Differential effects of nutrients and consumer pressure on sympatric cryptic coral species (Pocillopora spp.) in Moorea, French Polynesia sampled in November 2021.

Website: https://www.bco-dmo.org/dataset/964151
Data Type: Other Field Results
Version: 1
Version Date: 2025-06-16

Project
» Moorea Coral Reef Long-Term Ecological Research site (MCR LTER)
» Collaborative research: Coral community resilience: testing the role of hidden diversity in pocilloporid corals at Moorea (Pocilloporid Coral Diversity)
» Collaborative Research: Tipping points in coral reefs and their associated microbiomes: interactive effects of herbivory, nutrient enrichment, and temperature (RECHARGE)

Program
» Long Term Ecological Research network (LTER)

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Abstract
Cryptic species (evolutionarily distinct lineages that do not align with morphologically defined species) are being increasingly discovered but are poorly integrated into ecological theory. In particular, we still lack a useful understanding of if and how cryptic species differ in ways that affect community recovery from disturbances and responses to anthropogenic stressors, such as the removal of consumers and pollution from nutrients. On coral reefs, nutrient pollution increases the growth of macroalgae that displaces corals. Reductions in herbivorous fishes reduce the suppression of macroalgae, while reductions in coralivorous fishes reduce predation on corals. An unresolved question is if and how cryptic coral species respond differently to these impacts, thereby differing in their ability to influence coral community dynamics and maintain coral dominance. Therefore, we assessed how the response of cryptic Pocillopora species over a period of three years following a simulated disturbance from a cyclone depended on the experimental reduction of fish consumer pressure and nutrient addition. After three years, five morphologically cryptic, but genetically distinct, Pocillopora species recruited to the reef. However, recruitment was dominated by two species: P. tuahiniensis (46%) and P. meandrina (43%). Under ambient conditions, recruitment of P. tuahiniensis and P. meandrina was similar, but experimentally reducing consumer pressure increased recruitment of P. tuahiniensis by up to 73% and reduced recruitment of P. meandrina by up to 49%. In both species, nutrient enrichment increased recruitment and colony growth rates equally, but colonies of P. tuahiniensis grew faster, and were up to 25% larger after three years, than those of P. meandrina, and growth was unaffected by reduced consumer pressure. Predation by excavating corallivorous fish was higher for P. meandrina than for P. tuahiniensis, especially under nutrient enrichment. In contrast, polyp extension (an indicator of elevated heterotrophic feeding as well as susceptibility and attractiveness to corallivores) was lower for P. meandrina than for P. tuahiniensis, especially under low to medium consumer pressure. Overall, we uncovered ecological differences in the response of morphologically cryptic foundation species to two pervasive stressors on coral reefs. Our results demonstrate how cryptic species respond differently to key anthropogenic stressors, which may contribute to response diversity that can support ecological resilience or increase extinction risk.

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Coverage

Location: Moorea, French Polynesia
Spatial Extent: **Lat**:-17.477 **Lon**:-149.818
Temporal Extent: 2018 - 2021

Dataset Description

Funding distinction:

- OCE-1829867 funded the genetic identification and time to analyze the data and write the paper.
- The other funding supported the field work to set up the experiment, record survival and growth, and collect tissue for DNA.

Methods & Sampling

In July 2018, on the north shore fore reef of Moorea, French Polynesia (-149.818, -17.477), we established a factorial field experiment where we reduced consumer pressure and elevated inorganic nutrient concentrations. At 12m depth, we established four pairs of plots, with each plot approximately 30m^2 . Within each 30m^2 plot, there were four randomly placed exclosures (~1.25 m^2 each). Each of the four exclosures had different size openings that allowed different size fishes access to the benthos. 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) that allowed access to all fishes, including herbivores, corallivores, and predators.

In November 2021, divers on SCUBA sampled colonies for genetic analysis. Small specimens (~2 verrucae per colony) were collected from each colony. All *Pocillopora* at least 2 cm diameter were sampled. Genomic DNA was extracted from tissues from each of the *Pocillopora* spp. sampled in November 2021 using Chelex 100 (Bio-Rad, USA), followed by PCR amplification of the mitochondrial Open Reading Frame (mtORF) gene. Sanger sequencing was performed at Florida State University

Data Processing Description

Using GENEIOUS v.9.1.8 (Biomatters), forward mtORF sequences (~800bp) were aligned and samples were identified to haplotype based on previously published sequences of mtORF haplotypes.

BCO-DMO Processing Description

* added AphiaID to datasets
* added sampling latitude and longitude to data itself

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Data Files

File
964151_v1_speciesid.csv (Comma Separated Values (.csv), 43.80 KB) MD5:04b54195bec46e1781e2a5ebcc1cc3d6
Primary data file for dataset ID 964151, version 1

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Parameters

Parameter	Description	Units
Latitude	Latitude of sampling location, south is negative	decimal degrees
Longitude	Longitude of sampling location, west is negative	decimal degrees
Un_ID	Unique ID for each coral	units
Plot	The plot in which the coral is located. Plots are A3, A4, B1, B2, C2, C4, D1, D3. Each plot has 4 exclosures, each with a different level of herbivory	units
Herbivory_trt	This is the consumer pressure treatment. Treatments are 1X1, 2x2, 3X3, and open, which correspond to very low, low, medium, and high levels of herbivory and corallivory	units
Enrichment_trt	This is the enrichment treatment. Plots are either Enriched or Ambient. Plots that are Enriched have nutrients added with fertilizer-filled nutrient diffusers.	units
Coral_ID	The correct coral ID's for all corals. Use these. These are the ID's used for the "Un_ID" column. These reflect all corrections. For most corals "Coral_ID" and "Coral_ID_past" are exactly the same. They only differ if we made corrections in the "Coral_ID_field" or "Coral_ID_corrected" columns.	units
Haplotype	The mtORF haplotype from Sanger sequences	units
Species	The species name	units
Aphia_ID	Unique and persistent identifier assigned to each species name within the World Register of Marine Species (WoRMS) database.	units
flag_uncertain_recruit_time	1 = Recruitment_timepoint was uncertain. 0 = Recruitment_timepoint is known, can use	units
flag_partial_mortality	1 = Partial mortality. 0 = No partial mortality	units
flag_unlabelled	1 = "Poc in bags" samples sampled from the new tiny recruits in plots C and D, but which the datasheets were temporarily misplaced which allow us to figure out which samples are which.	units
flag_bad_sequence	1 = sample was sequenced but the mtORF sequence was poor quality, so no Species given; 0 = mtORF sequence was good and a Species name is provided	units
flag_missing_sample	1 = no tube or sample was provided; 0 = sample was provided	units

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Project Information

Moorea Coral Reef Long-Term Ecological Research site (MCR LTER)

Website: http://mcr.lternet.edu/

Coverage: Island of Moorea, French Polynesia

NSF Award Abstract:

Coral reefs provide important benefits to society, from food to exceptional biodiversity to shoreline protection and recreation, but they are threatened by natural perturbations and human activities, including those causing global-scale changes. These pressures increasingly are causing coral reefs to undergo large, often abrupt, ecological changes where corals are being replaced by seaweeds or other undesirable organisms. Historically, the major agent of disturbance to coral reefs has been powerful storms, but in recent decades, episodes of mass coral bleaching from marine heat waves have become more frequent and severe as the temperature of ocean surface waters continues to rise. Coral reefs are further stressed by local human activities that cause nutrient pollution and deplete herbivorous fishes that control growth of seaweeds. Studying how coral reefs respond to these two types of disturbance under different levels of nutrient pollution and fishing provides essential information on what affects the ability of coral reefs to buffer

environmental change and disturbances without collapsing to a persistent, degraded condition. The fundamental goals of the Moorea Coral Reef Long Term Ecological Research program (MCR LTER) are to understand how and why coral reefs change over time, to assess the consequences of these changes, and to contribute scientific knowledge needed to sustain coral reef ecosystems and the important societal services they provide. This research improves understanding and management of coral reefs, which benefits all groups concerned with the welfare of this ecologically, economically and culturally important ecosystem. In addition to academic communities, scientific findings are communicated to interested individuals, non-governmental organizations, island communities and governmental entities. These findings also are integrated into K-12, undergraduate, graduate and public education activities through a multi-pronged program that includes inquiry-based curricula, interactive and media-based public education programs, and internet-based resources. MCR?s research, training, education and outreach efforts all emphasize broadening participation in STEM fields and strengthening STEM literacy.

New research activities build on MCR LTER?s powerful foundation of long-term observations and broad ecological understanding of oceanic coral reefs to address the following core issues: How is the changing disturbance regime (recurrent heat waves in addition to cyclonic storms) altering the resilience of coral reefs, and what are the ecological consequences of altered resilience? Research activities are organized around a unifying framework that explicitly addresses how reef communities are affected by the nature and history of coral-killing disturbances, and how those responses to disturbance are influenced by the pattern of local human stressors. New studies answer three focal questions: (1) How do different disturbance types, which either remove (storms) or retain (heat waves) dead coral skeletons, affect community dynamics, abrupt changes in ecological state, and resilience? (2) How do local stressors interact with new disturbance regimes to create spatial heterogeneity in community dynamics, ecosystem processes, and spatial resilience? And (3) What attributes of coral and coral reef communities influence their capacity to remain resilient under current and future environmental conditions? These questions provide an unparalleled opportunity to test hypotheses and advance theory regarding ecological resilience and the causes and consequences of abrupt ecological change, which is broadly relevant across aquatic and terrestrial ecosystems.

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.

From http://www.lternet.edu/sites/mcr/ and http://mcr.lternet.edu/:
The Moorea Coral Reef LTER site encompasses the coral reef complex that surrounds the island of Moorea, French Polynesia (17°30'S, 149°50'W). Moorea is a small, triangular volcanic island 20 km west of Tahiti in the Society Islands of French Polynesia. An offshore barrier reef forms a system of shallow (mean depth ~ 5-7 m), narrow (~0.8-1.5 km wide) lagoons around the 60 km perimeter of Moorea. All major coral reef types (e.g., fringing reef, lagoon patch reefs, back reef, barrier reef and fore reef) are present and accessible by small boat.

The MCR LTER was established in 2004 by the US National Science Foundation (NSF) and is a partnership between the University of California Santa Barbara and California State University, Northridge. MCR researchers include marine scientists from the UC Santa Barbara, CSU Northridge, UC Davis, UC Santa Cruz, UC San Diego, CSU San Marcos, Duke University and the University of Hawaii. Field operations are conducted from the UC Berkeley Richard B. Gump South Pacific Research Station on the island of Moorea, French Polynesia.

MCR LTER Data: The Moorea Coral Reef (MCR) LTER data are managed by and available directly from the MCR project data site URL shown above. The datasets listed below were collected at or near the MCR LTER sampling locations, and funded by NSF OCE as ancillary projects related to the MCR LTER core research themes.

This project is supported by continuing grants with slight name variations:

- LTER: Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR II - Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR IIB: Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR III: Long-Term Dynamics of a Coral Reef Ecosystem
- LTER: MCR IV: Long-Term Dynamics of a Coral Reef Ecosystem

Collaborative research: Coral community resilience: testing the role of hidden diversity in pocilloporid corals at Moorea (Pocilloporid Coral Diversity)

Coverage: Moorea, French Polynesia

NSF Award Abstract:
While most coral reefs in the world are threatened by multiple disturbances that are driving coral cover downward, the coral reefs at Mo'orea, French Polynesia, provide a striking exception. However, it is not yet clear what makes the coral communities of Mo'orea an exception to the trend of global decline in coral cover, and what drives spatial variation in recovery patterns around the island. The most recent wave of recovery on the outer reefs is dominated by corals in the genus Pocillopora (the cauliflower coral). While the colonies of this coral all look similar to one another, they actually represent multiple 'hidden' species that are genetically divergent but visibly indistinguishable. The morphological similarity makes it hard to identify species in the field, and this often forces researchers to pool these corals into a single group, which has impeded a full understanding of coral recovery. The ecological differences among these hidden species remain poorly understood, but they may be a crucial factor keeping the ecosystem in a coral-dominated state. This project is studying how 'hidden diversity' provides a form of 'ecological insurance' that provides reef-building coral communities around this island with ecological and evolutionary options that buffer reefs from unpredictable and unfavorable environmental conditions. If multiple cryptic species exhibit a diversity of responses to disturbance and stress, then it increases the ability of the community to recover and re-organize after impacts compared to that if all the species responded the same way. By studying the reefs at Mo'orea, this project provides unique, important, and transferable knowledge to better understand fundamental mechanism driving coral community recovery following catastrophic damage, and will provide much-needed information to better manage coral reefs and favor them remaining in a coral-dominated state. A PhD student and a postdoctoral researcher at Florida State University (FSU) are being supported and mentored during the project, and a program of professional growth is being provided for a technician who will work on the project. The investigators are working with science educators from Florida schools to introduce marine biology clubs that will provide outreach opportunities for FSU and California State University Northridge participants to engage high school students and teachers in the research themes at the core of this project.

This project will test the hypothesis that the presence of morphologically similar yet genetically divergent lineages of corals in the genus Pocillopora drives rapid recovery of coral communities dominated by Pocillopora on the outer reefs of Mo'orea, French Polynesia. By creating a diverse portfolio in the capacity of the Pocillopora community to recover and reorganize after disturbance, hidden ecological differences among coral lineages in their response to disturbance is expected to promote community resilience. A well-studied genetic marker will be used to distinguish coral colonies among different lineages. Field-based projects, co-located with Moorea Coral Reef-Long-Term Ecological Research (MCR-LTER) sites, will determine how pocilloporid lineages differ in their distribution and abundance, spatial and temporal patterns of annual recruitment, symbiont composition, and post-settlement growth and survival. These data will be used to build Integral Projection Models (IPMs) to compare population differences among lineages in their sensitivity to size-dependent perturbations, and their capacity for population growth following disturbance. Results from the field projects and IPMs will be synthesized to estimate response diversity as the multivariate dispersion of lineage dissimilarity, and to assess the extent to which it predicts variation among sites in the recovery rate of pocilloporid percent cover, estimated empirically from the MCR-LTER time series. The intellectual merits of this project lie in developing new and transferable understanding of: i) the ecological differences within an ecologically important coral genus, ii) why pocilloporids at Mo'orea are an exception to the global trend of declining coral cover, and iii) the potential for hidden response diversity to act as a fundamental mechanism determining the capacity for coral communities to reestablish and reorganize following disturbances.

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.

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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Program Information

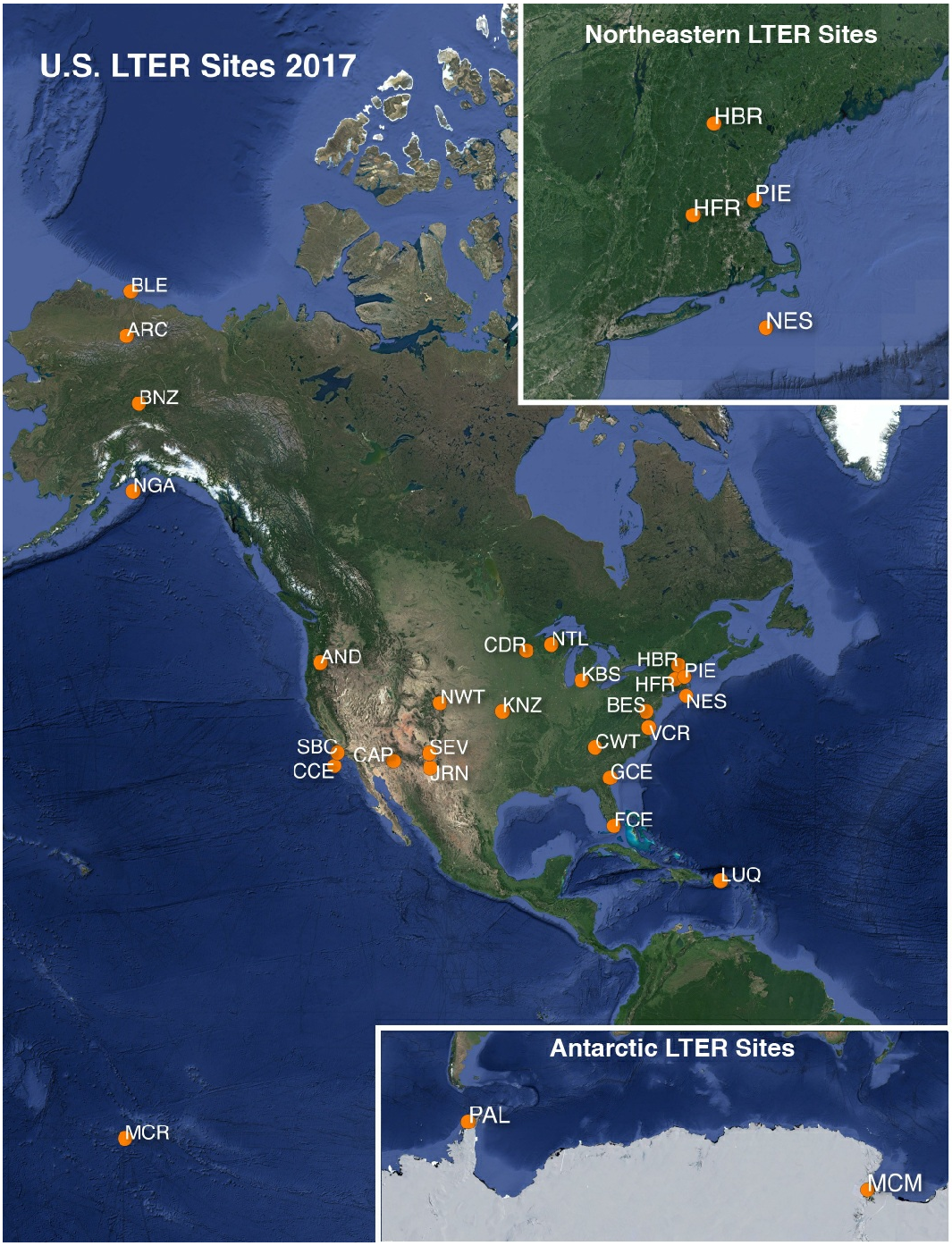
Long Term Ecological Research network (LTER)

Website: http://www.lternet.edu/

Coverage: United States

adapted from http://www.lternet.edu/

The National Science Foundation established the LTER program in 1980 to support research on long-term ecological phenomena in the United States. The Long Term Ecological Research (LTER) Network is a collaborative effort involving more than 1800 scientists and students investigating ecological processes over long temporal and broad spatial scales. The LTER Network promotes synthesis and comparative research across sites and ecosystems and among other related national and international research programs. The LTER research sites represent diverse ecosystems with emphasis on different research themes, and cross-site communication, network publications, and research-planning activities are coordinated through the LTER Network Office.



2017 LTER research site map obtained from https://lternet.edu/site/lter-network/

Site Codes

AND	Andrews Forest LTER
ARC	Arctic LTER
BES	Baltimore Ecosystem Stu
BLE	Beaufort Lagoon Ecosystems LTER
BNZ	Bonanza Creek LTER
CCE	California Current Ecosystem LTER
CDR	Cedar Creek Ecosystem Science Reserve
CAP	Central Arizona-Phoenix LTER
CWT	Coweeta LTER
FCE	Florida Coastal Everglades LTER
GCE	Georgia Coastal Ecosystems LTER
HFR	Harvard Forest LTER
HBR	Hubbard Brook LTER
JRN	Jornada Basin LTER
KBS	Kellogg Biological Station LTER
KNZ	Konza Prairie LTER
LUQ	Luquillo LTER
MCM	McMurdo Dry Valleys LT
MCR	Moorea Coral Reef LTEF
NWT	Niwot Ridge LTER
NTL	North Temperate Lakes I
NES	Northeast U.S. Shelf LTE
NGA	Northern Gulf of Alaska I
PAL	Palmer Antarctica LTER
PIE	Plum Island Ecosystems LTER
SBC	Santa Barbara Coastal L
SEV	Sevilleta LTER
VCR	Virginia Coast Reserve L

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1637396
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829867
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023701
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023424

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