Impacts of turf-coral interactions from allelopathy experiments in Mo'orea, French Polynesia during austral summer (Mar 2022) and austral winter (Sep 2022)

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Data Type: Other Field Results, experimental
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Project
» Positive Effects of Coral Biodiversity on Coral Performance: Patterns, Processes, and Dynamics (Coral Biodiversity)

Contributors	Affiliation	Role
Hay, Mark E.	Georgia Institute of Technology (GA Tech)	Principal Investigator
Stewart, Frank James	Montana State University	Co-Principal Investigator
Pratte, Zoe	Montana State University	Scientist
Altman-Kurosaki, Noam T	Georgia Institute of Technology (GA Tech)	Student
Gerlach, Dana Stuart	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
We evaluated turf-coral interactions and their impacts relative to those of macroalgae by placing corals (Acropora pulchra and Porites rus) in contact with turf communities from territories of two species of damselfishes, with two common macroalgae, and with inert algal mimics as physical controls. After 13 days, turfs reduced coral photosynthesis by 31–59%, while macroalgae and mimics had minimal effects. After 24 hours of contact, chemicals from turf surfaces suppressed coral photosynthesis, affecting A. pulchra more strongly than P. rus. The experiment was repeated during the austral winter using freshly collected turf and also turf that had been collected for the austral summer experiment and kept frozen. Measurements and observations indicate that the significant allelopathic effects observed during the austral summer experiment were undetectable during the austral winter experiment.

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Coverage

Location: Mo‘orea, French Polynesia (17°29’18.6”S 149°52’53.9”W), < 3m depth
Spatial Extent: **Lat**:-17.4885 **Lon**:-149.881639
Temporal Extent: 2022-03-07 - 2022-09-11

Dataset Description

This dataset is part of a larger study of the coral reef ecosystem in Mo’orea, French Polynesia that examines mechanisms governing interactions between damselfish, corals, and turf algae. The different analyses from the broader study are listed here, with links to these associated data in the 'Related Datasets' section below.

Analyses undertaken include:

- Fertilizer impacts on damselfish behavior (*Damselfish video dataset 949539)*
- Fertilizer impacts on biomass plus isotopic composition of algal turfs (*Damselfish turf biomass dataset 9xxxxx)*
- Fertilizer impacts on coral predation and herbivory (*Corallivory dataset 9xxxxxx, Herbivory dataset 9xxxxx)*
- Impacts of fertilizer and caging on coral and algal growth (*Coral growth dataset 9xxxxx, Algal overgrowth dataset 9xxxxxx)*
- Coral-turf allelopathy (***this dataset of turf extracts PAM data***, *Coral-algal contact dataset 9xxxxxx)*
- Species composition of turf gardens (*dataset 949552 + supplemental for Coral Reefs paper)*

Organism identifiers for taxonomic names within this dataset:
Scientific name, LSID (Life Science Identifier)
Stegastes nigricans, urn:lsid:marinespecies.org:taxname:218849
Stegastes punctatus, urn:lsid:marinespecies.org:taxname:712757
Acropora pulchra, urn:lsid:marinespecies.org:taxname:207015
Porites rus, urn:lsid:marinespecies.org:taxname:207231
Sargassum pacificum, ????? urn:lsid:marinespecies.org:taxname:495052 or three others
Amansia rhodantha,

Methods & Sampling

We utilized turfs from territories of *Stegastes nigricans* and *Stegastes punctatus* to assess: i) turf effects on corals, ii) differential impacts based on turf species composition, and iii) variance in effects on the coral *Acropora pulchra* versus *Porites rus*. Species composition of turfs in territories of *S. nigricans* versus *S. punctatus* was assessed by collecting turf haphazardly from territories (n = 12) of each damselfish species spread across an approximately 0.07 km^2 region in both March and September 2022. Samples from *S. nigricans* territories were collected using a 1.3 cm grommet punch and from *S. punctatus* territories by cutting a similarly sized area from territories on *A. pulchra* bases. Turfs were stored in 4% formalin in seawater, and species composition quantified following methods of Diaz-Pulido and McCook (2002). See Related Datasets section below for dataset 949552 on turf cover species composition.

In March 2022 (mean water temp = 28.6°C; Leichter et al. 2023), we tested the impacts of the macroalgae *Sargassum pacificum* and *Amansia rhodantha*, turfs from *S. nigricans* or *S. punctatus* territories, plastic macroalgal mimics, turf mimics, and no contact controls on the common corals *A. pulchra* and *P. rus* (n = 12 for each coral x treatment). Macroalgae were chosen due to their high abundance and differing impacts on corals (Rasher and Hay 2010; Longo and Hay 2017; Clements et al. 2020).

For our assays, seven 6 to 8 cm length coral fragments were collected from 12 individuals of both *A. pulchra* and *P. rus* in the study area. The fragments were attached with epoxy into the cut-off necks of plastic bottles (Z-spar Splash Zone Compound, Kopcoat, Pittsburgh, Pennsylvania, USA – see Clements et al. 2020), and attached to inverted bottle caps secured to a metal rack ~20 cm above the substrate to limit abrasion from sediments (Figure S1, Altman-Kurosaki et al., 2024). Treatments were assigned using a randomized block design such that each block (coral colony) had one algal treatment affixed to a different fragment from that colony, thus minimizing potential variance associated with individual colonies.

Algal treatments and mimics were applied to corals by zip-tying algae or controls directly to the corals. Turf treatments from *S. nigricans* and *S. punctatus* territories consisted of ~1.3 cm^2 pieces of substrate with natural turfs attached. Turf mimics (controls for effects of substrate) were substrates of similar size, sterilized in bleach, rinsed thoroughly with filtered seawater, and dried at 60°C for three days prior to use in the field. Macroalgal treatments were thalli ~6 cm in length while controls for the physical presence alone were similar sized plastic aquarium plants resembling *Sargassum*. After 13 days, treatment effects on corals were assessed via *in situ* pulse-amplitude-modulated (PAM) fluorometry directly at the site of coral-algal contact. PAM fluorometry quantifies the photosynthetic efficiency of coral endosymbionts (Y, or effective quantum yield) which is a correlate of coral fitness. PAM readings were conducted between 0900–1400 hours and were blocked in time, with each block consisting of a random replicate from each coral x algal treatment, and with readings for each coral x algal treatment within a block randomly interspersed through time. Readings took two days, with half of the blocks being assessed each day. PAM fluorometer readings did not show any significant differences based on the date of assessment, thus allowing the measurements from the two separate days to be combined for further analyses

In March 2022, we tested for algal allelopathy by extracting the surface chemicals from both of the turf communities using methods of De Nys et al. (1998). Twenty milliliter volumes of turf algae collected from *S. nigricans* or *S. punctatus* territories were spun for 30 seconds in a mesh bag and blotted with paper towels to remove excess water. Algae were then vortexed for 30 seconds in 50 mL of hexane, the hexane decanted, and then evaporated under a fume hood for 8.5 hours, leaving the lipid soluble surface extracts. Surface extracts from each turf type were separately resuspended in 1 mL of methanol before being added to phytagel strips following the methods outlined in Rasher and Hay (2010). Control strips were made with 500 mL of methanol but no algal extract. Strips were refrigerated for less than 12 hours prior to deployment in the field.

Effects of extracts were assessed *in situ* by zip-tying phytagel strips directly to fragments of *A. pulchra* and *P. rus* for 24 hours in the field. New coral fragments were collected, placed on racks, and blocked by colony (as above) so that a control strip and strips with extracts from each turf type were blocked by individual coral colony for each of the two coral species (n = 12 blocks per treatment). Treatment effects on photosynthetic efficiency were measured after 24 hours using PAM fluorometry, with assessments conducted between 0900–1400 hr. PAM readings were compared between coral x algal treatments using beta regression with coral colony ID as a random effect.

We hypothesized that seasonal outcomes of coral-algal interactions could be due to seasonal variance in the production of allelochemicals by algae or resistance to those chemicals by corals. Given this, the surface extract assay was repeated with newly collected coral fragments in austral winter from September 25–28, 2022, when temperatures averaged 26.3°C (i.e., 2.3°C cooler than during the austral summer experiments in March). To account for differences in turf allelopathy due to seasonal changes, we tested the allelopathy of turf extracts using from turf that was freshly collected in September (austral winter) versus extracts from turf that had been collected in March (austral summer) and preserved at -80°C. If extracts from turf that were collected in March had a reduced effect in September and/or if extracts from turf that was collected in September had a lower impact on corals relative to the March turf, then this could suggest that allelopathic effects of turfs on corals are reduced in winter months. PAM readings were compared between coral species x treatments using beta regression with coral colony ID as a random effect.

Data Processing Description

Code for processing data can be found at: https://github.com/naltmank/coral_turf_contact_exp ***[recommend getting a DOI for the code if possible]***

Pulse-amplitude-modulated (PAM) fluorometer readings were compared between coral x algal treatments using beta regression with coral colony ID as a random effect. [***more details needed on how that was done]***

BCO-DMO Processing Description

- Imported data from source files "turf_extract_pam_data_winter.csv" and "turf_extract_pam_data_march.csv" into the BCO-DMO data system.
- Concatenated austral winter and austral summer data into single data file
- Modified parameter (column) names to conform with BCO-DMO naming conventions. Replaced dot separators with underscores. The only allowed characters are A-Z,a-z,0-9, and underscores. No spaces, hyphens, commas, parentheses, periods, or Greek letters.
- Converted date format from mm/dd/yyyy to yyyy-mm-dd (ISO Date 8601 format)
- Added a column for Season (either austral winter or austral summer)

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Related Publications

Altman-Kurosaki, N. T., Pratte, Z. A., Stewart, F. J., & Hay, M. E. (2024). Coral–algal competition: allelopathy,

temporal variance, and effects on coral microbiomes. Coral Reefs. https://doi.org/10.1007/s00338-024-02585-7
Results

Clements, C. S., Burns, A. S., Stewart, F. J., & Hay, M. E. (2020). Seaweed-coral competition in the field: effects on coral growth, photosynthesis and microbiomes require direct contact. Proceedings of the Royal Society B: Biological Sciences, 287(1927), 20200366. doi:10.1098/rspb.2020.0366
Related Research

Diaz-Pulido, G., & McCook, L. (2002). The fate of bleached corals: patterns and dynamics of algal recruitment. Marine Ecology Progress Series, 232, 115–128. https://doi.org/10.3354/meps232115
Related Research

Rasher, D. B., & Hay, M. E. (2010). Chemically rich seaweeds poison corals when not controlled by herbivores. Proceedings of the National Academy of Sciences, 107(21), 9683–9688. https://doi.org/10.1073/pnas.0912095107
Related Research

de Nys, R., Dworjanyn, S., & Steinberg, P. (1998). A new method for determining surface concentrations of marine natural products on seaweeds. Marine Ecology Progress Series, 162, 79–87. https://doi.org/10.3354/meps162079
Methods

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Parameters

Parameter	Description	Units
Date	Date of pulse-amplitude-modulated fluorometer measurement (PAM reading)	unitless
Season	Indicates season for the experiment (either austral summer or austral winter)	unitless
Table_coordinate	Physical location of coral fragment on a gridded coordinate table	unitless
Sample_ID	Sample identification for a given coral fragment	unitless
Colony_number	Colony number (parent colony ID) for a given coral fragment in the surface extract experiments	unitless
Coral_treatment	The coral species in a given coral-algal pairing (Acropora pulchra or Porities rus)	unitless
Algal_treatment	Indicates the algal treatment used in the coral-algal experiment. Options are 1) the algae used in the coral-algal contact experiment (Amansia, S nigricans turf, Macroalgae mimic, etc.), 2) the source of surface extract in the allelopathy experiment (e.g. Control, S nigiricans turf, S punctatus turf), or 3) the source and season of the turf used in the seasonal allelopathy experiment (e.g. Summer S nigricans turf, Winter S nigricans turf, Summer S punctatus turf, Winter S punctatus turf), unitless	unitless
Colony_ID	Combined ID with colony number and coral treatment in the surface extract experiments	unitless
PAM_reading	PAM (pulse-amplitude-modulated) fluorometer reading indicating effective quantum yield (Y)	dimensionless
Yield	PAM reading divided by 1000 since effective quantum yield (Y) is bounded between 0 and 1	dimensionless
ColonyID_Control_yield	The effective quantum yield of the branch from a given colony that was used as the control in the seasonal allelopathy experiment. Used in preliminary analyses of the seasonal allelopathy experiment to examine colony level effects"	dimensionless
file_name	original file name of the coral-turf extract PAM data	unitless

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Instruments

Dataset-specific Instrument Name	Walz in-situ PAM Fluorometer
Generic Instrument Name	Fluorometer
Dataset-specific Description	Treatment effects on corals were assessed with a Walz in situ pulse-amplitude-modulated (PAM) fluorometer directly at the site of coral-algal contact
Generic Instrument Description	A fluorometer or fluorimeter is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. The instrument is designed to measure the amount of stimulated electromagnetic radiation produced by pulses of electromagnetic radiation emitted into a water sample or in situ.

Dataset-specific Instrument Name	camera
Generic Instrument Name	Underwater Camera
Generic Instrument Description	All types of photographic equipment that may be deployed underwater including stills, video, film and digital systems.

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Project Information

Positive Effects of Coral Biodiversity on Coral Performance: Patterns, Processes, and Dynamics (Coral Biodiversity)

Coverage: Moorea, French Polynesia, South Pacific Ocean (17º32'S 149º50'W)

NSF Award Abstract:
Coral reefs are extremely diverse, supply critical ecosystem services, and are collapsing at an alarming rate, with 80% coral loss in the Caribbean and >50% in the Pacific in recent decades. Previous studies emphasized negative interactions (competition, predation) as structuring reef systems, but positive interactions in such species-rich systems could be of equal importance in maintaining ecosystem function. If foundation species like corals depend on positive interactions, then their fitness may decline with the loss of surrounding species, creating a biodiversity meltdown where loss of one coral causes losses of others. This project conducts manipulative field experiments to understand the role of coral biodiversity in facilitating coral growth, survival, resilience, and retention of these foundation species and the critical ecosystem services they provide in shallow tropical seas. This project is committed to: 1) Educating and exciting influential business and civic leaders about conservation and restoration of coastal marine systems before these systems lose ecological function and value. This will involve influential Rotary clubs within North Georgia/Atlanta (the major economic engine of the southeastern US) as an initial focus. 2) Using the Research News and Institute Communications Office at Georgia Tech and well-developed contacts with science writers to produce popular press pieces on important ocean ecology discoveries emerging from these studies. (3) Organizing a public workshop of internationally prominent scientists focused on Maintaining Marine Biodiversity as a Strategy to Sustain Ecosystem Services and Coastal Cultures and Economies. A previous effort like this, organized by the investigators, attracted about 200 attendees and was webcast to numerous high schools in Georgia and to foreign investigators in less developed countries that could not attend. Speakers also conducted in-person video interviews with local high school classes. Due to that success, this model will be repeated. 4) Working with an association of educators and cultural leaders in French Polynesia to produce electronic format presentations on our work and on reef conservation that are appropriate for use by both teachers and leaders within Polynesian culture.

Ecologists have excelled at demonstrating the importance of direct (often negative) interactions among species pairs. However, when these interactions occur in a complex context among thousands of other species in the field, the sum of the many, poorly-known, indirect interactions can counterbalance, or even reverse, the better-known direct interactions, generating diffuse mutualisms instead of agonistic outcomes. In a proof-of-concept initial experiment, coral growth and survivorship were greater in coral polycultures than monocultures, especially during early stages of community development. Processes generating this outcome are unclear but understanding these is of critical importance as diversity and function of reefs decline and as humans need to predict and adapt to changing environments. This interdisciplinary investigation merges expertise in experimental field ecology, chemical ecology, and the ecology of microbiomes to investigate the functional role of biodiversity in coral reef ecosystems. Experiments use a novel coral transplantation method and field manipulations to assess: 1) whether greater coral species diversity enhances coral community performance, as well as growth and survivorship of individual corals, 2) whether greater genotypic diversity enhances coral performance within a species, 3) whether greater diversity of seaweed competitors further suppresses corals and enhances seaweed performance, and 4) the processes driving the patterns documented above, including the roles of disease, intraspecific versus interspecific competition, predators, mutualists, and differential access to, or use of, resources. The research investigates the relationship between biodiversity and ecosystem function across dimensions of coral taxonomic diversity, from species to genotypes, and creates a series of experiments elucidating general principles underlying ecosystem dynamics. Filling these knowledge gaps advances our fundamental understanding of how biodiversity influences ecosystem function at multiple scales and provides insight into the processes promoting coral coexistence in these species-rich ecosystems. Findings will have practical implications for coral management and restoration and may improve predictions regarding coral reef resilience and recovery in the face of changing climate.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1947522

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