EasyGrantsID: 59023

National Fish and Wildlife Foundation – Papahanaumokuakea 2018, Full Proposal

Title: Understanding environmental stressors and deep reefs to support management of Papahanaumokuakea

Organization: Bishop Museum

Grant Information

Title of Project

Understanding environmental stressors and deep reefs to support management of Papahanaumokuakea

Total Amount Requested	$ 899,833.39
Matching Contributions Proposed	$66,647.00
Proposed Grant Period	02/01/ 2018 - 02/01/ 2019

Project Description

Perform collaborative, multi-disciplinary research to determine how predicted environmental stressors will affect key species and habitats at French Frigate Shoals in the Papahanaumokuakea Marine National Monument. Project will determine how changing climate conditions will impact: (1) low-lying sand and coral reef habitats and associated species (turtles, seals, birds, fishes, coral, algae), (2) mesophotic diversity, and (3) trophic connections between shallow and mesophotic coral ecosystems.

Project Abstract

This project will utilize a multidisciplinary approach to address six management priorities at French Frigate Shoals (FFS). Research activities will utilize technical divers, snorkeling, data loggers, and land-based activities to characterize environmental processes.

Coral reefs and low-lying islets at FFS provides essential habitat to key species (e.g., sea turtles, monk seals, seabirds, fishes, and corals). These habitats are highly responsive to climate change and sea-level rise, and are expected to undergo significant geomorphic change. Geological investigations will reveal reef island origin and evolution under the changing sea level regime of the Holocene (1a), and numerical modeling of coastal processes will simulate island change under higher sea level (1b). Structure-from-Motion photogrammetry will create 3D models of reefs to quantify shifts in habitat composition and structure associated with changes in live coral and algae cover (1c). Mesophotic abiotic features, fish and algal diversity will be characterized to fill gaps in the taxonomic understanding of these habitats (2a, c). Telemetry-tagging and stable isotope analyses will determine the magnitude of nutrient and energy flow between habitats (2b).

The outcome will be a clear understanding of how environmental stressors affect key habitats and species at FFS, and improved characterization of MCEs including trophic dynamics and energy flux between habitats.

Organization and Primary Contact Information

Organization	Bishop Museum
Organization Type	Non-profit Corporation 501(c)(3)
City, State, Country	,,
Region (if international)	
Primary Contact	Richard L Pyle
Position/Title	

Phone and E-mail	x ; deepreef@bishopmuseum.org

Additional Contacts

Role	Name
Other Authorized Personnel	Toni-Ann Samio
Principal	John Burns

Project Location Information

Project Location Description	French Frigate Shoals, Northwestern Hawaiian Islands, Papahanaumokuakea Marine National Monument, Hawaii (HI)
Project Country(ies)	North America - United States
Project State(s)	Hawaii
Project Congressional District(s)	All Districts (HI)

Permits and Approvals

Permits/Approvals Description:	If awarded, we will apply for necessary permits in consultation with Dr. Randall Kosaki of the Papahanaumokuakea Marine National Monument.
Permits/Approvals Status:	Intend to Apply
Permits/Approvals Agency-Contact Person:	NOAA - Randall Kosaki
Permits/Approvals Submittal-Approval Date:	01/10/2017

I. PERSONNEL	$14,000.00

Staff Name	Position	Annual Salary	Project Hours	Hourly Rate	LOE (%)	Project Salary	% Fringe	$ Fringe	Total Personnel
Richard Pyle	Bishop Museum Researcher	$59,159.80	351.59	$28.44	17	$10,000.00	40.00	$4,000.00	$14,000.00
Totals						**$10,000.00**		**$4,000.00**	**$14,000.00**

II. TRAVEL	$0.00

Domestic Airfare – Per Flight

Purpose/Destination	Unit Cost	Quantity	Total Cost
SubTotal			**$0.00**

International Airfare – Per Flight

Purpose/Destination	Unit Cost	Quantity	Total Cost
SubTotal			**$0.00**

Train – Per Ticket

Purpose/Destination	Unit Cost	Quantity	Total Cost
SubTotal			**$0.00**

Rental Car – Per Day

Purpose/Destination	Days/Duration	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Taxis – Per Trip

Purpose/Destination	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Mileage – Per Mile

Purpose/Destination	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Gasoline – Per Gallon

Purpose/Destination	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Per Diem (M&IE) – Per Day

Purpose/Destination	Days/Duration	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Lodging – Per Night

Purpose/Destination	Days/Duration	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

Meals (no M&IE) – Per Meal

Purpose/Destination	Days/Duration	Unit Cost	Quantity	Total Cost

SubTotal **$0.00**

III. EQUIPMENT $137,980.00

Item Name	Description	Unit Cost	Quantity	Total Cost
Multi-sensor array units	Sensors used for long-term monitoring of abiotic	$25,445.00	4	$101,780.00
Batteries system for multi-sensor array	Batteries system for multi-sensor array	$16,000.00	1	$16,000.00
Rebreather System	Rebreather device and associtated support equipmen	$20,200.00	1	$20,200.00

IV. MATERIALS & SUPPLIES $14,239.00

Type	Purpose	Unit of Measure	Unit Cost	Quantity	Total Cost
TidbiT v2 temperature loggers	Logging Temperature data	Degrees Celsius	$133.00	16	$2,128.00
Downoad Station for Temperature Sensors	Allows downloading data from sensors		$124.00	1	$124.00
Helium	Helium cylinders for mixed-gas diving	Cylinder	$372.00	3	$1,116.00
Oxygen	Oxygen cylinders for mixed-gas diving	Cylinder	$120.00	5	$600.00

Sofnolime	CO2 absorbent for mixed-gas diving		$160.00	4	$640.00
Assorted Diving Supplies	Assorted small equipment items and supplies		$2,500.00	1	$2,500.00
eDNA Sample Bottles	Collect water samples for eDNA analysis		$100.00	4	$400.00
eDNA Filters	Filters for preparing water samples for eDNA analy		$130.00	2	$260.00
eDNA Extraction Supplies	Supplies for extracting eDNA		$1,200.00	1	$1,200.00
KAPA Supplies	Supplies needed to perform eDNA analysis		$604.00	2	$1,208.00
PCR Purification	Supplies for PCR purification		$543.00	1	$543.00
PIPPIN Cartridges	Cartridges for eDNA analysis		$60.00	12	$720.00
Assorted Laboratory Consumables	General supplies for laboratory analysis		$2,800.00	1	$2,800.00

V. CONTRACTUAL SERVICES — $717,978.46

Subcontract/Contract – Per Agreement

Contractor Name	Description	Total Cost
The Medical Foundation for the Study of the Enviro	Charter the Searcher for field expedition	$197,500.00
The Evolutonary Genetics Core Facility	eDNA sequencing services	$8,800.00

SubTotal **$206,300.00**

Subgrant – Per Agreement

Subrecipient	Description	Total Cost
University of Hawaii at Manoa	Research for Theme 1 and Theme 2 objectives	$429,286.46
University of Hawaii at Hilo	Research for Theme 1 objectives	$82,392.00

SubTotal **$511,678.46**

VI. OTHER DIRECT COSTS — $0.00

Type	Purpose	Unit of Measure	Unit Cost	Quantity	Total Cost

VII. TOTAL DIRECT COSTS — $884,197.46

VIII. INDIRECT COSTS — $15,635.93

Explanation of Modified Total Direct Cost Base(MTDC)	Rate Type	NICRA Expiration	$MTDC	Rate(%)	Total Cost
Bishop Museum charges no indirect on equipment over $5,000, or on any contractual services or subgrant awards. An indirect rate of 55.37% is applied to Personnel costs and Materials and Supplies.	Fixed	6/30/2018	$28,239.00	55.37	$15,635.93

IX. TOTAL PROJECT COSTS — $899,833.39

Budget Narrative

Budget Narrative:

1. Personnel

Personnel -	$10,000 is requested to support Dr. Pyle's role in performing taxonomic research on mesophotic fishes and participation on the cruise to French Frigate Shoals. The standard Fringe rate at Bishop Museum is 40% of Salary ($4,000).

2. Travel

Domestic Airfare - Per Flight -
International Airfare - Per Flight -
Train - Per Ticket -
Rental Car - Per Day -
Taxis - Per Trip -
Mileage - Per Mile -
Gasoline - Per Gallon -
Per Diem (M&IE) - Per Day -
Lodging - Per Night -
Meals (No M&IE) - Per Meal -

3. Equipment

Equipment -	$101,780 is requested for four AML Oceanographic METREC-X multi-parameter instrument cluster for long term abiotic monitoring (4 x $25,445 = $101,780). $16,000.00 is requested to power the Multisensor Array with: 4 Deep Sea Power and Light SeaBattery (16 x $1,000.00 = $16,000.00). $20,200.00 is requested to purchase a new rebreather system, inclusive of backup computer and oxygen monitoring systems and gas analysis system ($15,200.00) and a portable air compressor with associated filters ($5,000.00). No indirect is applied to equipment items that cost more than $5,000.

4. Materials and Supplies

Materials and Supplies -	$2,252.00 is requested for 16 TidbiT v2 temperature loggers ($133.00 x 16 loggers =$2,128.00), and $124 for a USB Base Station needed for downloading data. $4,850 is requested for diving supplies, including helium (3 cylinders x $372.00 = $1,116.00), oxygen (5 cylinders x $120 = $600.00), CO2 absorbent (4 kegs x $160 = $640.00), and assorted support equipment including supplies for bailout cylinders and other small equipment items ($2,500.00). $7,131.00 is requested to puchase supplies necessary for eDNA analysis, including sample bottles (4 x $100 = $400), filters (2 x $130 = $260), DNA extraction supplies ($1,200), KAPA supplies (2 x $604 = $1,208), PCR purification ($543), PIPPIN Cartriges (12 x $60 = $720), and other laboratory consumables ($2,800). 55.37% indirect is applied to all materials and supplies.

5. Contractual Services

Subcontract/Contract - Per Agreement -	Searcher vessel and crew will be contracted to conduct a 13-day research expedition at French Frigate Shoals. This includes 6-days of total transit, and $7500 for loading and unloading days. Vessel and crew will provide two 20-ft zodiacs to facilitate shore-based research activities and diving operations. $8,800.00 is requested for eDNA sequencing services. This includes 4 MiSeq sequencing lanes (4 lanes x $2,200/lane = $8,800). Bishop Museum charges no indirect on contractual services.
Subgrant - Per Agreement -	UH Manoa will receive a sub-grant to conduct research for the proposed Theme 1 and Theme 2 objectives. UH Hilo will receive a sub-grant to conduct research for the proposed Theme 1 objectives. See full proposal for details of research activities, and see budget justification (Other Documents) for breakdown of use of funds.

6. Other Direct Costs

Other Direct Costs -

7. Indirect Costs

Indirect Costs -	Bishop Museum charges no indirect on equipment over $5,000, or on any contractual services or subgrant awards. An indirect rate of 55.37% is applied to Personnel costs and Materials and Supplies.

Matching Contributions

Matching Contribution Amount:	$4,600.00
Type:	In-kind
Status:	Pledged
Source:	Joshua Copus (Personal)
Source Type:	Non-Federal
Description:	Time spent by Joshua Copus to participate on the expedition and process environmental data and eDNA analysis will be supported by external sources (two months at half time)

Matching Contribution Amount:	$30,400.00
Type:	In-kind
Status:	Pledged
Source:	Richard Pyle (Personal)
Source Type:	Non-Federal
Description:	Two Poseidon Rebreather Systems will be made available for use on this project, in addition to the system purchased with support from this project. This will enable two divers to complete full trimix dives to 100 m, with a third complete system avail

Matching Contribution Amount:	$11,500.00
Type:	In-kind
Status:	Pledged
Source:	Association for Marine Exploration
Source Type:	Non-Federal
Description:	A complete portable stainless steel gas filling and transfer system, including primary and backup booster pump) will be available for use on this project. These items are necessary for filling rebreather and bailout gas cylinders, and will be complem

Matching Contribution Amount:	$5,500.00

Type:	In-kind
Status:	Pledged
Source:	Richard Pyle (Personal)
Source Type:	Non-Federal
Description:	A complete Sony 4K video system, including Nauticam housing and Light & Motion LED lighting system will be made available for use on this project, to capture specimen and in-situ habitat images at mesophotic and shallow depths at FFS during the exped

Matching Contribution Amount:	$4,800.00
Type:	In-kind
Status:	Pledged
Source:	University of Hawaii - Hilo
Source Type:	Non-Federal
Description:	The Kolor Abyss housing will be used to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the re

Matching Contribution Amount:	$3,500.00
Type:	In-kind
Status:	Pledged
Source:	University of Hawaii - Hilo
Source Type:	Non-Federal
Description:	Seven GoPro cameras will be used and placed into the Kolor Abyss housing to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get

Matching Contribution Amount:	$2,934.00
Type:	In-kind
Status:	Pledged
Source:	University of Hawaii - Hilo
Source Type:	Federal

Description:	The 360-HERO mount, housing, and domes will be used to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual

Matching Contribution Amount:	$2,590.00
Type:	In-kind
Status:	Pledged
Source:	University of Hawaii - Hilo
Source Type:	Non-Federal
Description:	Seven GoPro cameras will be used and placed into the 360-HERO housing to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get ex

Matching Contribution Amount:	$823.00
Type:	In-kind
Status:	Pledged
Source:	University of Hawaii - Hilo
Source Type:	Non-Federal
Description:	The Kolor software will be used to stitch the GoPro videos to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas.

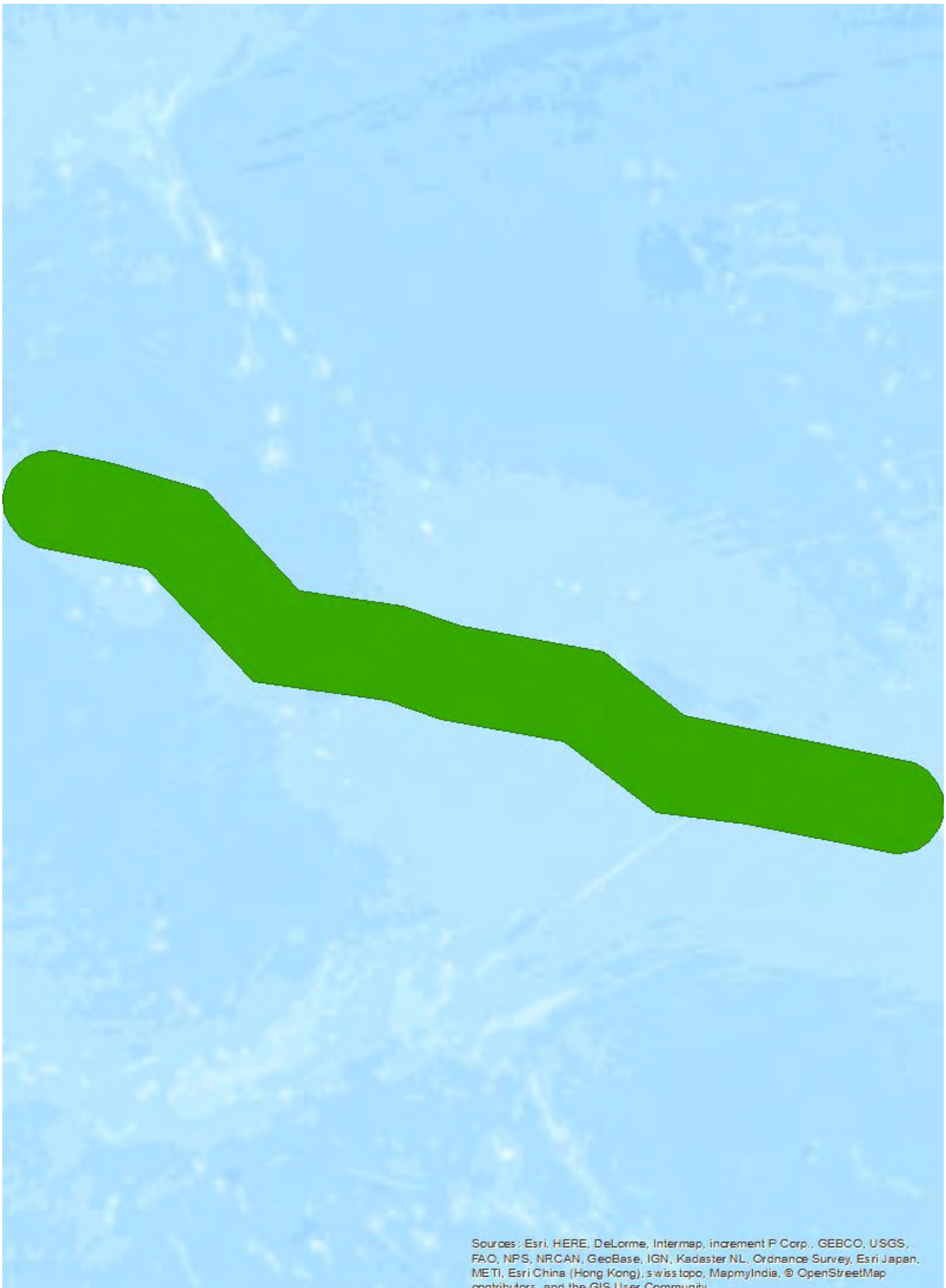
Total Amount of Matching Contributions:	$66,647.00

EasyGrantsID: 59023

National Fish and Wildlife Foundation – Papahanaumokuakea 2018, Full Proposal

Title: Understanding environmental stressors and deep reefs to support management of Papahanaumokuakea

Organization: Bishop Museum



The following pages contain the uploaded documents, in the order shown below, as provided by the applicant:

Upload Type	File Name	Uploaded By	Uploaded Date
Papahanaumokuakea Full Proposal Narrative 2018	FullProposalNarrative.pdf	Pyle, Richard	12/20/2017
Project Map	ProjectMaps.pdf	Pyle, Richard	12/20/2017
Photos - Jpeg	Photos_Page_1.jpg	Pyle, Richard	12/20/2017
Photos - Jpeg	Photos_Page_2.jpg	Pyle, Richard	12/20/2017
Photos - Jpeg	Photos_Page_3.jpg	Pyle, Richard	12/20/2017
Resumes	Resumes.pdf	Pyle, Richard	12/20/2017
Board of Trustees, Directors, or equivalent	BoardOfDirectors.pdf	Pyle, Richard	12/20/2017
Statement of Litigation	StatementOfLitigation.pdf	Pyle, Richard	12/20/2017
Other Documents	Other_References.pdf	Pyle, Richard	12/20/2017
Other Documents	Other_SearcherLOS.pdf	Pyle, Richard	12/20/2017
Other Documents	Other_DataManagement.pdf	Pyle, Richard	12/20/2017
Other Documents	Other_BudgetJustification.pdf	Pyle, Richard	12/20/2017
Other Documents	Other_MatchingFunds.pdf	Pyle, Richard	12/20/2017

The following uploads do not have the same headers and footers as the previous sections of this document in order to preserve the integrity of the actual files uploaded.

Full Proposal Project Narrative

1. **Research Goal(s):** The overarching goal of this project is to conduct collaborative and multi-disciplinary research to determine how changing climate conditions will impact: (1) low-lying sand and coral reef habitats and associated species (turtles, seals, birds, fishes, coral, algae), (2) mesophotic diversity, and (3) trophic connections between shallow and mesophotic coral ecosystems at French Frigate Shoals (FFS), in the Papahānaumokuākea Marine National Monument (PMNM). The specific themes and management questions/applications that will be addressed and the extent to which these questions will be answered in the proposed period of performance are outlined below.

Research themes addressed:

1. Understanding the potential impacts of predicted environmental stressors on priority species.
    a. Historical reconstruction of beach erosion and accretion during the recent Holocene.
    b. Predictive modeling of environmental stressor impacts to nesting and foraging habitats for sea turtles, monk seals and birds in Papahānaumokuākea.
    c. 3D photogrammetry and modeling of structural changes in the wake of mass coral bleaching events in Papahānaumokuākea.
2. Increasing understanding of the mesophotic zone.
    a. Characterize abiotic features of the mesophotic zone.
    b. Study trophic dynamics and the flow of energy and nutrients between shallow and mesophotic coral reef habitats.
    c. Fill gaps in taxonomic research of the mesophotic zone.

Specific management questions/applications:

Theme 1a: *Did the reef islands at FFS form ca. 6,000 to 4,000 years ago as sea level rose out of the last ice age toward this highstand? Or did they emerge as sea level fell in the more recent 1,000 to 2,000 years?*

Extent to which these questions will be answered by the end of the proposed period of performance:

As recently as 2,000 to 4,000 years ago, sea level in the tropical Pacific stood 1 to 2-m higher than present, comparable to global mean sea-level rise (SLR) scenarios anticipated later this century (Grossman et al. 1998, Sweet et al. 2017). Research on other atoll systems finds evidence for island formation as a response to both rising sea level since the last ice age and sea level receding in the recent 1,000 to 2,000 years. Now that sea level is rising again, workers have interpreted reef island origin and evolution, and the prevailing sea level regime at the time, as foreshadowing their future disposition (McLean and Kench 2015).

In Hawai‘i, the middle Holocene sea-level highstand is named after Kapapa Island in Kaneohe Bay, where a paleo-beach deposit from the episode was first recognized (Stearns 1935). Maximum sea level during the Kapapa highstand was 2.00 $\pm$ 0.35m approximately 3,500 years BP (Fletcher and Jones 1996, Grossman and Fletcher 1998). Following this period, sea-level slowly withdrew, exposing coastal plains throughout the Pacific, until it began to rise again sometime in the past several centuries, driven by anthropogenic climate change. This study will employ similar methods used to understand the formation of Kapapa Island in Kaneohe Bay. Cores and trenches will be used to understand the interior stratigraphic architecture of islands at FFS (see Map 1). Key sedimentary units will be sampled for age (radiocarbon) and composition analysis. The age relationship of the platform and key sedimentary units within the islands will be interpreted for island origin and subsequent evolution. These will be analyzed to assess changes in sediment source that characterize recent history of the islands at FFS. The sampling and analyses will be conducted during the 12-month proposed period of performance to provide a complete historical reconstruction of beach erosion and accretion at FFS during the recent Holocene. At least one manuscript will be submitted for publication within proposed period of performance, and results will be made available to resource managers and the public through reports and outreach mechanisms described in this proposal.

What makes this approach achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain (if applicable):

As global mean SLR continues to accelerate (Chen et al. 2017), administrators of the PMNM are faced with the need to develop responsive management plans for critical ecosystems and endangered species. Central to this is the challenge of improving understanding of how essential habitats will respond to SLR. Reef islands at FFS provide crucial habitat to sea turtles, monk seals, and various seabirds. These islands are geologically-ephemeral sedimentary

features composed of carbonate sand and gravel, partially stabilized by plant cover, and constantly reshaped by tides, winds, waves, and wave-driven currents. These sandy environments are highly responsive to SLR and are likely to undergo significant geomorphic change that will intensify with time (Romine et al. 2016, Vitousek et al. 2017, see Photo 1). Understanding and predicting these geomorphic changes will provide managers with the information required to effectively conserve these important habitats at FFS.

This research will be the first to document reef island history anywhere in the PMNM. The described results are achievable because we are applying proven methodology to a new system and possess the expertise to execute the proposed research activities. The resulting data will be critically valuable for providing historical records to enable modeling of how predicted SLR (Theme 1b) will impact essential island habitat for sea turtles, monk seals, and various seabirds not only at FFS but throughout PMNM.

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described: We plan for at least one manuscript to be submitted for publication within the grant period. There are also likely to be follow-on papers, however, submitted beyond the end of the grant period.

Theme 1b: *How will wave sea level rise impacts to the convergence and/or divergence of wave-driven sand transport cause the islands to accrete or erode? How will changes in island size and configuration affect nesting and foraging habitats for sea turtles, monk seals and birds in Papahānaumokuākea?*

Extent to which questions will be answered by the end of the proposed period of performance:

As sea level rises, waves will increasingly mobilize sediments from the beachface leading to shoreline recession, wave overtopping and back-beach deposition, and longshore sediment transport changing the geomorphic footprint of the island. These processes can be simulated by integrating longshore and cross-shore sediment transport to predict shoreline change on a variety of timescales. The model uses an extended Kalman filter data-assimilation technique to auto-tune model parameters and improve confidence in long-range shoreline predictions (Vitousek et al. 2017). The model has been successfully applied to predict shoreline change under SLR on 500 km of coastline in southern California. As part of the proposed work, the existing model will be augmented with a dedicated wave refraction/focusing/dissipation module to simulate transport on reef-fronted islands and atolls. Model scenarios will explore how SLR and perturbations to the island's shape and nearshore bathymetry at FFS will affect the convergence or divergence of wave-driven sand transport, causing the islands to accrete or erode, respectively. Digital elevation models and data from Theme 1a will be integrated with existing LiDAR and historical habitat survey data to process the model scenarios and answer the Theme 1b questions within the proposed period of performance.

Discuss what makes these goals achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain (if applicable):

We hypothesize that the current island configuration results from transport convergence zones. However, it remains unclear as to whether sand production from the reef is large enough to support island emergence and growth under static (or even rising) mean sea level conditions, or whether emergence is only possible during falling sea levels. Models of paleo-sea level and morphologic evolution, as revealed by the proposed field work, will help to understand these processes and to predict the island's fate under scenarios of future SLR. Finally, the scenarios of island morphologic change will be combined with surveys of habitat thresholds to understand the viability of the habitat for amphibious marine life and nesting seabirds in FFS and PMNM (Baker et al. 2006). Our proposed objectives are both achievable and important for understanding habitat dynamics at FFS under future climate scenarios.

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described: We expect to submit additional manuscripts for publication beyond the grant period.

Theme 1c: *How are thermal stress events and mass coral bleaching affecting the community composition and 3D habitat structure of coral reef habitats in Papahānaumokuākea?*

Extent to which these questions will be answered by end of the proposed period of performance:

To improve the capability and accuracy of quantifying the structural features of coral reefs with non-invasive methods, we developed techniques for creating high-resolution underwater 3D reconstructions utilizing Structure-from-Motion (SfM) photogrammetry (Burns et al. 2015, see Photo 2). This approach generates high-resolution orthophotos and digital elevation models that enable quantitative analyses of structural parameters (e.g., rugosity, surface complexity, slope, curvature) that are known to affect biodiversity and productivity (Burns et al. 2015, Figueira et al. 2015, Leon et al. 2015, Burns et al. 2016, see Photo 3). This method has been used by Co-PI Burns to monitor coral health, community composition, and 3D habitat structures at sites throughout the PMNM since 2012. Long-term sites have been monitored annually to track changes in benthic composition and 3D habitat structure. We used this approach to determine statistically significant shifts in coral composition, habitat complexity, and coral volume following the 2014-15 mass bleaching mortality at Lisianski (Couch et al. 2017, see Photo 4). This project

will use the same approach to quantify temporal shifts in coral community composition and 3D habitat complexity at FFS using new and existing high-resolution 3D reef reconstructions (Burns et al. 2016). Eleven long-term sites have been used for surveying coral health and 3D habitat structure at FFS from 2015–2017 (see Map 2). As part of this project, the existing 3D models will be processed and analyzed to determine how levels of bleaching and other health conditions associated with thermal stress are affecting coral composition and 3D habitat complexity by the end of the proposed period of performance. In addition to this analysis, 10 new sites will be established in shallow habitats that have been shown to exhibit high levels of bleaching from existing RAMP survey data. Creating a more robust baseline will enhance monitoring of impacts from thermal stress and bleaching to coral reef habitats at FFS. 3D models will also be generated from imagery collected at mesophotic survey locations (Theme 2) to create 3D habitat models of mesophotic habitats. These models will be analyzed in the same manner as the shallow sites and will allow us to compare coral composition, 3D structure, and impacts associated with thermal stress across a substantial depth gradient at FFS during the proposed period of performance.

What makes this approach achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain:

Corals provide the ecological and structural foundation of coral reef ecosystems. The architectural complexity of coral substrate creates a diverse range of microhabitats that profoundly influence biodiversity, productivity, and overall ecosystem functionality (Luckhurst and Luckhurst 1978; Wilson et al. 2007; Graham and Nash 2013). Furthermore, the extraordinary reef building capacity of scleractinian corals, enabled by their symbiotic partner *Symbiodinium*, is greatly influenced by physical characteristics of coral colonies. Therefore, understanding coral structural complexity is critical to the field of coral reef ecology. Building on previous work conducted by co-PI Burns will make this approach achievable and will enhance the current efforts to track temporal changes in coral community composition and 3D habitat complexity. Adding additional 3D monitoring sites around FFS will improve the ability to track changes occurring to coral reefs associated with thermal stress and bleaching. Understanding how corals respond to these stressors is critical for identifying vulnerable habitats and determining how changes in habitat complexity will affect fish assemblages and associated marine organisms. Creating 3D models of mesophotic habitats will also provide a valuable comparison of coral reef habitat dynamics across a substantial depth gradient. The findings from this study will advance our understanding of coral reefs throughout PMNM and the Main Hawaiian Islands (MHI). Using proven methodology (Burns et al. 2016, Couch et al. 2017) will make this approach achievable and will provide valuable results and findings for managers within the proposed period of performance.

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described:

Creating new sites in shallow areas will provide a more expansive baseline for tracking future changes to coral community composition and 3D habitat structure of shallow reefs surrounding the islands of FFS. These sites can be used in future surveys to track changes in coral reefs associated with thermal stress and coral mortality.

Theme 2a: *What characteristics define the abiotic features of the mesophotic zone surrounding FFS?*

Extent to which these questions will be answered by the end of the proposed period of performance:

Mesophotic coral ecosystems are loosely defined in terms of depth (~30–40m to ~150m) and associated fauna (dominated by coral, algae, or sponges). Although light attenuation has been considered a key abiotic factor defining the MCE zone and temperature is likely a key driver of community composition by depth, little else is known about the abiotic features of MCEs and their relative importance in characterizing this ecosystem. We will gather both water samples and environmental data across a range of depths. Water samples will be taken at 10-m depth intervals from 0–100 m for later analysis of key single-point water quality parameters. Temperature loggers will be installed at 10-m intervals from 1–100 m for long-term monitoring. Additionally, four data-logging instrument clusters will be installed at depths of 10 m, 40 m, 70 m, and 100 m for long-term monitoring of environmental parameters including conductivity, dissolved oxygen, PAR, pH and current at 10-minute time intervals. Deployment sites will be selected to coincide with previous survey transects that have been completed by NOAA PMNM and NOAA CREP divers which will provide a baseline biodiversity survey for future comparisons. Additionally, eDNA sampling will be conducted at each deployment site (discussed below in Theme 2c). Using multiple instrument clusters in combination with discrete sensors and samples will let us characterize key abiotic features of the mesophotic zone across a substantial depth gradient. All of the abiotic data will be made freely available online as soon as they are recovered from the loggers.

What makes this approach achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain (if applicable): Capturing robust data on core abiotic environmental features at a range of depths is critical for understanding how these features change across both depth (including both shallow and mesophotic coral ecosystems) and time (at scales ranging from within a single hour to trends across multiple years). Such data are important for monitoring both short-term and long-term trends not only

to record possible effects of climate change, but also to understand both inter- and intra-habitat variation and the possible effects on ecosystem-level questions. Temperature loggers deployed at 10-m intervals from the surface down to 100 m will capture data at 10-minute intervals for multiple years and will reveal diel, monthly, seasonal and multi-annual patterns, including both short-term dynamics (e.g., internal waves, thermoclines) and long-term trends (seasonal variation, climate change effects). Four instrument clusters deployed at 30-m depth intervals from 10–100m will log data on temperature, conductivity, dissolved oxygen, PAR, pH and current velocity at 10-minute time intervals for multiple years. These data will complement the temperature data to help understand how these features change in concordance with and independently of each other, as well as complement the taxonomic data provided by the eDNA surveys (discussed below in Theme 2c). Additional abiotic features analyzed from collected water samples will establish baseline information for long-term studies. All of these data will be particularly useful for comparing to analogous data from elsewhere within the PMNM as well as the MHI, and provide a pilot study for obtaining additional funding for additional long term monitoring sites across PMNM and MHI. This sampling strategy will provide the necessary information to address the extent to which mesophotic habitats may or may not serve as potential refugia for shallow-reef environments, and vice-versa. Within the scope of this project, we will recover, download and re-deploy the temperature loggers and instrument clusters to capture initial data and ensure proper functionality of equipment. These loggers and instruments will be again recovered, downloaded, and redeployed in the fall of 2018 during a NOAA mesophotic diving expedition (see Map 3).

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described: Temperature loggers and instrument clusters will need to be recovered, downloaded and redeployed in future years to monitor long-term trends. We expect this to occur during future NOAA mesophotic diving cruises and other research projects supported by NFWF and others. The preliminary results of this study will act as a pilot study that will allow us to make FFS a permanent station for long term monitoring and allow us to add sampling arrays at other locations throughout PMNM and the MHI.

Theme 2b: *Are wide-ranging carnivores a trophic link between shallow and mesophotic coral ecosystems? Should shallow and mesophotic coral ecosystems be managed as tropically distinct ecosystems, or together as a single unified coral reef ecosystem?*

Extent to which questions will be answered by the end of the proposed period of performance: Determining whether wide-ranging carnivores are a trophic link between shallow and mesophotic coral ecosystems at FFS will require 18-24 months during which we will: (1) Evaluate whether individual carnivores utilize both mesophotic and shallow habitats (telemetry tracking), and (2) Determine in which of these habitats carnivores forage (stable isotope analyses). Equipment deployment, predator tagging and tissue sample collection will occur during the summer 2018 research cruise. Stable isotope analyses will be conducted during the latter half of 2018 and first half of 2019. Recovery of fish tracking data will occur during a summer 2019 cruise. Analyses of fish tracking data and overall synthesis of tracking and stable isotope results will be completed by the end of 2019.

Discuss what makes these goals achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain (if applicable): Our goal is highly achievable because we have successfully implemented previous similar studies in PMNM and already have ongoing predator tracking research at FFS, positioning us to take full advantage of our existing telemetry infrastructure and local knowledge of this atoll. Our recent study conducted at Pearl and Hermes Reef (PHR) in PMNM (Papastamatiou et al. 2015a), showed that Galapagos sharks and giant trevally associated with mesophotic reefs also utilize shallow reef habitats. The bulk tissue and amino acid compound specific isotopic compositions of these predators suggest they primarily forage in shallow reefs, although approximately 35% of resources came from mesophotic reefs. Overall, results from PHR suggest mesophotic reefs are both foraging grounds and refuge habitats for mobile predators, and frequent movements between habitats suggest mobile predators may function as significant transporters of nutrients, particularly from shallow to mesophotic reefs. Our previous study provided important insights into trophic linkages between shallow and mesophotic habitats at PHR, but we don't know whether similar dynamics exist at FFS. Obtaining a better understanding of shallow-mesophotic trophic dynamics and energy flow at FFS is vital for understanding ecosystem function at FFS, and for elucidating whether shallow-mesophotic trophic dynamics are broadly similar across the predator-rich atolls within PMNM. Furthermore, we will use more recently developed analytical methods to estimate the amount of nitrogen being deposited in specific habitats. We are well-placed to answer these questions because we have an ongoing study of predator ecology at FFS with telemetry infrastructure already in place, and demonstrated ability to capture, biopsy (for isotope analyses) and tag coral reef predators in both shallow and mesophotic habitats at this atoll.

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described: In addition to the primary goals of the study, we will also determine how predator use of

mesophotic and shallow habitats varies over multi-year timespans using long-life (10-year) acoustic transmitters. We have already successfully tracked multiple individuals of several shark species over for 8 to 10 years, including some individuals at FFS, demonstrating that long-term tracking is feasible. Predators tagged at PHR as part of our published study (Papastamatiou et al. 2015a) are still being detected in both mesophotic and shallow habitats (last downloads September 2017). Understanding both short-term and long-term patterns of habitat use is important for effective management of coral reef predators. For example, our results will provide important insights into the ability of mesophotic reefs to act as 'refuge' habitats for larger predators. Mesophotic reefs could provide relief from fishing pressure due simply to their depth (e.g. spear fishers can't reach them), even in locations with large human populations (Slattery et al. 2011, Papastamatiou et al. 2015a).

Theme 2c: *How can we fill existing gaps in taxonomic research of the mesophotic zone?*
Extent to which these questions will be answered by end of the proposed period of performance:
Many species of algae and several species of fishes have already been collected at FFS and elsewhere at PMNM, but require taxonomic research to properly document and describe. We will 1) complete taxonomic descriptions to name previously discovered but undescribed algal and fish species; 2) conduct video surveys and collections of algae, fishes, and invertebrates across mesophotic depths using mixed-gas closed-circuit rebreathers; and 3) collect water samples across all depths for environmental DNA (eDNA) analysis to broadly characterize the biodiversity. These efforts will provide a robust understanding of biodiversity patterns across the full depth range of coral-reef habitat, which is critical to understanding community composition across different depth regimes, identify the potential for MCE habitats to serve as a refuge for shallow-reef habitats, and serve as a baseline for long-term monitoring of patterns of biodiversity in response to the effects of climate change, ocean acidification and other anthropogenic and natural processes.
What makes this approach achievable and important for the conservation and management of species and habitats in Papahānaumokuākea and the main Hawaiian chain (if applicable):
Characterizing the mesophotic fishes and algal flora of the Hawaiian Archipelago is critical to understand the biogeography of the tropical Pacific, to identify the constituents of native communities (enabling ecological study of these organisms), and to contribute to broader goals of worldwide biological enumeration. UH Botany currently has a MCE macroalgal collection of 921 specimens from the MHI and 866 specimens from the NWHI. Bishop Museum houses the world's largest collection of mesophotic fish specimens from the NWHI as well as the broader Pacific. However, aside from these groups and corals, very little is known of the other taxa that occupy this ecosystem. eDNA surveys will provide valuable resolution to the poorly studied groups within PMNM, as well as the potential to resolve cryptic species relationships. The proposed research will test hypotheses of phylogeography and distribution, endemism, and deep reef refugia, using additional phylogenetic, phylogeographic and systematic approaches. Macroalgae are most commonly described from intertidal and shallow subtidal marine environments worldwide, and are less well known from mesophotic habitats given the technical difficulties of accessing depths greater than 30 m. In clear tropical waters, light penetration can extend to extreme depths (> 150m; Kahng et al. 2010; Rooney et al. 2010; Spalding 2012; Pyle et al. 2016), suggesting that the majority of habitat available for the establishment and evolution of macroalgae is unexplored. Thus, our concept of species-level biodiversity and biogeography for macroalgae is very poorly known in clear, tropical waters. Recent access to submersibles and advances in technical diving technology have allowed extensive *in situ* collections at mesophotic depths throughout the Hawaiian Archipelago, and have revealed astounding results; over 45% of the mesophotic flora are new records for Hawai'i, or species new to science based on morphological comparisons with the shallow flora (Spalding 2012). Furthermore, in the two algal groups analyzed in detail to date using combined molecular and morphological approaches (the sea lettuces, or Ulvales, and the brown algal genus *Distromium*), 100% are new to science. Thus, detailed analyses using both morphological and molecular techniques are necessary to properly describe this mesophotic flora, and to test species-level hypotheses regarding biogeography, endemism, and deep reef refugia. Spalding et al. (2016) discovered that mesophotic Ulvales in Hawaiian waters form unique communities comprising four new species within the genera *Ulva* and *Umbraulva*, each with discrete geographic and/or depth-related distributional patterns, and with some biogeographic ties to New Zealand and Australia. These four species were not found in shallow water, and included the first record of the genus *Umbraulva* in Hawai'i (see Photo 5). Our molecular and morphological analyses of mesophotic collections of the brown blade-like alga, *Distromium*, indicated that three undescribed species are present in the Hawaiian flora, which can be partially differentiated based on island distribution and depth. Other novel diversity is currently being described from the brown algal order Sporochnales, including representatives of the genera *Sporochnus*, *Carpomitra*, and a new genus restricted to the mesophotic.
The fishes of the NWHI have been extensively explored in both shallow and mesophotic depths. These explorations have discovered the highest rates of marine endemism in the world (Kane et al. 2014; Kosaki et al. 2016), as well as

several new species (Pyle and Kosaki 2016; Pyle et al. 2016). Many fish specimens collected from MCEs since 2009 are housed at Bishop Museum. Several of these have already been identified as new species but await scientific description, and several others require more careful examination for morphological and genetic characters to determine their taxonomic identity and/or determine them to be species new to science. Through this project, these specimens will be carefully examined and analyzed, and specimens identified as being new to science will be properly described and named. This effort is important for documenting the complete extent of biodiversity inhabiting MCEs at FFS, both for its own sake, and to make more reliable comparisons with shallow-reef species.

Goals that will not be achieved within the grant period, but are anticipated as a direct result of the grant, should also be described: MCE collections of new species or records that are not described within the grant period will form the basis for future research on MCE diversity, and provide the baseline collections needed to acquire additional funding for species descriptions. Further eDNA collections are anticipated to be completed in the fall of 2018 during a NOAA mesophotic diving expedition, and other future expeditions and will be compared to the long-term abiotic monitoring discussed above providing to our knowledge the first long term monitoring station for both environmental parameters and biodiversity. These data will allow us to directly observe the result of how changes in the environment effect biodiversity through time. All specimens will be deposited at Bishop Museum, and preserved for both molecular and morphological analyses. #

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2. **Activities and Methods:** This project is divided into two main components: a field expedition to FFS, and follow-up research an analysis. The field expedition will involve thirteen days on-site at FFS aboard the chartered vessel *Searcher*, which includes berths for up to twelve researchers, and support of wet-diving operations and shore-based crew (see attached letter of support). The bulk of the data-gathering portion of this project will take place during the field expedition, which we have planned for the summer of 2018. Following the field expedition, new data will be combined with existing data and synthesized for analysis, interpretation and publication. This portion of the project will take place over the remainder of 2018 and into early 2019.

Theme 1: Understanding the potential impacts of predicted environmental stressors on priority species.#

Activity 1: Historical reconstruction of beach erosion and accretion during the recent Holocene (Theme 1a)#

We propose to visit at least one, and time permitting, two or three of the sandy islands of FFS. We will dig three to six strategically-sited trenches in each island to expose the interior stratigraphic architecture. Key sedimentary units will be sampled for age (radiocarbon) and composition analysis. The island surface will subsequently be restored to an undisturbed state. Being careful to avoid living coral, we will sample short cores from the surrounding reef platform using a small hand-held drill. The age relationship of the fossil reef platform and key sedimentary units within the islands will be interpreted for island origin and subsequent evolution. Composition and age of sand from the trenches will be compared to surface samples collected on the surrounding sea floor. These will be analyzed to assess changes in sediment source that may characterize recent history.#

We will also collect topographic data to construct a digital elevation model (DEM) of each island that we visit. This will be useful for future monitoring and to augment LiDAR data obtained by the USGS in 2010. We will collect contemporary island topography data from drone imagery and Structure-from-Motion (SfM), a low-cost alternative to LiDAR that derives 3D structure from sets of 2D images. Including RTK-GPS control points with drone surveys will allow us to georeference our model of the island. A vertical datum will be derived from RTK-GPS control points tied to a local short-term tide gauge that we will install for the duration of the field work. The DEM will be used in numerical modeling (Program Priority 1b) to simulate island response to SLR. It will also be used to orthorectify imagery we may use to document historical changes.#

Activity 2: Predictive modeling of environmental stressors impacts to nesting and foraging habitats for sea turtles, monk seals and birds in Papahānaumokuākea (Theme 1b)#

As part of the proposed work, the existing model will be augmented with a dedicated wave refraction/focusing/dissipation module to simulate transport on reef-fronted islands and atolls. Model scenarios will explore how SLR and perturbations to the island's shape and nearshore bathymetry will affect the convergence or divergence of wave-driven sand transport, causing the islands to accrete or erode, respectively. We hypothesize that the current island configuration results from transport convergence zones. However, it remains unclear as to whether sand production from the reef is large enough to support island emergence and growth under static (or even rising) mean sea level conditions, or whether emergence is only possible during falling sea levels. Models of paleo-sea level and morphologic evolution, as revealed by the proposed field work, will help to understand these processes and to predict the island's fate under scenarios of future SLR. Finally, the scenarios of island morphologic change will be combined with surveys of habitat thresholds to understand the viability of the habitat for amphibious marine life and nesting seabirds in FFS and MNM.#

Activity 3: 3D photogrammetry and modeling of structural changes at FFS to determine how thermal stress and coral bleaching impact coral community composition and 3D habitat complexity (Theme 1c)#

High-resolution (mm-scale) 3D reconstructions will be generated at newly established survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of each plot. Scale markers will be placed across the study area to ensure model precision and accurate georeferencing. The resulting photographs will be digitally reconstructed using SfM modeling software. SfM software generates 3D digital surface models in three primary stages: 1) photo alignment, 2) geometry building, and 3) texture building. This process will create 3D point clouds that result from the projection and intersection of pixel rays from the different positions and oriented images in 3D space (Clayput et al. 2016, James et al. 2017). These points are then triangulated and rendered with the original high-resolution imagery to create textured 3D mesh and georeferenced digital elevation models, which can be used to quantify metrics of 3D structural complexity (Burns et al. 2015, Leon et al. 2015, James et al. 2017, see Photo 3). The 3D reconstructions will be exported as DEMs and orthophotos to ArcGIS topographic software (ESRI Inc., USA) for quantification of coral health, community composition and metrics pertaining to structural complexity (Burns et al. 2015). All new and previously generated 3D reconstructions at FFS will analyzed in this manner.#

The 3D models generated by co-PI Burns in 2015-17 at established long-term monitoring sites (see Map 2) will be analyzed with Cloud compare software (CloudCompare v 2.6.1) to quantify temporal changes occurring to 3D habitat complexity and volumetric properties of corals (see Photo 4). 3D point clouds derived from each model will be aligned using an Iterative Closest Point (ICP) algorithm. To examine temporal differences in 3D structure the Multiscale Model to Model Cloud Comparison (MC32) algorithm will be used to identify and quantify areas exhibiting statistically significant change (Burns et al. 2016, see Photo 4). Quantifying temporal changes will elucidate the impacts of reduced health, thermal stress, and disturbance-induced mortality on structural characteristics that are known to drive biodiversity and ecosystem function on coral reefs.#

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Theme 2: Increasing understanding of the mesophotic zone #

Activity 1: Data Logger Deployment (Theme 2a)

We will deploy a series of sensors and data loggers across a range of depths during closed-circuit mixed-gas rebreather dives to record key environmental parameters. Temperature loggers (TidbiT v2) will be deployed on the bottom at 10-m intervals to a depth of 150 m along a transect, the location of which will be determined through analysis of bathymetry and coordination with other components of this project. These loggers will provide information on internal waves and other dynamic thermal patterns. Four instrument clusters will be deployed along the same transect by divers at depths of 10 m, 40 m, 70 m and 100 m. These arrays, AML Oceanographic METREC-X multi-parameter instrument clusters with UV Biofouling Control (https://amloceanographic.com/) record temperature, conductivity, current, PAR, pH, and dissolved oxygen daily for periods of up to 3-5 years. These data loggers will be deployed during the research cruise on this project, and recovered, downloaded and redeployed after several days to capture initial environmental parameter values and verify correct functionality. The loggers will be recovered, downloaded and redeployed again by technical divers later in the year during a scheduled NOAA mesophotic diving cruise in the fall of 2018, providing several months of data. These data will be used to characterize the abiotic features of MCEs compared to adjacent shallow coral reefs, and allow more detailed modeling of current and future oceanographic conditions both within MCEs, and between MCEs and shallow reefs. All data will be made publicly available online after downloading from the loggers.

Activity 2: Tracking coral reef predator movements between deep and shallow coral reef habitats at FFS (Theme 2b)

We will use state-of-the-art acoustic monitoring to track movements of sharks and jacks between mesophotic and shallow coral reef habitats at FFS to determine whether wide-ranging carnivores provide a trophic link between shallow and mesophotic coral ecosystems. This will increase our understanding of the mesophotic zone, and help managers determine whether shallow and mesophotic coral ecosystems should be managed as trophically distinct ecosystems, or together as a single unified coral reef ecosystem. We will supplement these tags with sensors which measure activity and swimming depth, so that we can directly compare behavior between habitats (e.g. are they more active/foraging while on shallow reefs?). This method involves capturing and implanting predators (sharks and jacks) with long-life (10 year) acoustic transmitters, and then tracking their subsequent movements using underwater receivers deployed in both shallow and mesophotic habitats. Once deployed, receivers can listen continually for individually-coded transmitters for up to 18 months without intervention. This is a well-established method that is widely regarded as the most appropriate for long-term studies of fish movements and habitat use (e.g. Heupel et al. 2006, Heupel & Webber 2012). The major advantages of acoustic monitoring include the ability to simultaneously monitor the movements of multiple tagged individuals using a remote system of receivers that have minimal impact on the environment and leave no trace when removed. Co-investigators Meyer and Papastamatiou have decades of

experience using this technology, and have published dozens of papers based on this methodology, including several previous publications on predator movements at FFS (Meyer et al. 2007a,b, Meyer et al. 2010, Papastamatiou et al. 2013). All three co-investigators (Meyer, Papastamatiou, Popp) collaborated on a combined acoustic monitoring and stable isotope (see Activity 2 below) study to determine predator trophic linkage of shallow and mesophotic habitats at PHR (Papastamatiou et al. 2015a). We are proposing to repeat the successful PHR study at FFS, and augment the methods by deploying small video cameras and accelerometers on predators to directly document habitat use and foraging activities. These cameras are deployed on predators for several days before releasing and floating to the surface for recovery. We will fit a sub-set of sharks and trevally with acceleration/depth sensing acoustic transmitters (Vemco V13AP). When receivers detect these tagged animals, they also record the activity and swimming depth of the predator, so that we can compare behavior of predators in different habitats (Papastmatiou et al. 2015b). Co-investigators Meyer and Papastamatiou have been using predator-mounted camera and accelerometer technology for almost a decade (Nakamura et al. 2011, 2015, Papastamatiou et al. 2015b). Predator tagging, camera and receiver deployments will be completed during the 2018 research cruise. Camera footage will also be recovered during the 2018 cruise. Underwater receivers will monitor and record predator movements for ~12 months before being recovered and downloaded during a 2019 research cruise (we have successfully maintained continuous acoustic monitoring coverage at FFS since 2005). Analyses of predator movement data will be completed by the end of 2019.

Activity 3 – Using stable isotope ratios to assess predator foraging habitats and evaluate nutrient transfer (Theme 2b)

We will use stable isotope analyses (bulk tissue and amino acid compound specific) to infer predator foraging habitats and evaluate the direction of nutrient transfer. These analyses will be validated using the predator mounted cameras and acceleration transmitters, which reveal habitat use and foraging activities. This will increase our understanding of the mesophotic zone by producing a more complete understanding of the trophic dynamics connecting or separating shallow and deep coral reef habitats, and help managers to determine whether shallow and mesophotic coral ecosystems should be managed as trophically distinct ecosystems, or together as a single unified coral reef ecosystem. This method involves taking small, non-lethal tissue biopsies from sharks and jacks used in the acoustic tracking study (and reference samples from prey) and measuring their carbon and nitrogen isotopic ratios to determine likely prey sources. $\delta^{15}N$ values at the base of the food web and an animal's trophic position are captured in amino acid compound-specific nitrogen isotope analyses (Papastamatiou et al. 2015a, Ohkouchi et al. 2017), whereas the $\delta^{13}C$ values of the essential amino acids record the source of carbon of primary producers from the foodweb from which they feed (Larsen et al. 2013). Benthic algae are the major carbon source for shallow reef food webs in PMNM (Hilting et al 2013), whereas MCE fish assemblages are high in planktivores and low in herbivores (Slattery et al. 2011, Kahng et al. 2014, Kane et al. 2014). These differences are captured well by the isotopic compositions of amino acids, hence it is possible to resolve the source contributions to predator diet on shallow versus MCE habitats (Papastamatiou et al. 2015a, Bradley et al. 2016). We can use the methods of Nelson et al 2013, to estimate the amount of primary productivity being transported between locations, in particular the quantity of nitrogen transferred from shallow to mesophotic reefs. Co-investigator Popp has nearly four decades of experience in stable isotope analyses, and we previously used these well-established techniques to determine whether mobile predators forage in shallow or mesophotic habitats at PHR (Papastamatiou et al. 2015a). Tissue samples will be collected at FFS during the summer 2018 research cruise and stable isotope analyses will be completed by Spring 2019.

Activity 4: Water Sampling (Themes 2a, 2c)

We also collect water samples at 10-m depth intervals from 0–100 m during mixed-gas closed-circuit rebreather dives in conjunction with the biotic surveys discussed below. These samples will be used for two purposes. First, they will be analyzed for key abiotic characteristics such as temperature, pH, turbidity, chlorophyll, conductivity, dissolved oxygen, and salinity that can be used to create predictive models to identify potential MCE habitat, aid in understanding the impacts of future climate change, and assess similarities and differences between shallow and MCE zones. In addition, these samples will be analyzed for environmental DNA (eDNA). By identifying a spectrum of biodiversity, eDNA analysis surveys the entire community (rather than specific, targeted taxa). We will compare eDNA data collected at FFS with survey data collected through NOAA's Pacific Ramp Program, and PMNM mesophotic surveys to both compare results of each method and ground truth the eDNA data. This will provide a critical baseline in assessing biodiversity composition across multiple depths.

Activity 5: MCE Biotic Surveys (Theme 2c)

Divers using mixed-gas closed-circuit rebreathers will conduct visual and video surveys of benthic habitat at depths of 0–100 m. These surveys will be focused on documenting occurrence records of as many species of fishes, invertebrates and algae as possible. Results from these efforts will complement existing data at depths from 0–90 m at FFS, to improve our understanding of patterns of biodiversity across the entire coral-reef depth range. This understanding is critical for determining the extent to which MCEs may or may not serve as refugia for shallow coral-reef ecosystems (and vice versa), and also for helping to define the specific conservation needs related to MCEs (e.g.,

the tendency for MCEs to harbor proportionally more endemic species). Where appropriate and feasible, specimens will be collected for later taxonomic analyses.

Activity 6: Taxonomic Research (Theme 2c)

Many species of algae and several species of fishes have already been collected at FFS and elsewhere in the NWHI, but require taxonomic research to properly document and describe (see Photo 6). A large number of fish specimens collected from MCEs during technical diving activities since 2009 are housed at Bishop Museum. Several of these have already been identified as new species, and several others require more careful examination for morphological and genetic characters to determine their taxonomic identity and/or determine them to be species new to science. Through this project, these specimens will be carefully examined and analyzed, and specimens identified as being new to science will be properly described and named. This effort is important for documenting the extent of mesophotic biodiversity at FFS, both for its own sake and for more reliable comparisons with shallow-reef species. For macroalgal molecular analyses, the use of short DNA sequences that allow differentiation of samples at the species level (aka DNA barcoding; Hebert et al. 2003) allows unknown individuals to be assigned to species and enhances the discovery of new species (Stoeckle 2003, Moritz & Cicero 2004), both of which are fundamental aims of the proposed research. A DNA barcoding approach will be used to characterize algal specimens based on three independent molecular markers for each algal lineage, and morphological / anatomical identifications will complement this approach to flag taxa for in-depth systematic study using more character-rich phylogenetic markers. The results of the DNA barcoding will be used to inform subsequent phylogenetic analyses and the subsequent morphological analyses. Taxa that are shown to have unexpected patterns of molecular diversity, or that represent novel diversity will be targeted for more in-depth characterization with longer molecular regions, and comparisons with related species from other regions of the world.#Over the past several years, we have processed 866 specimens of mesophotic algae collected in the PMNM by NOAA researchers, and 921 specimens collected from the MHI during various surveys. For all specimens, mounting on archival-grade herbarium paper, sub-sampling for molecular analyses (desiccation in silica gel or frozen), and fixing for morphological analyses in formalin, have been completed. To date we have extracted DNA from ca. 65% of specimens, and have analyzed several lineages of green and brown algae for detailed systematic analyses (Ulvales, *Distromium*, and Sporochnales). The proposed research will include DNA extractions for the remainder of specimens, and the processing, extractions, and DNA barcoding of new samples collected from FFS, as well as full systematic study of select algal lineages.

3. **Tracking Metrics:**

Project Activity	Metric	Challenges/Limitations
Historical reconstruction of beach erosion and accretion	No. of islands surveyed; No. of trenches sampled; No. of fossil reef cores	Weather conditions, site accessibility, and presence of emergent reef
3D reef surveys	No. of shallow sites surveyed	Weather conditions and site accessibility during the expedition
Temporal analysis of 3D reef models at LTM sites	No. of existing models analyzed temporally to detect 3D change	
Establishment of new 3D monitoring sites	No. of sites established and surveyed for long-term 3D monitoring	
Analysis and synthesis of Theme 1 data	Project report completion and No. of additional publications	
Abiotic features of mesophotic habitats	No. of features and data points logged across multiple depths	Only one week of data during cruise; long-term data acquired on a planned future NOAA cruise and future cruises
eDNA sample analysis	No. of samples collected and sequenced.	Weather conditions and sample contamination
Predator tagging (acoustic)	No. of individuals successfully tagged	Weather conditions and site accessibility during the expedition
Predator tagging (camera)	No. of individuals successfully tagged No. of cameras recovered	
Predator tissue sampling	No. of tissue samples collected	
Acoustic receiver deployment	No. of receivers deployed	
Acoustic receiver recovery	No. of receivers recovered	
Stable isotope analyses	No. of samples completed	
Taxonomic research and analyses of mesophotic algal and fish speciments	No. of samples documented, processed and described	Weather conditions limiting new collections
Analysis and synthesis of Theme 2 data	Project report completion and No. of additional publications	

4. **Project Team:**

Theme 1: Understanding the potential impacts of predicted environmental stressors on priority species

Charles Fletcher (SOEST, UHM): Lead Investigator for Theme 1 Dr. Fletcher is Professor of Geology and Geophysics and Associate Dean at the School of Ocean and Earth Science and Technology at the University of Hawaii at Manoa. He has led several investigations of island evolution, beach processes, sea level history and impacts, and carbonate sedimentary processes during a career extending over 30 years and documented by over 100 peer-reviewed publications. He has awarded over 25 graduate degrees to students who have passed through his lab and is well prepared to successfully complete the research described. Dr. Fletcher has brought over $10M in external funding to the University of Hawaii in support of research directed at improving understanding of fundamental and applied aspects of coastal processes, geomorphology, and stratigraphic evolution.

Sean Vitousek (UIC): Co-Lead for Theme 1 Dr. Vitousek is a former student of Dr. Fletchers, who is currently Research Assistant Professor of Environmental Fluid Mechanics at University of Illinois at Chicago. He has developed a model that integrates longshore and cross-shore sediment transport processes by waves and sea-level rise to predict shoreline change on a variety of timescales. The model uses an extended Kalman filter data-assimilation technique to auto-tune model parameters and improve confidence in long-range shoreline predictions. This is the only process-based, observation assimilating, shoreline evolution model in the scientific literature. Sean has extensive experience working on continental and insular carbonate shorelines and has several notable publications documenting this work. Sean is an experienced ocean and coastal modeler who brings extensive quantitative expertise to this project.

Haunani Kane (SOEST, UHM): Cultural Liaison Haunani is a native Hawaiian PhD student being advised by Dr. Fletcher. Her publications include investigations into reef island stratigraphic architecture and coastal geomorphic evolution resulting from Holocene sea level change. She is a navigator with the Polynesian Voyaging Society and navigated the Hokulea on the leg of the Malama Honua voyage that raised Rapa Nui from the sea. Haunani will enter training for her role as cultural liaison. She will also be responsible for modeling the evolution of FFS reef islands including radiocarbon dating, sedimentary composition, and stratigraphic analysis.

Kammie Tavares (SOEST, UHM): Graduate student Kammie is a native Hawaiian undergraduate student in the SOEST Global Environmental Science degree. Her senior thesis under Dr. Fletcher models future beach loss at critical habitat sites for sea turtles and monk seals on Oahu. She has experience in reef island excavation, coastal process modeling, and aerial photogrammetry.

Kristian McDonald (SOEST, UHM): Graduate Student Kristian McDonald is a native Hawaiian graduate student under the advisement of Dr. Fletcher. His MS thesis involves modeling historical and future shoreline change on the island of Kauai and construction of an online ARC GIS database for use by the County of Kauai in managing their set-back ordinance and for development of policies to adapt to sea level rise. Kristian uses drones to document beach changes on Oahu and will be pilot for drone collection of data to build a digital elevation model of field sites at FFS.

Jade Delevaux (SOEST, UHM): Geospatial technician Dr. Jade Delevaux is a geospatial analyst in Dr. Fletchers research group. She lead author of several peer-reviewed publications modeling watershed to coastal zone sediment, groundwater, and biogeochemical linkages. She is experienced in using GIS, remote imagery, and field observations to model coastal processes. She serves on this project as technical geospatial lead and important field crew for the numerous field activities that are planned.

John Burns (University of Hawaii): Dr. Burns has over a decade of experience studying coral reef biology and ecology. He is an expert and pioneer in underwater 3D modeling of coral reef ecosystems, and for the last 6 years has been conducting coral health and 3D reef surveys throughout the PMNM. Dr. Burns published the methods described in this paper for quantifying 3D characteristics of coral reefs and measuring temporal change (Burns et al. 2015, 2016). Dr. Burns has also recently co-authored a paper to specifically address how mass bleaching in the PMNM has altered coral community composition and 3D habitat complexity (Couch et al. 2017).

Theme 2: Increasing understanding of the mesophotic zone

Richard L. Pyle (Bernice P. Bishop Museum): Pyle has a long history of exploration and documentation of MCE fishes using closed-circuit mixed-gas rebreathers and other technologies across the Pacific, and within the NWHI going back to 1990 (including annual NOAA MCE technical diving cruises to the NWHI going back to 2009). He has served as an author on many publications relevant to this project, including a checklist of fishes for Midway Atoll, several new fish species descriptions from the NWHI, and a robust archipelago-wide checklist of fishes currently nearing completion (among others). He is also an expert in biodiversity data management. He will oversee taxonomic work on fishes, including both in-situ surveys and new fish species descriptions. Pyle will also assist collection of data related to abiotic features.

Joshua M. Copus (Hawaii Institute of Marine Biology): Copus is a graduate student at the University of Hawai‘i, expecting to complete his PhD work on MCE fishes in 2018. He has extensive experience exploring MCEs using

closed-circuit mixed-gas rebreathers throughout the Pacific and in Hawai‘i (including several expeditions to the NWHI), and is an expert on interpreting genetic data for biogeographic, phylogenetic and taxonomic purposes. He will oversee the collection of data on abiotic features and associated water samples, coordinating the eDNA analysis and interpretation, and conducting taxonomic work (both in-situ surveys and new fish species descriptions).

Heather L. Spalding (University of Hawaii): Spalding is a post-doctoral scholar at the University of Hawai‘i and a leading world expert on mesophotic macroalgae. She has over 22 publications on macroalgal diversity, ecology, and physiology, and has participated in over 20 MCE cruises using either technical diving and/or *Pisces* submersibles in the MHI and off central California. She will oversee the collection and taxonomic work on macroalgae, including field collections, video analyses of benthic cover, and molecular and morphological analyses.

Alison R. Sherwood (University of Hawaii): Sherwood is a leading world expert on algal diversity and the description of novel species, with over 60 publications based on the Hawaiian flora, and 17 years experience working with the flora. She will jointly oversee the taxonomic work on the macroalgal collections, lead the molecular analyses, and processing of specimens in the field. The Sherwood Laboratory at the University of Hawai‘i has undertaken two previous NSF-funded algal biodiversity surveys, which included characterization of thousands of diverse algal collections. Both prior biodiversity surveys led by the Sherwood Lab involved strong collaboration with researchers at the Bishop Museum, as well as taxonomic collaborators on the US mainland and elsewhere.

Carl Meyer (University of Hawaii): Dr. Meyer has twenty-five years of experience in fish telemetry, and over a decade of experience studying predator movements in Papahānaumokuākea.

Yannis Papastamatiou (Florida International University): Papastamatiou has seventeen years of experience in fish telemetry, and over a decade of experience studying predator movements in Papahānaumokuākea.

Brian Popp (University of Hawaii): Popp has 38 years of experience in stable isotope studies and for the last 10 years has been a world leader in the application of carbon and nitrogen isotopic compound-specific isotope results to marine ecology. Meyer, Papastamatiou, and Popp recently published a study of predator-mediated trophic linkages between mesophotic and shallow coral habitats at PHR (Papastamatiou et al. 2015) that provides a valuable comparison and framework for work proposed at FFS. Meyer & Papastamatiou have collaborated on predator tracking studies at FFS using for over a decade and have intimate knowledge of the local environment at this atoll, and a demonstrated ability to perform successful acoustic monitoring studies at this location (Meyer et al. 2007a,b, Meyer et al. 2010). Popp and colleagues resulted published a study using results of amino acid compound specific isotope analyses of mesophotic and shallow reef fish in the MHI to evaluate the differences in trophic ecology and flow of carbona nd nitrogen in these populations. These results placed important constraints on models used to predict trophic positions of ecosystem components that are widely used to manage shallow and mesophotic reef fish populations.

****1-2 berths will be available for communications and cultural team members appointed by the Advisory Committee if deemed necessary for this proposal***

5. **Collaboration, Communication and Cultural Considerations**:

Collaboration

All PIs on this project have collaborated on previous research expeditions to the PMNM. We will coordinate with monthly meetings to ensure adequate planning and preparation occurs prior to the expedition and that we stay on-track to achieve our project goals. One exceptional component of this project is how the overlap among theme areas will promote synergistic collaboration and produce better products than if each theme was addressed individually. For example, the SLR data and predictions from theme 1a and 1b will help predict impacts to coral reefs, which is being assessed in 1c. The 3D modeling methods will be applied to imagery collected for theme 2, which will integrate results from deep sites with shallow sites to improve our understanding of coral ecology at FFS across spatial and temporal gradients. The abiotic and biotic characterization of theme 2 and analysis of food webs will help distinguish how mesophotic habitats serve as refugia for shallow sites, which will enhance our overall understanding of benthic habitats in the PMNM. Each set of activities will provide results that will benefit the research goals of all activities, and serve to collectively support management and conservation of marine habitats in the Hawaiian Archipelago. The project team has an excellent track record for producing scientific products and disseminating data, and have all worked together on prior projects. This group is poised to produce excellent results from this proposed project.

Communication

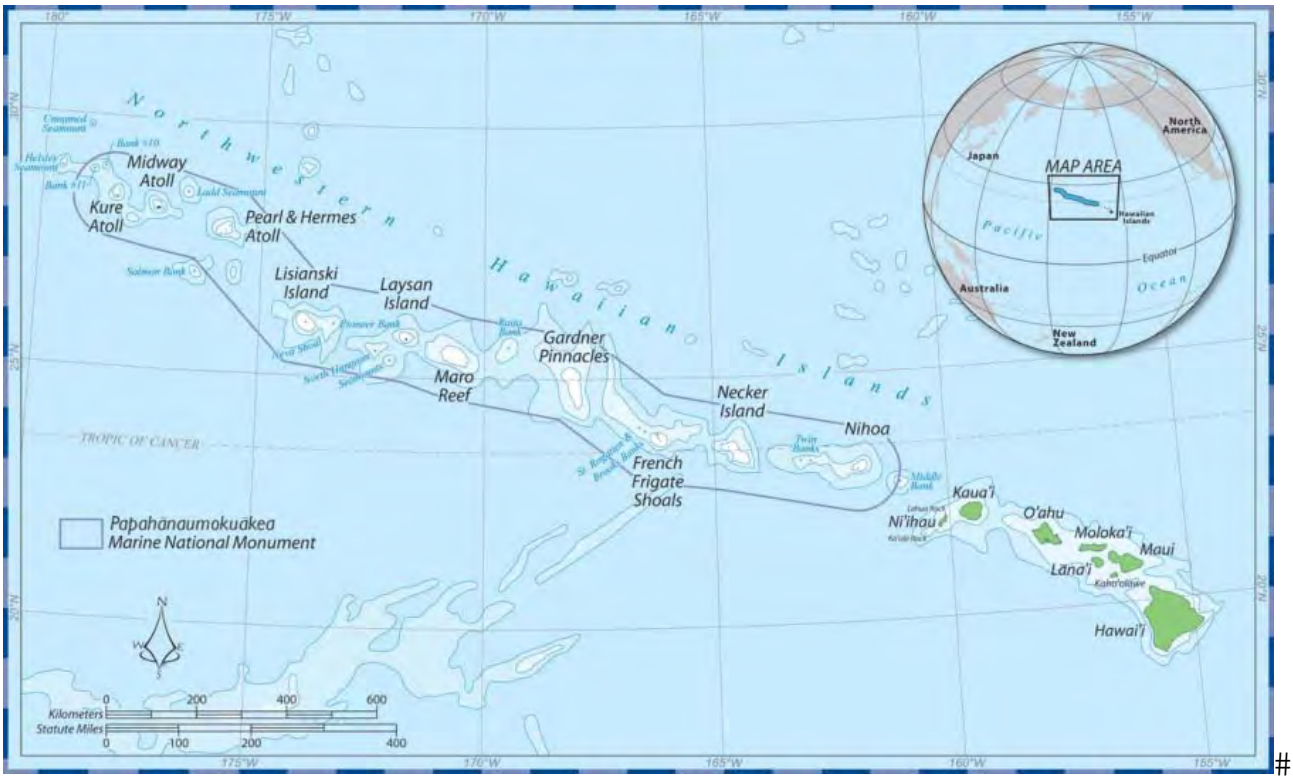
The Coral Health Atlas (http://coralhealth.uhh.hawaii.edu/) is designed to provide interactive access to coral reef data and ecosystem characteristics at study sites throughout the Hawaiian Archipelago. This website has been developed by co-PI Burns, and the research aim, results and underwater imagery from this study will be integrated into the user-friendly interactive map of Coral Health Atlas. Displaying an array of data visualization products in an exciting and

interactive manner will have excellent benefits for the public as well as K-12 education programs. Multiple K-12 programs on Hawai‘i Island and Maui have already used the website for class projects. Hosting 360 panoramic video and 3D reef models further engages students by allowing them to virtually explore the underwater world of their islands. The Coral Health Atlas is securely hosted on UHH servers and maintained by UHH personnel, thus ensuring the website can be updated and used for outreach and research purposes in the future. This website will help to rapidly disseminate findings from this study and raise public awareness about our research.
The PIs will develop technical reports and presentations for managers to rapidly make our findings available. We will communicate openly with agency personnel and other groups working in PMNM to ensure our results and findings are available to any interested parties. In addition to sharing our results and findings through technical reports and presentations, we will produce publications for peer-reviewed scientific journals. Our goal is to produce high quality products that will benefit conservation and management of marine resources throughout the Hawaiian Archipelago.

Cultural Considerations
Prior to departure the science team will meet to discuss the traditional use and place names of Papahānaumokuākea. We will go over a series of oli that enable us as kānaka (people) to acknowledge our journey from ao to pō, and the knowledge that we seek as researchers. Our protocol plan will involve reciting oli and pule when we cross into (and depart) Papahānaumokuākea, as we approach (and depart) Lalo (French Frigate shoals), and prior to starting work each day. In addition, we will have group discussions centered around huli ‘ia, a tool developed by Na Maka o Papahānaumokuākea, to document environmental observations experienced through all of our senses while in Papahānaumokuākea. Researchers participate in discussions contributing their observations sharing noticeable dominant characteristics of lani (sky), honua (earth), and kai (ocean) as a way to characterize that time (season) and space (Papahānaumokuākea). This broader holistic view will support our research team in intimately understanding moods and characteristics of Papahānaumokuākea and through this documentation process, supports the development of best practices enabling communities to adjust and adapt their activities to assist in mālama ‘āina (care for the land).

Education plan
Knowledge and lessons learned at Lalo will be shared through a variety of different methods listed below:
- During the cruise, team members will come prepared with evening talks to educate each other and broaden the presentation of our results in each of our classrooms at the University of Hawai‘i.
- Through a partnership with the Office of Hawaiian Affairs, a short summary of the preliminary results, including photos and video collected during the research cruise, will be shared with the Hawaiian community.
- Team members will host an interactive booth at the SOEST Open House, a biannual event that is held over the course of two days and attracts over 6,000 visitors, predominately local elementary to high school age students.
- Data gathered from the research cruise will be adapted for educational materials made available to local schools in Hawai‘i as well as across the U.S. affiliated Pacific Islands via the Pacific Resources for Education and Learning (PREL).
- Each team will produce a series of peer reviewed publications, and present results at local and international conferences.
- We will collaborate with traditional Hawaiian nomenclature experts and the PMNM in developing Hawaiian species names for new species of culturally important *limu* (macroalgae) species. Examples of past collaborations include the new species *Ulva ohiohilulu*, *Ulva iliohaha*, *Umbraulva kaloakulau*, and *Umbraulva kuaweuweu* (Spalding et al. 2016).

6. **Other (Optional):** Provide any further information important for the review of this proposal.



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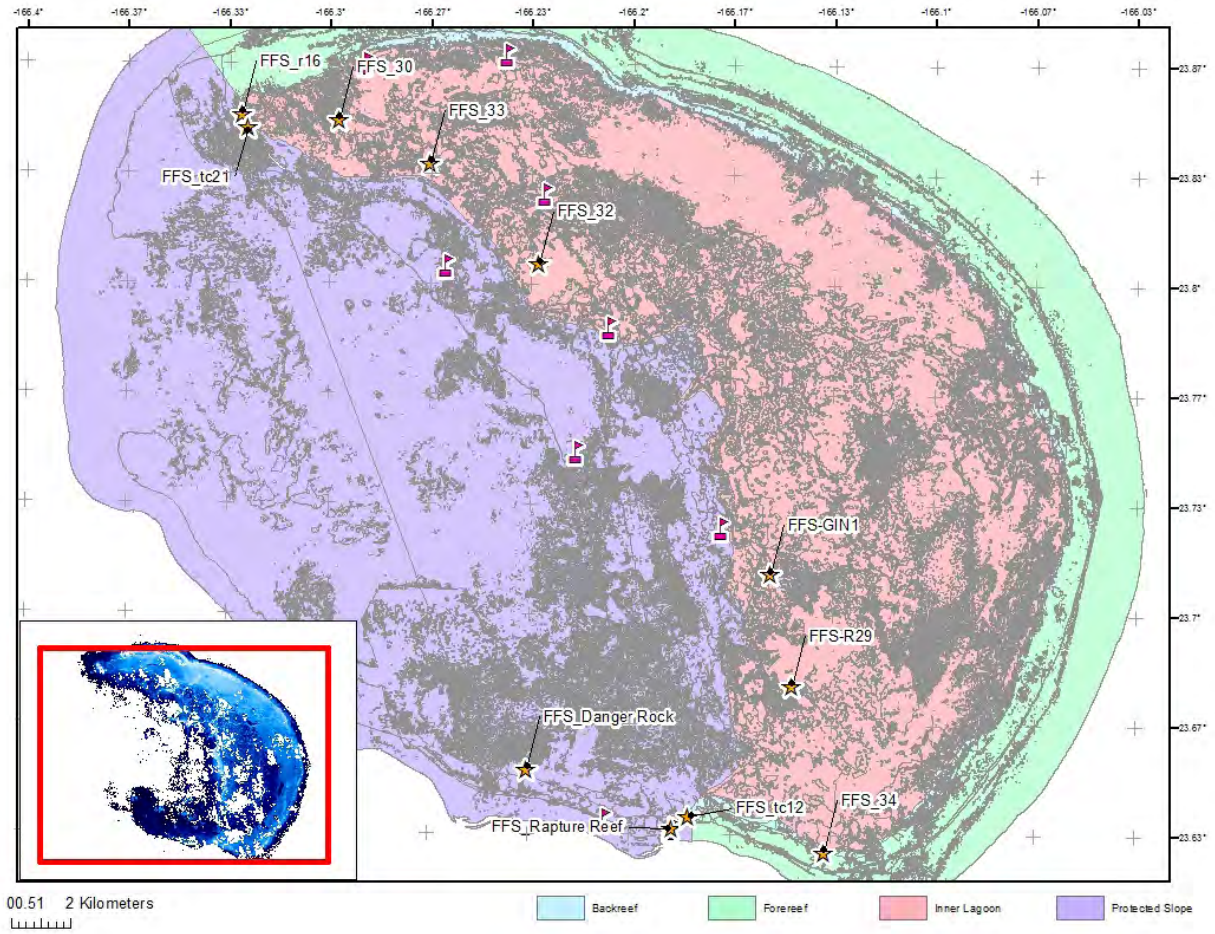
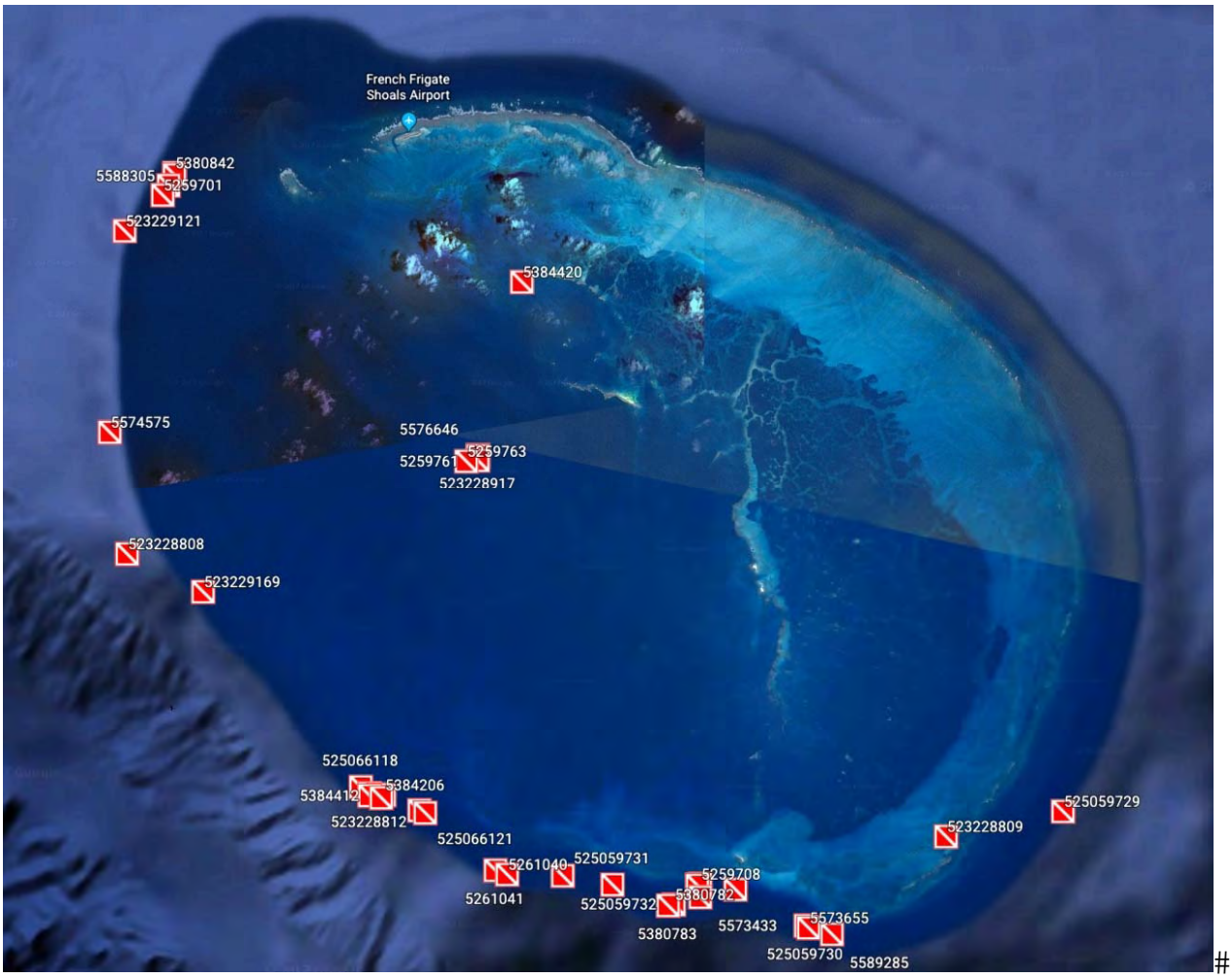
Map 1. *Site map of the Northwestern Hawaiian Islands.*



Map 2. *Long-term monitoring sites used for 3D characterization of coral reefs at French Frigate Shoals. The eleven sites (indicated with star symbols) have been monitoring using 3D reconstruction techniques since 2015. These sites will be revisited for this proposed project, and additional sites will be added in locations where corals have exhibited high levels of bleaching.*



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Map 3. *Sites used for surveys of mesophotic coral ecosystems. The existing survey data from these sites will be used to identify the optimal locations for the activities proposed in the proposal narrative.*
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Photo 1. *Whale Skate Island at French Frigate Shoals has disappeared over the past 4 decades: (a.) 1963, (b.) 2002. Is this to be the fate of other reef islands at FFS?*#

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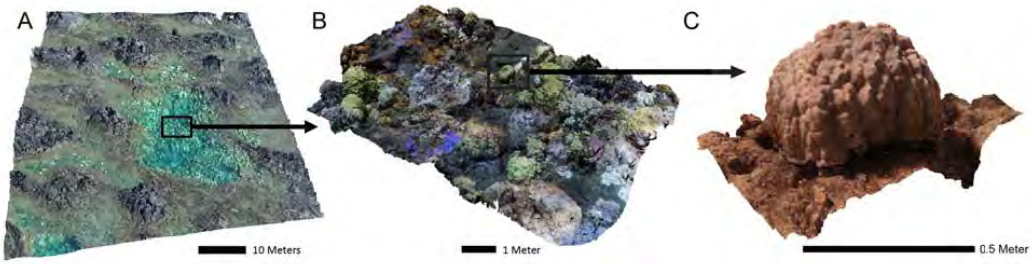

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Photo 2. *Example of 3D reef reconstructions at multiple scales. (a) Oblique view of large area of reef substrate surveyed with drone imagery showing (b) Oblique view of a 3D model of coral colonies (mm-resolution) and (c) an individual colony (mm-resolution) reconstructed from this same location surveyed with single lens cameras.*

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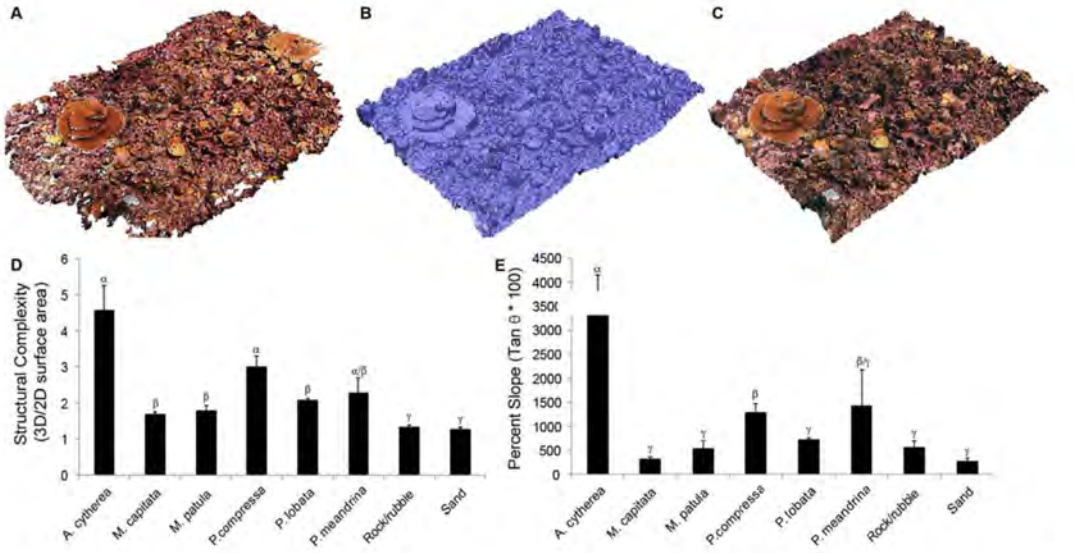

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Photo 3. *SfM software detects invariant features and uses intrinsic and extrinsic camera parameters to reconstruct a (a) 3D point cloud which is (b) georeferenced triangulated into a solid mesh which can be (c) textured using the high resolution photographs. The resulting model can be spatially analyzed to (d,e) extract 3D structural metrics for each benthic feature such as structural complexity and slope (figures from Burns et al. 2015).* #

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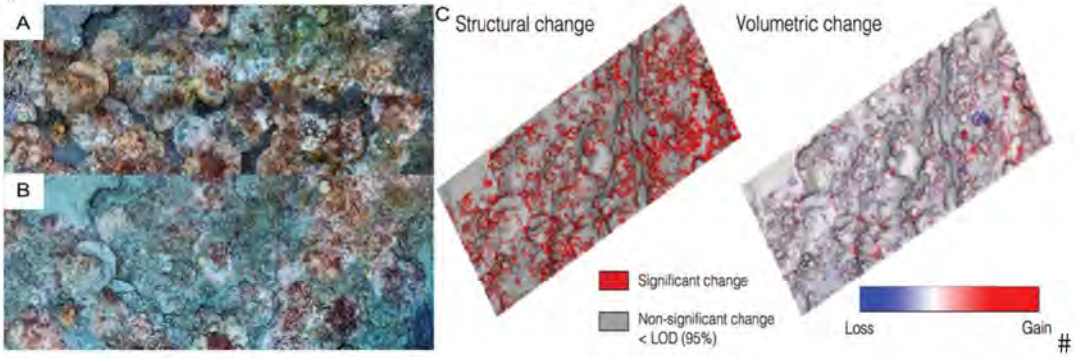

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Photo 4*. Orthophoto-mosaics of a 25 x 15-m study plot in Waiʻōpae, HI. Each pixel contains x,y,z positions. The two mosaics highlight the ability of this technique to visually and quantitatively analyze coral community composition and 3D reef structure before (a) and after (b) multiple disturbance events. The 3D models can be compared to (c) quantify and statistically analyze changes in volume and structural complexity.* #

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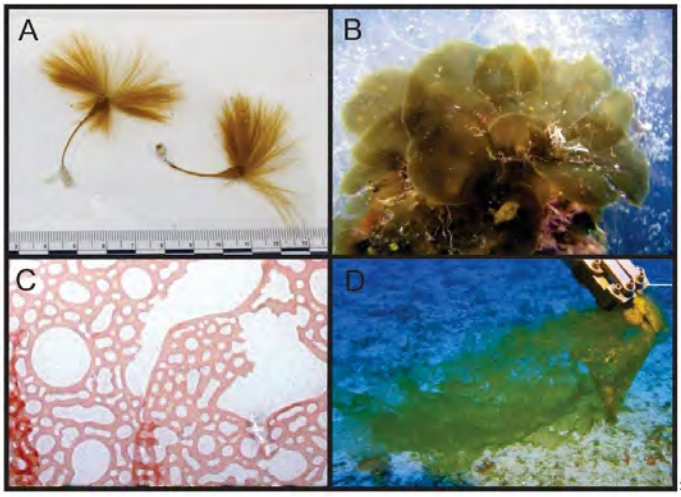

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Photo 5. *New algal species from the Hawaiian mesophotic. A) New species from a new proposed genus within the Sporochnales B) Distromium n. sp. C) Kallymenia n. sp. D) Ulva ohiohilulu (Spalding et al. 2016).*

Photo 6. *Representative algal dominated mesophotic reef in the PMNM containing the green alga Microdictyon sp. at 64 m, Pearl and Hermes. Photo from R. Kosaki (PMNM).*

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(a) Professional Preparation

Undergraduate Institution	Albion College	Geology	B.A., 1979
Graduate Institution	University of Delaware	Geology	M.S., 1982; PhD, 1986

(b) Appointments

2010 - present	Associate Dean for Academic Affairs, SOEST, Univ. Hawaii
2004 - 2010	Chairperson, Dept. of Geology and Geophysics, Univ. Hawaii
1997 – present	Professor, Dept. of Geology and Geophysics, Univ. Hawaii
1993 - 1996	Associate Professor, Dept. of Geology and Geophysics, Univ. Hawaii
1991 - 1992	Assistant Professor, Dept. of Geology and Geophysics, Univ. Hawaii
1986 - 1990	Assistant Professor, Dept. of Geology and Astronomy, West Chester Univ. (PA)

(c) Publications (5)

1. in press, **Fletcher**, C.H. *Climate Change: What the science tells us*, 2nd Ed., J. Wiley & Sons, NY, 265p.
2. **Fletcher**, C.H. (2017) *Physical Geology: The Science of Earth*, 3rd Ed., J. Wiley and Sons, NY, 678p.
3. Kane, H. H., **Fletcher**, C. H., Cochrane, E. E., Mitrovica, J. X., Habel, S., Barbee, M. 2017. *Coastal plain stratigraphy records tectonic, environmental, and human habitability changes related to sea-level drawdown, 'Upolu, Sāmoa.* Quaternary Research (2017), 87, 246–257 doi:10.1017/qua.2017.2
4. Habel, S., **Fletcher**, C.H., Rotzoll, K. and El-Kadi, A. 2017. *Development of a model to simulate groundwater inundation induced by sea-level rise and high tides in Honolulu, Hawaii*. Water Research. ISSN 0043-135.http://dx.doi.org/10.1016/j.watres.2017.02.035
5. Spirandelli, D.J., Anderson, T.R., Porro, R., and **Fletcher**, C.H. 2016. *Improving Adaptation Planning for Future Sea-Level Rise: Understanding Uncertainty and Risks Using a Probability-Based Shoreline Model.* Journal of Planning and Research 1-14. DOI: 10.1177/0739456X16657160

Additional publications (5)

1. Habel, S., **Fletcher**, C. H., Barbee, M., Anderson, T. R. 2016. *The influence of seasonal patterns on a beach nourishment project in a complex reef environment.* Coastal Engineering: Volume 116, Pages 67–76http://dx.doi.org/10.1016/j.coastaleng.2016.06.006
2. Romine, B.M., **Fletcher**, C.H., Frazer, L.N., and Anderson, T.R., 2016. *Beach erosion under rising sea-level modulated by coastal geomorphology and sediment availability on carbonate reef-fringed island coasts.* Sedimentology. DOI 10.1111/sed.12264
3. **Fletcher** C H (2016) *Climate Change Booklets for the USAPI*. Pacific Islands Climate Education Partnership. NSF Grant #1239733
4. Cochrane, E., Kane, H., **Fletcher**, C., Horrocks, M., Mills, J., Barbee, M. Morrison A., Matavai Tautunu, M., 2015. *Lack of suitable coastal plains likely influenced Lapita (~2800 cal BP) settlement of Samoa: Evidence from SE Upolu.* The Holocene, DOI: 10.1177/0959683615596841

5. Anderson, T.R., Fletcher, C.H., Barbee, M.M., Frazer, L.N., and Romine, B.M. 2015. *Doubling of coastal erosion under rising sea level by mid-century in Hawaii.* Natural Hazards. DOI 10.1007/s11069-015-1698-6

(d) Synergistic Activities

2017	Waikiki Beach Community Advisory Committee, Waikiki Beach SIDA
2017	Hawaii State Hazard Mitigation Forum, Hawai Emergency Management Agency
2017	Expert Working Group, Resilient Hawaiian Communities Initiative (PICCC)
2016-2017	Lead Author, USAPI Regional Team for the US Fourth National Climate Assessment
2016-2017	Planning Team, City and County of Honolulu, Most Resilient City
2015-present	Hawaii OP, DLNR – Interagency Climate Change Adaptation Committee

Sean Vitousek

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EMPLOYMENT

University of Illinois at Chicago (UIC) Winter 2016 - present
Research Assistant Professor
Civil & Materials Engineering

United States Geological Survey (USGS) Summer 2014 - Winter 2015
Mendenhall Postdoctoral Scholar
Pacific Coastal & Marine Science Center, Santa Cruz, CA
Supervisor: Patrick Barnard
Project: Long-term shoreline change modeling, impacts of sea-level rise

Stanford University Winter 2014 - Summer 2014
Postdoctoral Scholar and Lecturer, Civil & Environmental Engineering
Environmental Fluid Mechanics & Hydrology
Classes taught: CEE 262C: Modeling environmental flows

EDUCATION

Stanford University Fall 2008 - Fall 2013
Doctor of Philosophy, Civil & Environmental Engineering
Environmental Fluid Mechanics & Hydrology
Advisor: Oliver B. Fringer
Dissertation Title: *Towards Internal Wave Resolving Simulations of the Ocean*

University of Hawai'i Fall 2005 - Fall 2007
Masters of Science, Geology & Geophysics
Coastal Geology Group
Advisor: Charles H. Fletcher
Masters Thesis Title: *Nearshore Hydrodynamics at Kaanapali, Maui & Hawai'i Extreme Wave Statistics*

Princeton University 2005
Bachelor of Science in Engineering, Civil & Environmental Engineering
Senior Thesis Advisor: George W. Scherer
Senior Thesis Title: *The Mechanisms of Salt Swelling in Cement*
Graduated with Honors

Hawai'i Preparatory Academy 2001
Graduated *cum laude*

GRANTS

Coastal Impacts Associated with Climate Change, funded by the U.S. Geological Survey to assess impacts of sea-level rise on the US West Coast ($300k over 5 years). Sole PI. 2016

Computational Fluid Dynamics for the Environmental-Water Resources Engineering Curriculum, funded by the UIC Teaching Excellence Review Committee to integrate the use of numerical modeling in the Civil & Materials Engineering curriculum ($20k). Co-PI w/ Ben O'Connor, Karl Rockne. 2016

SELECTED PUBLICATIONS

- **Sean Vitousek**. A nonhydrostatic, generalized vertical-coordinate ocean model. 2017. (in prep).
- **Sean Vitousek**. An alternative derivation of the Boussinesq-type water wave equations. 2017. (in prep).
- Patrick Limber, Patrick L. Barnard, **Sean Vitousek**, and Li H. Erikson. A model ensemble for projecting multi-decadal coastal cliff retreat during the 21st century. *Journal of Geophysical Research: Earth Surface*, 2017. (under review).
- Bo Zou, Karl J. Rockne, **Sean Vitousek**, and Mohamadhossein Noruzoliaee. Ecosystem and transportation infrastructure resilience to climate change in the great lakes. *Journal of Infrastructure Systems*, 2017. (under review).
- **Sean Vitousek**, Patrick L. Barnard, Charles H. Fletcher, L. Neil Frazer, Li Erikson, and Curt D. Storlazzi. Doubling of coastal flooding frequency within decades due to sea-level rise. *Scientific Reports*, 7(1):1399, 2017.
- **Sean Vitousek**, Patrick L. Barnard, and Patrick Limber. Can beaches survive climate change? *Journal of Geophysical Research: Earth Surface*, 122(4):1060–1067, 2017.
- **Sean Vitousek**, Patrick L. Barnard, Patrick Limber, Li Erikson, and Blake Cole. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research: Earth Surface*, 122(4):782–806, 2017.
- Ana Rueda, **Sean Vitousek**, Paula Camus, Antonio Tomás, Antonio Espejo, Inigo J. Losada, Patrick Barnard, Li Erikson, Peter Ruggiero, Borja G. Reguero, and Fernando J. Méndez. Global classification of coastal flooding hazard climates. *Scientific Reports*, 7(5038), 2017.
- Ana Rueda, Christie A. Hegermiller, José Antonio A. Antolínez, Paula Camus, **Sean Vitousek**, Peter Ruggiero, Patrick L. Barnard, Li H. Erikson, Antonio Tomás, and Fernando J. Méndez. Multiscale climate emulator of multimodal wave spectra: Muscle-spectra. *Journal of Geophysical Research: Oceans*, 122:1400–1415, 2017.
- Ana Rueda, Paula Camus, Antonio Tomás, **Sean Vitousek**, and Fernando J. Méndez. A multivariate extreme wave and storm surge climate emulator based on weather patterns. *Ocean Modelling*, 104:242 – 251, 2016.
- José Antonio A. Antolínez, Fernando J. Méndez, Paula Camus, **Sean Vitousek**, E. Mauricio González, Peter Ruggiero, and Patrick Barnard. A multiscale climate emulator for long-term morphodynamics (muscle-morpho). *Journal of Geophysical Research: Oceans*, 121(1):775–791, 2016.
- Patrick L Barnard, Andrew D Short, Mitchell D Harley, Kristen D Splinter, **Vitousek, Sean**, Ian L Turner, Jonathan Allan, Masayuki Banno, Karin R. Bryan, Andre Doria, Jeff E. Hansen, Shigeru Kato, Yoshiaki Kuriyama, Evan Randall-Goodwin, Peter Ruggiero, Ian J. Walker, and Derek K. Heathfield. Coastal vulnerability across the pacific dominated by el nino/southern oscillation. *Nature Geoscience*, 8(10):801–807, 2015.
- **Sean Vitousek** and Oliver B. Fringer. A nonhydrostatic, isopycnal-coordinate ocean model for internal waves. *Ocean Modelling*, 83(0):118 – 144, 2014.
- **Sean Vitousek** and Oliver B. Fringer. Stability and consistency of nonhydrostatic free-surface models using the semi-implicit θ-method. *International Journal for Numerical Methods in Fluids*, 72(5):550–582, 2013.
- **Sean Vitousek** and Oliver B. Fringer. Physical vs. numerical dispersion in nonhydrostatic ocean modeling. *Ocean Modelling*, 40(1):72 – 86, 2011.

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http://coralhealth.spatial.hawaii.edu/

(a) Professional Preparation

California Polytechnic State University, USA	Biology	BS	2002 - 2007
University of Hawaii at Hilo, USA	TCBES	M.S.	2008 - 2010
University of Hawaii at Manoa, USA	Biology	Ph.D	2011 - 2016

(b) Appointments

2017-2019	NSF Postdoctoral Research Fellowship, University of Hawaii at Hilo
2017	Postdoctoral Research, Papahānaumokuākea Marine National Monument, NOAA
2016-2017	Postdoctoral Researcher, Hawaii Institute of Marine Biology, UH Manoa
2014-2016	EPA STAR Graduate Research Scholar, University of Hawaii at Manoa
2012-2014	Research Assistant, Hawaii Institute of Marine Biology, University of Hawaii at Manoa
2011-2012	Research Assistant, EPSCoR Grant, University of Hawaii at Hilo
2010-2011	Teaching Assistant, Biology Dept., University of Hawaii at Manoa
2008-2010	Research Assistant, Hawaii Sea Grant, University of Hawaii at Hilo
2007-2008	Educational support technician, Cal Poly Center for Coastal Marine Sciences
2005-2007	Research Assistant, Cal Poly Foundation, Cal Poly Biology Department

(c) Products

(i) Five Related Products:

Burns JHR, Delparte D (2017) Comparison of commercial structure-from-motion photogrammetry software used for underwater three-dimensional modeling of coral reef environments. ISPRS/CIPA Archives, Underwater 3D Recording and Modeling, Commission II, Volume XLII-2/W3

Burns JHR, Alexandrov T, Ovchinnikova E, Gates RD, Takabayashi M (2016) Investigating the spatial distribution of Growth Anomalies affecting Montipora capitata corals in a 3-dimensional framework. Journal of Invertebrate Pathology. 140: 51-57

Burns JHR, Alexandrov T, Ovchinnikova E, Gates RD, Takabayashi M (2016) Data for spatial analysis of growth anomaly lesions on Montipora capitata corals using 3D reconstruction techniques. Data in Brief. 9: 460-462

Burns JHR, Delparte D, Kapono L, Belt M, Gates RD, Takabayashi M (2016) Assessing the impact of acute disturbances on the structure and composition of a coral community using innovative 3D reconstruction techniques. Methods in Oceanography. 15-16: 49-59

Burns JHR, Delparte D, Gates RD, Takabayashi M (2015) Integrating structure-from-motion photogrammetry with geospatial software as a novel technique for quantifying 3D ecological characteristics of coral reefs. PeerJ 3:e1077

(ii) Five Other Significant Products:

Couch CS, Burns JHR, Liu G, Steward K, Gutlay TN, Kenyon J, et al. (2017) Mass coral bleaching due to unprecedented marine heatwave in Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). PLoS ONE12(9): e0185121

Gregg TM, Mead L, Burns JHR, Takabayashi M (2015) Puka Mai He Ko 'a: The Significance of Coral in Hawaiian Culture. In *Ethnobiology of Corals and Coral Reefs* (pp. 103-115). Springer International Publishing.

Burns JHR, Gregg TM, Takabayashi M (2013) Does coral disease affect Symbiodinium? Investigating the impacts of growth anomaly on symbiont photophysiology. PLoS ONE 8(8): e72466

Burns JHR, Takabayashi M (2011) Histopathology of growth anomaly affecting the coral, Montipora capitata: Implications on biological functions and population viability PLoS One 6(12): 228852

Burns JHR, Rozet NK, Takabayashi . (2011) Morphology, severity, and distribution of growth anomalies in the coral, Montipora capitata, at Waiʻōpae, Hawaiʻi. Coral Reefs 30: 819-826.

(d) Synergistic Activities

PURPLE PRIZE – Malama Loko ia: Purple Maiʻa Foundation is a technology education nonprofit whose mission is to build pathways of knowledge together with high-opportunity youth in order to help communities thrive. 2017 Purple Prize was developed to enhance technology in water based conservation programs throughout the Hawaiian Island.

NOAA RAMP: Rapid Assessment and Monitoring Program that conducts annual surveys to document coral reef ecosystem characteristics at sites throughout the Main and Northwestern Hawaiian Islands. 2012 - present

Coral Health Atlas: A dynamic website designed to provide interactive access to coral health data and ecosystem characteristics at study sites throughout the Hawaiian Archipelago. 2012 - present

TEK X TECH: Innovative mobile technologies (Tech) coupled with Traditional Ecological Knowledge (TEK) for coral reef monitoring and community-based fisheries management in Hawaiʻi. 2013 - present

Manowai o Hanakahi: Summer workshops designed to educate K-12 students in topics related to marine biology and conservation throughout Hawaiʻi. 2010 - present

Ocean Day Hawaiʻi: Large annual outreach event that brings together multiple organizations working in marine conservation to promote education and interaction with the public. 2009 –present

(e) Collaborators & Other Affiliations

Collaborators and Co-Editors: Nikki Adams (Cal Poly, SLO), Jason Adolf (UH Hilo), Jim Beets (UH Hilo), Michael Best (UH Hilo), Lisa Canale (UH Hilo), Ben Clark (UH Hilo), Courtney Couch (UH Mānoa), Gert deCout (UH Mānoa), Donna Delparte (Idaho State U), Marta deMaintenon (UH Hilo), Megan Donahue (UH Mānoa), Anuschka Faucci (UH Mānoa), Kelly Gleason (NOAA-PMNM), Scott Godwin (NOAA-PMNM), Drew Harvell (Cornell), Cori Kane (Washing State U), Cliff Kapono (UCSD), Emily Kelly (UCSD), Mark Kimura (UH Hilo), Jack Kittinger (Conservation International), Randall Kosaki (NOAA-PMNM), Lucas Mead (County of Hawaii), Rebecca Most (The Nature Conservancy), Chris Nishioka (UH Hilo), Megan Ross (UH Mānoa), Francis Sansone (UH Mānoa), Kehau Springer (Conservation International), Misaki Takabayashi (UH Hilo), Rob Toonen (UH Mānoa), Nick Turner (UH Hilo), Dan Wagner (NOAA PMNM), Tracy Wiegner (UH Hilo), Chad Wiggins (The Nature Conservancy), Kalewa Correa (NOAA PMNM), Nakoa Goo (NOAA PMNM), Raphael-Ritson Williams (EPA STAR-UHM), Trevor Mendelow (View Into the Blue), Jeff Orlowski (Exposure Labs)

Graduate Advisor and Postdoctoral Sponsors: Dr. Ruth Gates (Hawaii Institute of Marine Biology), Dr. Misaki Takabayashi (University of Hawaii at Hilo), Dr. Randall Kosaki (NOAA), Dr. Patrick Hart (University of Hawaii at Hilo)

(f) Funding and Awards

2017-19	NSF Postdoctoral Fellowship Award
2017	1st Place – In flight Project – Purple Prize Challenge
2016	Finalist – Ocean 180 Video Challenge
2015	PADI Foundation Scholarship
2015	Beneath the Sea - Jordan Viders “Spirit of the Sea” Scholarship
2014-16	EPA STAR Fellowship
2014	Finalist – Rolex Awards for Enterprise
2014	Best Paper Award – Annual Albert Tester Memorial Research Symposium
2013	UH Manoa Edmonson Grant
2012	EPSCoR Cross-cutting Seed Grant
2012	UH Manoa GSO Grant
2010	Honorable Mention – Best Paper – Annual TCBES Symposium
2009-11	NOAA Sea Grant Fellowship
2007	Federal Pell Grant
2007	Federal SMART-Senior Grant
2006	State University Grant

RICHARD L. PYLE
Bernice P. Bishop Museum, Department of Natural Sciences, 1525 Bernice St., Honolulu, HI 96817, USA. Email: deepreef@bishopmuseum.org, Tel: (808) 848-4115, Fax: (808) 847-8252

Professional Preparation

University of Hawai‘i	Zoology	B.S.	1992
University of Hawai‘i	Zoology	Ph.D.	2003

Appointments

2012–present	Member, Catalog of Life Global Team
2010–present	Dive Safety Officer, B.P. Bishop Museum, Honolulu, Hawaii
2009–present	Committee Member, International Committee for Bionomenclature
2008–present	Council Member, International Commission on Zoological Nomenclature (ICZN)
2008–present	Convener, Taxonomic Names and Concepts Group, Biodiversity Information Standards (TDWG)
2008–present	Founding Board Member, Plazi.ch Association (Plazi)
2006–present	Commissioner, International Commission on Zoological Nomenclature (ICZN)
2003–present	Board of Directors, Association for Marine Exploration
2002–present	Database Coordinator, Department of Natural Sciences, B.P. Bishop Museum, Honolulu, Hawaii
2000–present	Associate Zoologist – Department of Natural Sciences, B.P. Bishop Museum, Honolulu, Hawaii
2001–2003	Research Assistant, Department of Zoology-University of Hawai‘i
2000	Teaching Assistant, Department of Zoology-University of Hawai‘i
1999–2000	Research Assistant, Department of Zoology-University of Hawai‘i
1997–2000	Research Assistant, Bishop Museum
1986–1997	Collections Technician, Bishop Museum
1985	Student Aquarist, Waikiki Aquarium

Publications (out of 200+)

Publications related to Project (5)

Pyle, R.L. and R.K. Kosaki. 2016. *Prognathodes basabei*, a new species of butterflyfish (Perciformes, Chaetodontidae) from the Hawaiian Archipelago. *ZooKeys* 614: 137-152. doi: 10.3897/zookeys.614.10200

Pyle, R.L., R.K. Kosaki and B.D. Greene. 2016. *Tosanoides obama*, a new basslet (Perciformes, Percoidei, Serranidae) from deep coral reefs in the Northwestern Hawaiian Islands. *ZooKeys* 641: 165–181. doi: 10.3897/zookeys.641.11500

Pyle, R.L., R. Boland, H. Bolick, B. Bowen, C.J. Bradley, C. Kane, R.K. Kosaki, R. Langston, K. Longenecker, A.D. Montgomery, F.A. Parrish, B.N. Popp, J. Rooney, C.M. Smith, D. Wagner & H. L. Spalding. 2016. A comprehensive investigation of mesophotic coral ecosystems in the Hawaiian Archipelago. *PeerJ* 4:e2475. doi: 10.7717/peerj.2475

Kosaki R. K., R. L. Pyle, J. C. Leonard, B.B. Hauk, R. K.Whitton, and D. Wagner. 2016. 100% endemism in mesophotic reef fish assemblages at Kure Atoll, Hawaiian Islands. *Marine Biodiversity*. 2016:1-2.

Randall, J.E., J.L. Earle, R.L. Pyle, J.D. Parrish & T. Hayes. 1993. Annotated checklist of the fishes of Midway Atoll, Northwestern Hawaiian Islands. *Pacific Science* 47(4):356–400.

Other Publications (5)

Weiss, Kenneth R. 2017. Naturalist Richard Pyle explores the mysterious, dimly lit realm of deep coral reefs. *Science* 355(6328): 900–904. doi: 10.1126/science.355.6328.900

Miller, J., et al. 2012. From taxonomic literature to cybertaxonomic content. *BioMed Central Biol.*, 10:87.

Patterson, D.J., Cooper, J., Kirk, P.M, Pyle, R.L. and Remsen, D.P. 2010. Names are key to the big new biology. *Trends in Ecology & Evolution*, 1297:1-6. doi:10.1016/j.tree.2010.09.004

Pyle, R.L., J.L. Earle & B.D. Greene 2008. Five new species of the damselfish genus *Chromis* (Perciformes: Labroidei: Pomacentridae) from deep coral reefs in the tropical western Pacific. *Zootaxa*. 1671: 3–31.

Polaszek, A., et al. 2005. Commentary: A universal register for animal names. *Nature* 437:477.

Synergistic Activities

Field Research experience. Over thirty years of experience on scientific field expeditions throughout the tropical Indo-Pacific, as well as active research activities in affiliation with Bishop Museum, the University of Hawaii, Hawaii Institute of Marine Biology, and Waikiki Aquarium.

Scientific publications. Author or co-author of over 200 publications in ichthyology and taxonomy, biodiversity database development, zoological nomenclature, and technical diving.

Educational and community outreach. Nearly 240 public presentations (including two TED talks); over 45 national and international documentary film projects (including an IMAX film and a 3-hour BBC documentary); subject of over forty published interviews and profiles (including the featured cover story for the March 3, 2017 issue of *Science*).

Scientific and Informatics community coordination. Convenor, Taxon Names and Concepts group, Biodoversity Information Standards (TDWG); Commissioner and Councillor, International Commission on Zoological Nomenclature (ICZN); Member, International Committee on Bionomenclature (ICB); Member, Catalog of Life (CoL) Global Team; Board Member, PLAZI; Board of Editors, *Indo-Pacific Fishes*.

Database development. Architect and lead developer for the Global Names Usage Bank, ZooBank, and many other database management systems for specimens, literature, geography, and image and other media content.

Carl Meyer
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a. Professional Preparation

University of Plymouth	Biology	B.Sc., 1990
University of Plymouth	Biology	M.Phil., 1993
University of Hawaii	Zoology	Ph.D., 2003

b. Appointments

2004-2017 Assistant Researcher, Marine Biology, University of Hawaii

c. Publications

(i) Five publications most closely related to proposal project

Papastamatiou YP, Meyer CG, Kosaki RK, Natalie J. Wallsgrove NJ, Popp BN. 2015. Movements and foraging of predators associated with mesophotic reefs and their potential for linking ecological habitats. Marine Ecology Progress Series: 521:155-170. doi:10.3354/meps11110

Meyer CG, Holland KN. 2012. Autonomous measurement of ingestion and digestion processes in free swimming sharks. Journal of Experimental Biology. 215, 3681-3684. doi:10.1242/jeb.075432.

Dale JJ, Stankus AM, Burns MS, Meyer CG. 2011. The Shark Assemblage at French Frigate Shoals Atoll, Hawai'i: Species Composition, Abundance and Habitat Use. PLoS ONE 6(2): e16962. doi:10.1371/journal.pone.0016962

Meyer CG, Papastamatiou YP, Holland KN. 2010. A multiple instrument approach to quantifying the movement patterns and habitat use of Tiger (*Galeocerdo cuvier*) and Galapagos sharks (*Carcharhinus galapagensis*) at French Frigate Shoals, Hawaii. Marine Biology. 157:1857–1868. DOI: 10.1007/s00227-010-1457-x

Meyer CG, Holland KN, Papastamatiou YP. 2007. Seasonal and diel movements of giant trevally (*Caranx ignobilis*) at remote Hawaiian atolls: implications for the design of Marine Protected Areas. Marine Ecology Progress Series. 333: 13-25.

(ii) Up to five other significant publications

Meyer CG. 2017. Electronic tags reveal the hidden lives of fishes. Bulletin of Marine Science. 93: 301-318. DOI: 10.5343/bms.2016.1030.

Bierwagen SL, Price DK, Pack AA, Meyer CG. 2017. Bluespine Unicornfish (*Naso unicornis*) are both natural control agents and mobile vectors for invasive algae in a Hawaiian Marine Reserve. Marine Biology 164:25 DOI 10.1007/s00227-016-3049-x

Meyer CG, Papastamatiou YP, Clark TB. 2010. Differential movement patterns and site fidelity among trophic groups of reef fishes in a Hawaiian Marine Protected Area. Marine Biology. 157:1499-1793. DOI: 10.1007/s00227-010-1424-6

Meyer CG, Papastamatiou YP, Holland KN. 2007. Seasonal, diel and tidal movements of green jobfish (*Aprion virescens*, Lutjanidae) at remote Hawaiian atolls: Implications for Marine Protected Area design. Marine Biology. 151: 2133-2143.

d. Synergistic Activities

Expert scientific testimony provided to Hawaii State Legislature, Western Pacific Regional Fisheries Management Council, Marine mammal Commission, Reserve Advisory Committee for Papahānaumokuākea Marine National Monument.

Reviewer for Biological Conservation, Caribbean Journal of Science, Coral Reefs, Deep Sea, Research, Endangered Species Research, Fisheries Research, Functional Ecology, Journal of Ethology, Journal of Experimental Marine Biology and Ecology, Journal of Fish Biology, Journal of Shellfish Research, Journal of the Marine Biological Association of the UK,Marine and Freshwater Research, Marine Biology, Marine Ecology Progress Series, PLoS ONE.

Public outreach lectures 2-3 times per year for clubs, organizations and the general public.

Extensive coverage in local, national and international media, including coverage of my research activities, and solicitations of my expert opinion on shark-related issues. A recent Google News search on "Carl Meyer" AND "shark", yielded 120 original media articles between 2011 and 2017. In addition to print and online media coverage, my research has also been featured in television documentaries such as "Ocean Mysteries with Jeff Corwin".

e. Collaborators & Other Affiliations

(i)Collaborators

P. Afonso, University of the Azores; J. Fontes, University of the Azores; K. Holland, University of Hawaii; M. Hutchinson, University of Hawaii; D. Coffey, University of Hawaii; M. Royer, University of Hawaii; J. Anderson, University of Hawaii; D. Pazmiño, James Cook University; G. Maes, James Cook University; M. Green, University of Tasmania; C. Simpfendorfer, James Cook University; Hoyos-Padilla M, Pelagios-Kakunjá A.C. Sinaloa; C. Duffy, New Zealand Department of Conservation; S. Kerwath, University of Cape Town; P. Salinas-de-León, Department of Marine Sciences; L. van Herwerden, James Cook University; S. Bierwagen, James Cook University; D. Price, University of Hawaii ; A. Pack, University of Hawaii; K. Stamoulis, Curtin University; A. Friedlander, University of Hawaii; I. Fernandez-Silva, California Academy of Sciences; R. Toonen, University of Hawaii; N. Hammerschlag, University of Miami; M. Grace, Florida Institute of Technology; S. Kessell, Michigan State University; T. Sutton, Nova Southeastern University; E. Harvey, Curtin University; C. Paris-Limouzy, University of Miami; D. Kerstetter, Nova Southeastern University; S. Cooke, Carleton University; B. Bowen, University of Hawaii; B. Popp, University of Hawaii; J. Randall, Bishop Museum; R. Coleman, University of Hawaii; J. DiBattista, Curtin University; L. Rocha, California Academy of Sciences; J. Reimer, University of the Ryukyus; J. Dale, Stanford University; J. O'Malley, NOAA; R. Kosaki, NOAA; Y. Papastamatiou, Florida International University; K. Sato, University of Tokyo; Y. Watanabe, Polar Research Institute; N. Wallsgrove, University of Hawaii; I. Nakamura, University of Tokyo.

(ii) Graduate and Postdoctoral Advisors

Dr. Kim Holland (Ph.D. Advisor) University of Hawaii at Manoa.

Dr. Malcom Jones (M.Phil. Advisor), University of Plymouth, England.

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(a) Professional Preparation:

Southampton College, Long Island University, USA	BS, Marine Science	1993 – 1997
Moss Landing Marine Laboratory (MLML), SFSU, USA	MS, Marine Science	1997 – 2002
University of Hawaii at Manoa (UHM), USA	PhD, Botany	2002 - 2012

(b) Appointments:

2017-present	Affiliate Faculty, Ecology, Evolution, and Ecology program, UHM, HI
2014-present	Lecturer, Departments of of Biology and Botany, UHM, HI
2012-present	Environmental Consultant, Aquatic Research Consultants LLC, HI
2012-2017	Postdoctoral Fellow, Papahanaumokuakea Marine National Monument, HI
2008-2010	NSF GK-12 Fellow, UHM, HI
2003-2012	Research Assistant, Department of Botany, UHM, HI
2002-2003	Teaching Assistant, Department of Botany, UHM, HI
2000-2001	Research Technician, Hydro-optics and Biological Instrumentation, CA
1999-2001	Research Assistant, MLML, CA
1999-2000	Field Technician, California State Water Quality Control Board, CA
1997-2002	Teaching Assistant, MLML, CA
1996-1997	Research Assistant, Plum Island Animal Disease Center, NY

(c) Products

(i) Five products most closely related to proposed project:

Wainwright BJ, Zahn LZ, **Spalding HL**, Sherwood AR, Smith CM, Amend AS. *in press*. Fungal associations with mesophotic macroalgae from the 'Au'au Channel, west Maui. *PeerJ*

Spalding, H.S., Conklin, K.Y., Smith, C.M., O'Kelly, C.J. & A.R. Sherwood. 2016. New Ulvaceae (Ulvophyceae, Chlorophyta) from mesophotic ecosystems across the Hawaiian Archipelago. 2016. *Journal of Phycology* 52: 40-53

Pyle, R.L., Boland, R., Bolick, H., Bowen, B.W., Bradley, C.J., Kane, C., Kosaki, R.K., Langston, R., Longenecker, K., Montgomery, A.D., Parrish, F.A., Popp, B.N., Rooney, J., Smith, C.M., Wagner, D., **Spalding, H.L.** 2016. A comprehensive investigation of mesophotic coral ecosystems in the Hawaiian Archipelago. *PeerJ* 4:e2475

Wagner, D., Barkman, A., **Spalding, H.L.**, Calcinai, B., Godwin, S.L. 2016. A photographic guide to the benthic flora and fauna from mesophotic coral ecosystems in the Papahānaumokuākea Marine National Monument. *Marine Sanctuaries Conservation Series* ONMS-16-04

Tsuda, R.T., **Spalding, H.L.**, Sherwood, A.R. 2015. New species records of marine benthic algae in the Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). *Bishop Museum Occasional Papers.* 116: 41-47

(ii) Five other significant products:

Cox TE, **Spalding HL**, Foster MS. 2017. Spatial and temporal variation of diverse intertidal algal assemblages in Hawai'i. *Marine Ecology* 38: e12429

Langston R, **Spalding HL.** 2017. A survey of fishes associated with Hawaiian deep-water *Halimeda kanaloana* (Bryopsidales: Halimedaceae) and *Avrainvillea* sp. (Bryopsidales: Udoteaceae) meadows. *PeerJ* 5: e3307

Sansone FJ, **Spalding HL**, Smith CM. 2017. Sediment biogeochemistry in mesophotic meadows of calcifying macroalgae. *Aquatic Biogeochemistry*: 1-24.

Baker E, Puglise K, Colin PL, Harris PT, Kahng SE, Rooney J, Sherman C, Slattery M, **Spalding, H.L.** 2016. Chapter 2. What are mesophotic coral ecosystems? *in* Baker, E.K., Puglise, K.A. and Harris, P.T. (eds.)

Mesophotic Reefs – A Life Boat For Coral Reefs? The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal

Sinniger F, Ballantine DL, Bejarano I, Colin PL, Pochon X, Pomponi SA, Puglise KA, Pyle RL, Reaka ML, **Spalding HL**, Weil E. 2016. Chapter 4. Biodiversity of mesophotic coral ecosystems. *in* Baker, E.K., Puglise, K.A. and Harris, P.T. (eds.) *Mesophotic Reefs – A Life Boat For Coral Reefs?* The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal

(d) Synergistic Activities

National Academy of Sciences: Distinguished young scientist for the Kavli Frontiers in Science Symposium, Indonesia, July 2017

Longitudinal Assessment: Our Project in Hawai'i's Intertidal (OPIHI): Senior consultant engaging undergraduates and educators in authentic research experiences in the Hawaiian intertidal.

NSF GK-12 fellowship: Developed innovative inquiry-based, mesophotic ecosystem and macroalgal-based curriculum for use in K-16. This resulted in the publication of two articles on curriculum development and broader impacts.

Outreach Specialist: "Educator-at-Sea" programs for mesophotic submersible cruises, including middle and high school teachers, and resource managers in Hawai'i.

Mentor for 30 undergraduates and 2 highschool students for senior research projects, internships, and research experiences at UH Mānoa.

(e) Collaborators and Other Affiliations

Collaborators and Co-Editors: Tracy Ainsworth (James Cook Uni.), Gilberto Amando-Filho (Instituto de Pesquisas Jardim Botânico do Rio de Janeiro), Anthony Amend (UHM), Dominic Andradi-Brown (Uni. Oxford), Elaine Baker (Uni. Sydney), David Ballantine (Smithsonian), Ivonne Bejarno (Uni. PR), Robert Bidigare (UHM), Raymond Boland (NOAA), Holly Bollick (BISH), Pim Bongaerts (Global Change Inst.), David Bourne (AIMS), Brian Bowen (HIMB), Christine Bradley (UHM), Thomas Bridge (ARC), Barbara Calcinai (MPU), Malia Chow (NOAA), Pat Colin (Coral Reef Res. Foundation Palau), Bryan Costa (NOAA), Traci Cox (Dauphin Is. Sea Lab), Gal Eyal (Tel-Aviv Uni.), Zachary Forsman (HIMB), Suzanne Frederiq (UL Lafayette), Ruth Gates (HIMB), Scott Godwin (BISH), Peter Harris (Geoscience Australia), Ove Hoegh-Guldberg (James Cook), RJ Jones (Uni. Sydney), Samuel Kahng (HPU), Cori Kane (UHH), Matthew Kendall (NOAA), Randy Kosaki (NOAA), Gerald Kraft (Uni. Melbourne), Lutz Krause (QIMR), Ross Langston (Windward, UH), Jack Laverick (Oxford), Joey Leckey (NOAA), William Leggart (James Cook), James Leichter (UCSD), Ken Longenecker (BISH), Anthony Montgomery (USFWS), Wendy Nelson (Uni. Auckland), Charles O'Kelley (Friday Harbor Labs), Jacqueline Padilla-Gamiño (UW), Frank Parrish (NOAA), Xavier Pochon (Cawthorne), Shirley Pomponi (HBOI), Brian Popp (UHM), Kimberly Puglise (NOAA), Richard Pyle (BISH), Jean-Baptiste Raina (James Cook), Marjorie Reaka (Uni. Maryland), John Reed (HBOI), Melissa Roth (UC Berkeley), Francis Sansone (UHM), Clark Sherman (UPR), Frederick Sinniger (Japan), Marc Slattery (UM), Tyler Smith (UVI), Gregory Torda (James Cook), Roy Tsuda (BISH), Daniel Wagner (NOAA), Benjamin Wainwright (UHM), Ernesto Weil (UPR), Robert Whitton (BISH), Erika Woosley (James Cook), Zakrzewski (QIMR)

Graduate Advisors and Postdoctoral Sponsors: Dr. Michael Foster (Moss Landing Marine Laboratories), Dr. Celia Smith (Department of Botany, UHM), Dr. Alison Sherwood (Department of Botany, UHM)

(f) Funding and Awards

2017	Finalist, Hilda-Canter Lund Annual Photography Award, British Phycological Society
2010	Provasoli Award, Outstanding paper in the *Journal of Phycology*
2009	UHM Dai Ho Chun Dissertation Award
2009	Runner-up, Best Student Presentation, Hawaii Conservation Conference
2004	Best Student Presentation, 29th Annual Albert L. Tester Memorial Symp.
2002	Outstanding Teaching Assistant, UHM Biology Department
2000	Best Student Presentation, Western Society of Naturalists Conference
2000	John H. Martin Memorial Scholarship, MLML
1999	Kim Peppard Memorial Scholarship, MLML

Biographical Sketch: ALISON R. SHERWOOD

Professional Preparation:

Institution	Location	Major / Area	Degree & Year
Dalhousie University	Halifax, Canada	Marine Biology	Bachelor of Science (1996)
University of Guelph	Guelph, Canada	Botany	Doctor of Philosophy (2001)
University of Hawai'i	Honolulu, U.S.A.	Algal systematics	Postdoctoral Fellow (2001-2004)

Appointments:

Time frame	Title	Institution
Aug. 2015 - present	Professor and Chair	Dept. of Botany, University of Hawai'i
Aug. 2013 – Aug. 2015	Professor and Associate Chair	Dept. of Botany, University of Hawai'i
Dec. 2011 – May 2013	Interim Chair	Dept. of Botany, University of Hawai'i
Aug. 2011 – Aug. 2015	Graduate Chair	Dept. of Botany, University of Hawai'i
Aug. 2008 – Aug. 2013	Associate Professor	Dept. of Botany, University of Hawai'i
Jun. 2005 – present	Associate in Science (Affiliate)	Bernice P. Bishop Museum
Aug. 2004 – Jul. 2008	Assistant Professor	Dept. of Botany, University of Hawai'i

Publications:

A. Five most closely related to proposed project:

1. Wainwright, B.J., Zahn, G.L., Spalding, H.L., Sherwood, A.R., Smith, C.M., Amend, A.S. *in press*. Fungal associations with mesophotic macroalgae from the 'Au'au Channel, west Maui. *PeerJ*
2. Spalding, H.S., Conklin, K.Y., Smith, C.M., O'Kelly, C.J. & A.R. Sherwood. 2016. New Ulvaceae (Ulvophyceae, Chlorophyta) from mesophotic ecosystems across the Hawaiian Archipelago. *Journal of Phycology* 52: 40-53.
3. Tsuda, R.T., Spalding, H.L. & A.R. Sherwood. 2015. New species records of marine benthic algae at Papahanoumokuakea Marine National Monument (Northwestern Hawaiian Islands). *Records of the Hawaii Biological Survey* 116: 41-47.
4. Wagner, D., Kosaki, R.K., Spalding, H.L., Whitton, R., Pyle, R.L., Sherwood, A.R., Tsuda, R.T. & Calcinai, B. 2014. Mesophotic surveys of the flora and fauna at Johnston Atoll, Central Pacific Ocean. *Marine Biodiversity Records* 7: e68.
5. Sherwood, A.R., Kurihara, A., Conklin, K.Y., Sauvage, T. & G.G. Presting. 2010. The Hawaiian Rhodophyta Biodiversity Survey (2006-2010): a summary of principal findings. *BMC Plant Biology* 10: 258.

B. Five Other Significant Publications:

1. Campbell, M., Presting, G.G., Bennett, M. & A.R. Sherwood. 2014. Complete chloroplast and mitochondrial genomic sequences of the Hawaiian invasive red alga *Gracilaria salicornia* (Rhodophyta). *Phycologia* 53: 109-116.
2. Sherwood, A.R., Carlile, A.L., Vaccarino, M.A. & Johansen, J.R. 2015. Characterization of Hawaiian freshwater and terrestrial cyanobacteria reveals high diversity and numerous putative endemics. *Phycological Research* 63: 85-92.
3. Sherwood, A.R., Carlile, A.L., Neumann, J.M., Kociolek, J.P., Johansen, J.R., Lowe, R.L., Conklin, K.Y. & G.G. Presting. 2014. The Hawaiian Freshwater Algae Biodiversity Survey (2009-2014): systematic and biogeographic trends with an emphasis on the macroalgae. *BMC Ecology* 14: 28.
4. Carlile, A.L., O'Kelly, C.J. & A.R. Sherwood. 2011. The green algal genus *Cloniophora* represents a novel lineage in the Ulvales: a proposal for Cloniophoraceae fam. nov. *Journal of Phycology* 47: 1379-1387.
5. Sherwood, A.R. & G.G. Presting. 2007. Universal primers amplify a 23S rDNA plastid marker in eukaryotic algae and cyanobacteria. *Journal of Phycology* 43: 605-608.

Synergistic Activities:

- Establishment of the Hawaiian Algal DNA library (HADL) –an archived resource of total genomic DNA samples from collections of Hawaiian algae. HADL currently houses ca. 5,600 extracts of marine, freshwater and subaerial algae (sub-samples of the DNA extracts are available to researchers who wish to include Hawaiian representatives in studies of phylogeny, biogeography and systematics).
- Establishment of the Hawaiian Algal Database (HADB), which displays data from the NSF-funded Rhodophyta Biodiversity Project (with co-PI Gernot Presting), and the Hawaiian Freshwater Algal Database (H*fw*ADB), from the NSF-funded Biodiversity Survey of Hawaiian Freshwater Algae (with co-PIs Pat Kociolek, Jeff Johansen, Rex Lowe and Gernot Presting)
- Mentor for Pacific Islander undergraduate students through NSF UMEB/URM summer research experiences program 2005-2014
- Mentor for Native Hawaiian undergraduate students through the University of Hawai'i's NHSEMP program (summer 2013 and 2014), and PIPES program (summer 2014)
- Mentor for Hawaiian Microbial DNA Discoveries REU students (summer 2016 and 2017)
- Associate Editor for the journal *Botany*, Editorial Board member for the *Journal of Phycology*

Joshua M. Copus
Hawaii Institute of Marine Biology
University of Hawaii at Manoa
jcopus@hawaii.edu, (808) 769-7014

(a) Professional Preparation

2011- present	University of Hawaii at Manoa, Zoology PhD., Zoology, in progress
2008- 2011	Northern Arizona University, Biological Sciences M.S., Biology, 2011
2006-2008	Northern Arizona University, Biological Sciences B.S., Biology, 2008
1999-2009	Glendale Community College, Glendale, Arizona
2004-2006	Rio Salado Community College, Phoenix, Arizona

(b) Appointments

2011- present	Hawaii Institute of Marine Biology, Research Assistant, Brian Bowen
2008 - 2011	Northern Arizona University, Department of Biological Sciences, Teaching Assistant: Introductory Biology, Animal Physiology
2006 – 2008	Northern Arizona University, Department of Biology, Stockroom Assistant
2002	Arizona Game and Fish Department, Intern: Endangered Southwestern Willow Flycatcher Survey and Nest Monitoring

(c) Products

(i) Five Related Products:

Coleman RR, and Copus JM. Community shift in coral reef fishes along a depth gradient in Pohnpei, Micronesia. Peerj*. In review.*

Andrews KA, Williams, AJ, Fernandez-Silva I, Newman SJ, Copus JM, Wakefield CB, Randall JE, Bowen, BW. 2016. Phylogeny of deepwater snappers (Genus *Etelis*) reveals a cryptic species pair in the Indo-Pacific and Pleistocene invasion of the Atlantic. Molecular phylogenetics and evolution 100: 361-371.

Hurley KKC, Timmers MA, Copus JM, Skillings D, and Toonen RJ. 2015. Mesophotic coral reefs fail to provide depth refuge for brachyuran crab communities in Hawaii. *Coral Reefs*, *35*(1), 103-112.

Copus JM, Earle JL, and Pyle RL. 2015. *Neoniphon pencei*, a new species of holocentrid (Teleostei: Beryciformes) from Rarotonga, Cook Islands. *Biodiversity Data Journal 3: e4180.* doi: 10.3897/BDJ.3.e4180

Copus JM, Ka'apu-Lyons CA, and Pyle RL. 2015. *Luzonichthys seaver*, a new species of Anthiinae (Perciformes, erSranidae) from Pohnpei, Micronesia. *Biodiversity Data Journal* 3:e4902.

(ii) Five Other Significant Products:

Copus JM, Forsman Z, Montgomery WL, Bowen BW, Toonen RJ. Review of the *Gila robusta* (Teleostei, Cyprinidae) species complex reveals a single morphologically plastic species. PeerJ. *In review.*

Kahng S, Copus JM, Wagner D. 2016. Mesophotic Coral Ecosystems. In: Rossi S, Bramanti L, Gori A, and Orejas C. Ed., Marine Animal Forests Springer Publishing.

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Copus JM, and Gibb AC. 2013. A forceful upper jaw facilitates picking-based prey capture: biomechanics of feeding in a butterflyfish, *Chaetodon trichrous*. *Zoology* 116:336-347.

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(d) Synergistic Activities

Science Alive! Bishop Museum: Participated in an interactive booth to educate public on ichthyology and rebreather diving 2014-2016.

Likable Science: on ThinkTech Hawaii 45 minute broadcast designed for science outreach. Topic: Mesophotic Coral Ecosystems. Jan. 9 2015

Watershed Research Education Program: Designed and implemented an instructional program for local K-12 teachers. Taught methods of stream assessment and ecology of Arizona stream systems, developed and completed field training of in-service teachers on activities for classrooms and stream environments. 2009.

Camp Verde Days: AZGFD Native Fish Booth to educate public on native fish conservation in the Southwest United States. 2009.

(e) Collaborations and other Affiliations

Collaboratiors and Co-Authors: Robert H. Reavis**,** Richard L. Pyle, John L. Earle, Cassie Ka'apu-Lyons, W. L. Montgomery, Sam Kahng, Danial Wagner, Zac Forsman, Rob J. Toonen, Molly A. Timmers, Kaleo K.C., Derek Skillings, Kim A. Andrews, Ashley Williams, Iria Fernandez-Silva , John S. Newman, C.B. Wakefield, John E. Randall, Richard Coleman.

Graduate Advisors: Dr. Alice C. Gibb (Northern Arizona University, Masters), Dr. Brian W. Bowen (Hawaii Institute of Marine Biology, PhD.).

(f) Funding and Awards

2016 - 2019	NSF Award OCE-1558852
2015-2016	Arizona Game and Fish Department contract
2013	XSEDE Open Source Grid Start Up Award
2012-2014	Seaver Institute, Exploring Foundation Reefs
2008	IGERT-UG Fellowship NSF, Northern Arizona University
2008	Sigma-Xi Scientific Research Society. Grants in Aid of Research
2008	American Academy of Underwater Sciences, Kevin Gurr Scholarship
2007	The Hooper Undergraduate Research Award, Northern Arizona University
2007	Lerner-Gray Fund for Marine Research, American Museum of Natural History
2007	Arizona Flycasters Scott and Travaini Memorial Scholarship

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‘Aulani Wilhelm
Conservation International, Senior Vice President for the Center for Oceans

Statement of Litigation

Instructions: Save this document on your computer and complete. The final narrative should not exceed two (2) pages; do not delete the text provided below. Once complete, upload this document into the on-line application as instructed.

Litigation: In the space provided below, state any litigation (including bankruptcies) involving your organization and either a federal, state, or local government agency as parties. This includes anticipated litigation, pending litigation, or litigation completed within the past twelve months. Federal, state, and local government applicants are not required to complete this section. If your organization is not involved in any litigation, please state below.

Bishop Museum is not currently involved with any litigation including any federal, state, or local government agency as parties, nor is any such litigation anticipated, pending, or completed within the past twelve months.

Understanding environmental stressors and deep reefs to support management of Papahānaumokuākea

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The Medical Foundation for the Study of the Environment

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SEARCHER-OPEN OCEAN RESEARCH
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To: Dr. John Burns & Dr. Rich Pyle
University of Hawaii & Bishop Museum
johnhr@hawaii.edu; deepreef@bishopmuseum.org

From: Captain Jonathan Littenberg
The Medical Foundation/Searcher
808 225-8982

December 18th, 2017

Dear Dr. Burns & Dr. Pyle,

Thank you for contacting us about use of the Searcher for your proposed research activities in the Papahānaumokuākea Marine National Monument. The Searcher is a 96-ft research vessel with a proven sea-going ability and trans-Pacific range. The Searcher is an ideal platform for day trips to months-long expeditions. Operated by the non-profit foundation, The Medical Foundation for the Study of the Environment (MFSE), the Searcher offers security, flexibility, and affordability other vessels cannot offer, and is NOAA fisheries compliant with the latest (VMS) Vessel Monitoring System.

It was great to discuss your proposed research project, “Understanding environmental stressors and deep reefs to support management of Papahanaumokuakea,” which you will submit to the National Fish and Wildlife Foundation. We are happy to send this letter of support to verify that we will be able to facilitate your proposed research operations. Our ship, crew, and two 20-ft zodiacs will be able to support your proposed diving activities and shore based research for a 13-day expedition to French Frigate Shoals. The proposed $197,500 rate will cover the 13-days of operations as well as 6-days of transit and 2.5-days of loading/offloading. We look forward to working with you, and please let us know if you have any additional questions.

Sincerely

Captain Jonathan Littenberg
Director, The Medical Foundation for the Study of the Environment

DATA ANALYSIS AND OTHER POST-CRUISE DISSEMINATION PLAN

I. Types of Data:

In-situ Data: Observational data will be recorded *in situ* during the proposed field activities at French Frigate Shoals. After completing fieldwork activities data will be transferred from physical datasheets into spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats). This will be completed for all metadata, observational data, GPS information, and any additional site notes.

Sedimentary Data and Predictive Modeling: All samples and cores collected at FFS will be stored at UH for processing and archival. Data derived from the analyses of core stratigraphy and sample composition will be stored in spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats). Data used for predictive modeling will be saved in separate locations with necessary metadata to ensure reproducibility of results.

Structure-fom-Motion Photogrammetry Data: All photographs and digitally reconstructed 3D models from both drones (Theme 1a,b) and underwater cameras (Theme 1c) will be stored as described below. Photographs will be stored in the RAW file format, and 3D models will be stored as .las point clouds. Data derived from volumetric and dimensional analysis will be stored in spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats).

Physiochemical Data: Coordinates will be recorded for all locations where water samples are taken and temperature loggers and instrument clusters are deployed. The loggers and instrument clusters will record temperature, conductivity, current, PAR, pH, and dissolved oxygen daily for the duration of deployment. After instrument retrieval and water sample analysis, the resulting data will be stored as text files in .txt or .csv format, and annotated with time stamps and geo-referenced. Project, deployment and dataset metadata will also be collected and will follow the standards established by the NOAA National Oceanographic Data Center (NODC).

Predator Data: All data from tags and acoustic sensors will be downloaded and stored after the field activities have been completed. Camera footage will be stored in RAW file format with necessary metadata. Data derived from the analyses of tags, acoustic sensors, and camera footage will be stored in spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats). Tissue samples will be collected and stored following standard protocols for stable isotope analyses. All data derived from the stable isotope analyses of predator tissue sample will be stored in spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats).

Taxonomic Data: New species of algae and fish collected during this proposed study will be housed at Bishop Museum and the University of Hawaii at Manoa. these specimens will be carefully examined and analyzed, and specimens identified as being new to science will be properly described and named. For macroalgal and fish molecular analyses, the use of short DNA sequences that allow differentiation of samples at the species level will be used to identify unknown individuals and properly assign species designation. All samples for DNA analyses will be properly preserved and processed following the methods outlined in the proposal. All data derived from taxonomic identification and molecular analyses will be stored in spreadsheets using non-proprietary software (i.e. open office platforms stored as ASCI files, .txt or .csv formats).

II. Data Formats and Standards:

Two formats of metadata will be comprised for this proposed project. First, contextual information describing the data and associated methodologies will be stored in a text-based document. Second, an XML file will be created to document all metadata using the ISO 19115 standards. Utilizing both these formats will provide both a complete explanation of the data (text-based format) and ensure compatibility with international standards (XML format). The standard XML fill will contain a complete description of all metadata content while the document file will provide a human-readable summary of the XML file. Quality control and quality assurance procedures will be used to assess all data spreadsheets for any transcription errors and anomalous outliers.

III. Policies and provisions for storage access, re-use, and distribution:

The UH Data Center, part of Information Technology Services (ITS) UH will serve as the major data storage and analysis site for the project. To keep pace with UH research efforts, ITS has developed an array of computing, networking, and support services to meet the technological needs and requirements of the research and educational community listed here: (http://www.hawaii.edu/its/services/datactr3.php). ITS supports a virtual server (VMware) service as a highly cost effective and efficient way to provision a server to meet the users' needs. A DNS service is included, and servers are monitored routinely to ensure they are online and operating properly. Additional services include software installation, security updates, and user management. Data storage services include bulk storage of research data, digital media, and other digital assets. This storage is handled by an on-campus storage cloud, which provides advanced RAID technology to ensure the safety, security, and integrity of the stored data. Back-ups of bulk storage occur nightly and are kept until the next backup occurs. For added redundancy and availability all project data will be stored on the project-specific external hard drives. All metadata will be stored along with the final data products to ensure preservation and archiving of both data and metadata for all aspects of this proposed project. Lastly, final data products will be publicly available for interactive exploration on the Coral Health Atlas website (http://coralhealth.uhh.hawaii.edu/).

All all raw data will be made freely available by the time of publication or the end of the funding period. Results and findings will be shared rapidly with NFWF in the form of reports in order to make key findings accessible to managers as soon as possible. Data outputs from the project will be archived in a national data center, such as the ESRI DataBasin, making data freely available for download. Public users will be able to interactively view and explore final data products on the Coral Health Atlas website (http://coralhealth.uhh.hawaii.edu/). All raw data used for manuscripts will be made freely available at the time of publication. When data are associated with a publication, the raw data and associated statistical analysis scripts will be archived and made available upon request at no charge to the user. As mentioned above, all final data products, raw data, and metadata will be archived on the UH ITS VMware data server and can be made available by request at no charge to the user. Prior to the end date of the funding period, or date of manuscript publication, data will be made available by request with the stipulation that if the data are used in publication then the researchers that collected the data need to be informed of the planned use and be offered authorship as appropriate.

V. Plans for archiving and Preservation of access:

Long-term archival and preservation of digital information will use cloud-based archives at the UH Data Center. Researchers will be given access to a temporary storage space to upload files for archival or to restore files. Each archived item will be assigned a unique identifier and associated with a metadata file describing all of the pertinent information of the archive. User files will be stored for 5 years while project documents will be kept for 10 years. A back-up plan of the critical systems will be established. User support and workshops on back-up best practices and on the available resources will be offered to faculty, staff and students. Users will be encouraged to use the ownCloud software for remote file-hosting and backup.

VI Data Analysis and Dissemination:

All data will be analyzed using methods described in the proposal. Each team has unique datasets (as described above), but all researchers will collaborate to properly collate datasets for large-scale analyses used to address the themes of this proposal. All statistical analyses will be directed to answer the questions outline in the narrative. Statistical analyses will occur immediately after the field activities to complete the project within the proposed period of performance. The key results and findings will be shared rapidly with NFWF through technical reports and presentations. Multiple publications will be developed from this proposal, and all data analyses and results for those publications will be made publicly available as described in this data management plan.

VII. Past Activities

All investigators have been actively involved in efforts to efficiently document and synthesize field and laboratory data. PI Pyle and Co-PI Burns, Fletcher, Spalding and Meyer have worked to develop strategies for data management and dissemination for several collaborative research projects funded by the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), NSF Centers of Research Excellence in Science and Technology (CREST) and NSF Experimental Program to Stimulate Competitive Research (EPSCoR). All personnel have demonstrated commitment to publishing quality data and associated metadata through their successful record of receiving multiple research grants and producing numerous publications (see CVs for all primary participants).

IMPLEMENTATION TIMELINE

Project Tasks	Months 1-3	Months 4-6	Months 7-9	Months 10-12
Project planning and coordination				
Fieldwork				
Analyses of island cores and samples				
3D Reconstruction and analysis of 3D models				
eDNA analysis				
Retrieval of sensors, arrays, and analysis of physiochemical data				
Stable isotope analysis				
Analysis of predator tag and acoustic data				
Taxonomic examination and documentation				
Development of reports and presentation to disseminate key findings to NFWF and managers				
Manuscript publications				
Outreach dissemination and public presentations				

Bishop Museum Budget Justification

Personnel Cost

Bishop Museum PI $14,000
$10,000 is requested to support Dr. Pyle's role in performing taxonomic research on mesophotic fishes and participation on the cruise to French Frigate Shoals. The standard Fringe rate at Bishop Museum is 40% of Salary ($4,000).

Equipment (>$5,000)

Multi-sensor array units $101,780
$101,780 is requested for four AML Oceanographic METREC-X multi-parameter instrument cluster for long term abiotic monitoring (4 x $25,445 = $101,780). No indirect is applied to equipment items that cost more than $5,000.

Batteries for multi-sensor array units $16,000
$16,000.00 is requested to power the Multisensor Array with Deep Sea Power and Light SeaBattery system ($16,000.00). No indirect is applied to equipment items that cost more than $5,000.

Rebreather diving unit $20,200
$20,200.00 is requested to purchase a new rebreather system, inclusive of backup computer and oxygen monitoring systems and gas analysis system ($15,200.00) and a portable air compressor with associated filters ($5,000.00). No indirect is applied to equipment items that cost more than $5,000.

Materials and Supplies

Temperature loggers $2,252
$2,252.00 is requested for 16 TidbiT v2 temperature loggers ($133.00 x 16 loggers =$2,128.00), and $124 for a USB Base Station needed for downloading data. 55.37% indirect is applied to all materials and supplies.

Diving supplies $4,856
$4,850 is requested for diving supplies, including helium (3 cylinders x $372.00 = $1,116.00), oxygen (5 cylinders x $120 = $600.00), CO2 absorbent (4 kegs x $160 = $640.00), and assorted support equipment including supplies for bailout cylinders and other small equipment items ($2,500.00). 55.37% indirect is applied to all materials and supplies.

eDNA supplies $7,131
$7,131.00 is requested to puchase supplies necessary for eDNA analysis, including sample bottles (4 x $100 = $400), filters (2 x $130 = $260), DNA extraction supplies ($1,200), KAPA supplies (2 x $604 = $1,208), PCR purification ($543), PIPPIN Cartriges (12 x $60 = $720), and other laboratory consumables ($2,800). 55.37% indirect is applied to all materials and supplies.

Contractual Services

Contract - Searcher research vessel $197,500
Searcher vessel and crew will be contracted to conduct a 13-day research expedition at French Frigate Shoals. This includes 6-days of total transit, and $7500 for loading and unloading days. Vessel and crew will provide two 20-ft zodiacs to facilitate shore-based research activities and

diving operations. Bishop Museum charges no indirect on contractual services.

Contract – eDNA sequencing $8,800
$8,800.00 is requested for eDNA sequencing services. This includes 4 MiSeq sequencing lanes (4 lanes x $2,200/lane = $8,800). Bishop Museum charges no indirect on contractual services.

Subgrant – UH Manoa $429,286.46
UH Manoa will receive a sub-grant to conduct research for the proposed Theme 1 and Theme 2 objectives. See full proposal for details of research activities, and see budget justification below for use of funds. Bishop Museum charges no indirect to subgrants.

Subgrant – UH Hilo $82,392
UH Hilo will receive a sub-grant to conduct research for the proposed Theme 1 objectives. See full proposal for details of research activities, and see budget justification below for use of funds. Bishop Museum charges no indirect to subgrants.

Indirect Costs

Indirect $15,635.93
Bishop Museum charges no indirect on equipment over $5,000, or on any contractual services or subgrant awards. An indirect rate of 55.37% is applied to Personnel costs and Materials and Supplies. Total indirect cost is $15,635.93.

Total Direct Costs	$884,197.46
Total Indirect Costs	$15,635.93
Total Costs	**$899,833.39**

Subgrant 1 - UHM Budget Justification

Personnel — Cost

UH Manoa PI — $33,451
$21,154 is requested for salary for co-PI Dr. Carl Meyer. Dr. Meyer will take a lead role in conducting project management, fieldwork, data analysis and report writing. 58.13% fringe is applied to this salary ($12,297).

Geospatial Analyst — $31,626
$20,000 is requested for the geospatial analyst salary. This position will be responsible for field work, data processing, trenching, reef mapping and sediment sampling. 58.13% fringe is applied to this salary ($11,626).

Graduate Assistant — $33,600
$30,000 is request for graduate assistant salary. This position will be responsible for processing digital elevation models and working with co-PI Vitousek on predictive habitat modeling. 12% fringe is applied to graduate assistant salaries ($3,600).

Graduate Assistant — $33,600
$30,000 is request for graduate assistant salary. This position will be responsible for processing radiocarbon dates, trenching, stratigraphic analysis, nearshore sediment compositional and age analysis. 12% fringe is applied to graduate assistant salaries ($3,600).

Travel

Travel to Hawaii for researchers — $8,200
$8,200 is requested to support travel for field work for co-PI Vitousek and co-PI Papastamatiou to Hawaii from their respective institutions. Travel costs will support trips for logistical coordinating, fieldwork, and dissemination. 41.5% indirect is applied travel.

Materials and Supplies

Acoustic transmitters — $20,000
$20,000 is requested for acoustic transmitters that will be implanted into predators to track their movements between shallow and mesophotic habitats. 25 transmitters (25 x $800 = $20,000) will be purchased for the project. 41.5% indirect is applied to all materials and supplies.

Acoustic receivers — $7,200
$7,200 is requested for receivers to detect predators implanted with acoustic transmitters. 4 receivers (4 x $1,800 = $7,200) will be purchased for the project. 41.5% indirect is applied to all materials and supplies.

Receiver batteries — $400
$400 is requested for batteries to power underwater receivers that detect tagged predators. 8 batteries (8 x $50 = $400) will be purchased for the project. 41.5% indirect is applied to all materials and supplies.

Acoustic releases — $7,200
$7,200 is requested for acoustic releases that allow surface recovery of receiver moorings deployed at shallow and mesophotic depths. 4 acoustic releases (4 x $1,800 = $7,200) will be

purchased for the project. 41.5% indirect is applied to all materials and supplies.

Hardware supplies $400
$400 is for hardware supplies to create moorings for underwater receivers. 41.5% indirect is applied to all materials and supplies. 41.5% indirect is applied to all materials and supplies.

Fishing supplies $400
$400 is requested for fishing supplies required for catching predators in order to tag and collect samples for stable isotope analysis. 41.5% indirect is applied to all materials and supplies.

Specimen collections $5000
$5,000 is requested for 100 specimen collections. This will cover the cost for DNA barcoding of new mesophotic algal specimens collected at FFS. 41.5% indirect is applied to all materials and supplies.

Phylogenetic marker sequencing $2,500
$2,500 is requested for full-length DNA marker sequencing for phylogenetic analyses of select taxa for full systematic analysis. 41.5% indirect is applied to all materials and supplies.

Basic molecular supplies $2,000
$2,000 is requested for Qiagen kits, exosap, etc., for both DNA barcoding and phylogenetic analyses of algal specimens. 41.5% indirect is applied to all materials and supplies.

Basic lab supplies $2,000
$2,000 is requested for gloves, agarose, tubes, tips, etc. to support microscopy and molecular analyses of mesophotic algal specimens. 41.5% indirect is applied to all materials and supplies.

Contractual Services

Contract – Bulk amino acid compound specific stable isotope analyses $16,000
$16,000 is requested for bulk analysis of stable isotopes isolated from tissue samples collected from predators. Samples will be sent for bulk analyses to enable analyses of food web dynamics at FFS. 41.5% indirect is applied to this contractual service.

Contract – Radio carbon dating and geochemical analysis $15,000
$15,000 is requested for analyzing trench samples, beach samples, and nearshore reef samples. All samples will be radiocarbon dated to analyze temporal relationships between sediment production and deposition. 41.5% indirect is applied to this contractual service.

Contract – UH Manoa supercomputer $10,000
$10,000 is requested for DEM processing of drone-derived imagery collected of the island habitats at FFS. Data will be processed using the UHM supercomputing facility. These services are exempt from Indirect Costs per UH policy.

Other Direct Costs

Postdoc stipend $110,000
$110,000 is requested for two postdoc stipends to process algal samples for taxonomic identification and molecular analysis. This fellowship payment is exempt from Indirect Costs per UH policy.

Indirect Costs

Indirect $90,709.46

UH Manoa charges no indirect on equipment over $5,000, contractual services to UH (e.g., supercomputer services), and postdoc stipends. An indirect rate of 41.5% is applied to Personnel costs, Travel, Materials and Supplies, and external contractual services. Total indirect cost is $15,632.61.

Total Direct Costs	$338,577
Total Indirect Costs	$90,709.46
Total Costs	**$429,286.46**

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Subgrant 2 - UHH Budget Justification

Personnel — Cost

Graduate Assistant $33,600
$30,000 is request for graduate assistant salary. This position will be responsible for processing coral reef imagery and processing 3D reconstructions, as well as assisting with temporal analysis of 3D reef models to detect structural change associated with bleaching. 12% fringe is applied to graduate assistant salaries ($3,600).

Travel

Travel to Oahu for researchers $2,000
$2,00 is requested to support travel for co-PI Burns and the graduate assistant to help with logistical planning and to conduct fieldwork during the expedition to FFS. 41.5% indirect is applied travel.

Equipment (>$5,000)

Custom Supermicro 4U GPU-compute server $21,700
$21,700 is requested for a high-power processing system to serve as local server for node processing of 3D benthic models from FFS. The server will facilitate all 3D reconstructions for coral reef models and temporal analyses of reef structure. No indirect is applied to equipment items that cost more than $5,000.

MSI WT73VR 7RM-687US Laptop $6,922
$6,922 is requested for a high-powered laptop with 3D modeling capability that will be used in the field to process imagery and ensure data collection is enabling full alignment and reconstruction of 3D reef models. No indirect is applied to equipment items that cost more than $5,000.

Materials and Supplies

Field supplies $1,000
$1,000 is requested for field supplies such as ground control points, transects, scale markers, and miscellaneous equipment used for 3D field surveys. 41.5% indirect is applied to all materials and supplies.

External hard drives $1,400
$1,400 is requested for external hard drives that will be used for storing imagery and data in the field that will be used for 3D reconstructions of coral reef habitats at FFS. 41.5% indirect is applied to all materials and supplies.

Indirect Costs

Indirect $15,770
UH Hilo charges no indirect on equipment over $5,000, contractual services to UH (e.g., supercomputer services), and postdoc stipends. An indirect rate of 41.5% is applied to Personnel costs, Travel, Materials and Supplies, and external contractual services. Total indirect cost is $15,770.

Total Direct Costs	$66,622
Total Indirect Costs	$15,770
Total Costs	**$82,392**

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MATCHING FUNDS — Amount

Personnel

Joshua Copus — $4,600

Salary for Joshua Copus to participate on the expedition and process environmental data and eDNA analysis will be provided by external sources (two months at half time)

Equipment

Poseidon Rebreather System — *$30,400*

Two Poseidon Rebreather Systems will be made available for use on this project, in addition to the system purchased with support from this project. This will enable two divers to complete full trimix dives to 100 m, with a third complete system available as backup.

Gas Filling and Transfer System — *$11,500*

A complete portable stainless steel gas filling and transfer system, including primary and backup booster pump) will be available for use on this project. These items are necessary for filling rebreather and bailout gas cylinders, and will be complemented by the air compressor purchased with support from this project.

Sony 4K Video System with Housing and Light — *$5,500*

A complete Sony 4K video system, including Nauticam housing and Light & Motion LED lighting system will be made available for use on this project, to capture specimen and in-situ habitat images at mesophotic and shallow depths at FFS during the expedition.

Supplies

Kolor Abyss 360 GoPro camera underwater housing — $4,800

The Kolor Abyss housing will be used to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the reefs at FFS.

GoPro Hero 4 black edition — $3,500

Seven GoPro cameras will be used and placed into the Kolor Abyss housing to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the reefs at FFS.

360-HERO 360 GoPro camera underwater housing and mount — $2,934

The 360-HERO mount, housing, and domes will be used to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the reefs at FFS.

GoPro Hero 3+ black edition — $2,590

Seven GoPro cameras will be used and placed into the 360-HERO housing to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the reefs at FFS.

Kolor PanoVideo Software — $823

The Kolor software will be used to stitch the GoPro videos to create 360-degree panoramic videos of the study sites that will be used for our outreach. These immersive videos will be hosted on the Coral Health Atlas, where users can get experience a virtual dive on the reefs at FFS.

TOTAL MATCH — **$64,647**#