Fish abundance for 4 year experiment (2018-2022) manipulating consumer pressure and nutrient availability on a coral reef in Moorea, French Polynesia

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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. To evaluate the effectiveness of our cages at excluding fishes, we conducted visual surveys of our experimental plots. We conducted a five minute in situ survey on each exclosure for each time point between 2018 and 2022. Each survey recorded the size and species of all fishes that were present or entered the cage during the survey. We converted the counts of fishes to biomass using length-weight relationships as used by the Moorea Coral Reef LTER time series data.

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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 (1inx1in) openings); 2) Low (5cm × 5cm (2inx2in) openings); 3) Medium (7.5cm × 7.5cm (3inx3in) openings); 4) High (4 sides of 2.5cm × 2.5cm (1inx1in) 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.

Within the exclosures we effected a second treatment in order to simulated the effects of a cyclone. To do so, we removed all branching corals (mostly *Acropora* spp. and *Pocillopora* spp.) and transplanted them to other areas of the reef away from the experiment. The removal of branching corals simulated a pulse disturbance such as the cyclone that reduced coral cover to < 5% on the forereefs of Moorea in 2010. Remaining patches of encrusting corals (mostly *Montipora* spp.) and mounding corals (mostly *Porites* spp.) and macroalgae (which were rare) were scrubbed with wire brushes to mimic the scouring from sediments that occurs during a large cyclone. Thus, after coral and macroalgae removal, mean coral cover in the plots was ~7% and macroalgae was ~0.5%. These treatments were called 'Disturbed' as opposed to plots where we did not remove corals that are referred to as 'Intact'.

We also included a third 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.

The treatments were arranged as in this example:

Plot A1 was Intact (coral remained) with Ambient nutrients and contained one replicate of each of the exclosure treatments (Very Low, Low, Medium, and High consumer pressure).

Plot A2 was Intact (coral remained) with Enrichned nutrients and contained one replicate of each of the exclosure treatments (Very Low, Low, Medium, and High consumer pressure).

Plot A3 was Disturbed (coral removed) with Enrichned nutrients and contained one replicate of each of the exclosure treatments (Very Low, Low, Medium, and High consumer pressure).

Plot A4 was Disturbed (coral removed) with Ambirnet nutrients and contained one replicate of each of the exclosure treatments (Very Low, Low, Medium, and High consumer pressure).

n=4 for each disturbance-nutrient-consumer pressure combination e.g., - Intact/Enriched/High consumer pressure; Disturbed/Ambient/Very Low consumer pressure etc.

Data Collection

To evaluate the effectiveness of our exclosures at excluding fishes, we conducted visual surveys of our experimental plots. We conducted a five minute in situ survey on each exclosure for each time point between 2018 and 2022. For each survey, we identified each individual fish that was present or entered the exclosure during the survey to species and estimated their total length to the nearest centimeter. We converted the counts of fishes to biomass using length-weight relationships as used by the Moorea Coral Reef LTER time series data (Moorea Coral Reef LTER 2026).

Data Processing Description

We converted the counts of fishes to biomass using length-weight relationships as used by the Moorea Coral Reef LTER time series data.

Moorea Coral Reef LTER, A. Brooks, and T. Adam. 2026. MCR LTER: Reference: Fish Taxonomy, Trophic Groups and Morphometry ver 7. Environmental Data Initiative. https://doi.org/10.6073/pasta/44ad62f4757072a915fac1500351b7b7 (Accessed 2026-05-07).

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Related Publications

Beijbom, O., Edmunds, P. J., Roelfsema, C., Smith, J., Kline, D. I., Neal, B. P., Dunlap, M. J., Moriarty, V., Fan, T.-Y., Tan, C.-J., Chan, S., Treibitz, T., Gamst, A., Mitchell, B. G., & Kriegman, D. (2015). Towards Automated Annotation of Benthic Survey Images: Variability of Human Experts and Operational Modes of Automation. PLOS ONE, 10(7), e0130312. https://doi.org/10.1371/journal.pone.0130312
Methods

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

Moorea Coral Reef LTER, Brooks, A., & Adam, T. (2026). *MCR LTER: Reference: Fish Taxonomy, Trophic Groups and Morphometry* [Dataset]. Environmental Data Initiative. https://doi.org/10.6073/PASTA/44AD62F4757072A915FAC1500351B7B7
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

Parameters for this dataset have not yet been identified

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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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