for doing nutrient analysis (nitrate, ammonium, orthophosphate, and silicate) on seawater samples.

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Project Information

Collaborative Research: Tipping points in coral reefs and their associated microbiomes: interactive effects of herbivory, nutrient enrichment, and temperature (RECHARGE)

Coverage: Mo’orea, French Polynesia

NSF Award Abstract:
Coral reefs are some of the most diverse, yet most imperiled, ecosystems on the planet. Global change has driven the decline of corals worldwide with many reefs now lacking corals and being overrun by macroalgae. This research examines the impacts of several factors of thermal stress, overfishing of important herbivorous fishes, and nutrient pollution on the health of corals and their ability to recover after large coral-killing disturbances. Importantly, the investigators address the impacts of global change on the coral microbiome, the microbes that associate with corals and impact coral health. The overarching hypothesis is that factors such as overfishing and nutrient pollution impact coral health via impacts to their microbes. This 6-year experiment on the coral reefs of Mo’orea, French Polynesia examines what levels of herbivory, mostly by parrotfishes and surgeonfishes, are needed to provide resistance and resilience of corals and their microbiomes when reefs are exposed to elevated nutrients and ocean temperatures. Notably, the team tests how local stressors (overfishing, nutrient pollution) potentially interact with global stressors (climate change and rising ocean temperatures) to impact coral reef health. This research may yield insight into how to manage local factors (reducing fishing, mitigating nutrient pollution) to help corals survive the global stress of climate change. The field experiment provides a realistic platform to test questions about how local management of fisheries can alter reef health and provides data about the recoverability of reefs should new water quality management be put into place. This interdisciplinary work trains a new generation of both marine ecologists

and microbiologists, including one postdoctoral researcher, two graduate students, as well as numerous undergraduates. The main international outreach effort is to map the microbiome of the island of Mo’orea. Mo’orea is approximately 130 square-kilometers in area and has five major watersheds that transport sediment and nutrients to the nearshore coral reef ecosystems. Thus poor stewardship of these watersheds likely contributes to the local phase shifts currently occurring in several areas of the lagoon. Therefore the team has engaged the local community to help collect microbiome samples from 50 terrestrial, 50 stream, 25 coastal sites, and 25 offshore sites around the island. The sampling effort is generating an island-wide map of the microbial communities associated with the soils, streams, and coastal waters that can be linked to adjacent coral reef health - The Moorea Microbiome! As part of this outreach effort, the team also collaborates with filmmakers to make a trilingual (English, French, and Tahitian) film about the project to serve as local engagement and teaching tool to help educate school groups and different stakeholders about both the seen and unseen connections between land and sea on their island.

On the island of Mo’orea, French Polynesia, coral communities have exhibited strikingly different trajectories, with some reefs recovering from disturbances and others undergoing protracted coral decline, accompanied by an increase in macroalgae. This diversity in coral community dynamics makes Mo’orea an excellent model system for testing why some reefs are resilient and return to abundant coral while others are not and undergo persistent phase shifts to macroalgal dominance. This 6-year experiment will measure the dynamics of benthic communities, coral demography, and the coral microbiome across seasonal change in ocean temperature, allowing the team to (1) link changes in coral microbiomes (e.g., a rise in pathogenic bacteria) to the trajectories of coral decline or recovery and (2) link nutrients, herbivory, and temperature to phase shifts in both benthic communities and coral microbiomes. Importantly, the team is testing the resistance of phase shifts of benthic communities and coral microbiomes by measuring their changes after removing the nutrient enrichment treatment at the end of year 3 and tracking recovery of the system for 3 more years. Thus, this project begins to answer whether reef and microbial community phase shifts can be easily reversed once they occur. Many studies have focused on the factors that disassemble coral reef communities, but this is the first to examine how reef communities can be reassembled from the microbiome upwards.

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-2023701
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023424

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