Research Proposal

to the

The Dr. Michael Hutchins Impact on Wildlife Fund
c/o Ms. Song Hutchins, President/CEO

Submitted by

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Title: Assessing Ecosystem Balance in Predator-Limited Southern Hemisphere Kelp Forests

Period of Research: November 1, 2022 – March 1, 2023

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Principal Investigator: Alyssa Adler, directly advised by Dr. Brian Silliman

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Assessing Ecosystem Balance in Predator-Limited Southern Hemisphere Kelp Forests

Project Summary

Ecosystems worldwide maintain equilibrium through a series of checks and balances. In 1960, a team of scientists sought to explain the verdancy of Earth, despite abundant herbivory. They attributed greenness to trophic cascades ecosystem-wide, predicting top-down linear effects between trophic levels. However, modern ecology has shown cascading effects across trophic levels can be multidirectional. While most studies on trophic cascades are conducted locally, the range of kelp species *Macrocystis pyrifera* spans continents, offering a unique opportunity to track fluctuations in trophic cascades within kelp systems over vast latitudinal ranges.

Kelp forests create habitat structure in temperate seas circumglobally, hosting productive and dynamic communities. These structurally significant brown algae thrive in mid-high latitudes, where long photo periods facilitate rapid growth, and upwelling replenishes nutrient-rich seawater. Historically, a trophic cascade in NE Pacific kelp forests triggered by the removal of sea otters results in significant increase of algal grazers (urchins, echinoid species), and subsequent decrease in kelp. A slow increase in sea otter populations in these regions over the last century, however, has resulted in fewer algivore urchins and more abundant kelp forests, demonstrating effective top-down control. This paradigm has been described in Pacific kelp systems, but while the sea otter's range does not extend to South America, *Macrocystis* co-exists with echinoid grazers throughout Patagonia.

Though this predation disparity has not been investigated through the range of *Macrocystis*, research in austral kelp forests confirms macroalgae *Ecklonia* display high phlorotannin content. These defensive chemical compounds reduce palatability and grazing success. Plasticity in chemical defense production among *Macrocystis* across a predator gradient would suggest novel flexibility between top-down and bottom-up control in one foundation species across latitudes. I will study *Macrocystis* in Patagonia, investigating structural and chemical defense as the ecosystem moves southerly and echinoid grazers persist.

Project Objectives and Methods

Q1: How does chemical defense against echinoid grazers in *M. pyrifera* change between predator-free South American *M. pyrifera* forests and predator-present North American forests?
H1: I predict habitat building *M. pyrifera* exhibits higher chemical defense in South America than in similar, predator-present North American forests.

Methods: I will use a combination of lab-based analysis and observational studies to determine chemical defense production in *M. pyrifera* across a predator gradient. In the field, 30m transects will be deployed at sites (n=15) at equal depths in both southern Patagonia and central California; this portion of the study will focus on Patagonia. To quantify site-specific predator and grazer presence, SCUBA divers will conduct roving fish counts and species ID, collect photo-quadrats to record invertebrate species and abundance, and record video along each transect to capture mid-water species. To quantify local grazer pressure on *M. pyrifera*, at each site a number of individuals will be selected, and a SCUBA team will record grazer ID to species level and abundance per kelp plant. The team will also quantify grazing scars per plant by counting scar length and number per blade for 6 separate blades at a standardized position on each *Macrocystis* individual. The SCUBA team will conduct sampling from each of these selected individual kelp, clipping 5cm of tissue from a submerged kelp blade at a standardized

position on the *Macrocystis* individual. After sampling, kelp tissue will be immediately placed in a drying oven at 40 degrees Celsius for 48 hours before being stored in sealed bags with silica beads to ensure continued dryness. Samples will be transported, then analyzed using the Denis-Coicalteu method to extract phenolic compounds. This analysis will determine phlorotannin content in each sample, and alongside data collected in the field will generate an understanding of chemical defense production in *M. pyrifera* across a natural gradient of grazer and predator density in the southern hemisphere.

Q2: How does algivore density affect phlorotannin content and structural defense in individual kelp?
H2: I predict increasing grazer density will result in increased levels of structural and chemical defense in *M. pyrifera*.

Methods: In a lab-based study conducted at the CADIC research institution in Ushuaia, Argentina, I will test grazer pressure on a variety of *Macrocystis* individuals collected from the field. Collected samples will be sub-sampled, where each blade will be clipped and analyzed using the Denis-Coicalteu method to extract phenolics. With a known chemical defense content, I will systematically increase grazer density in each tank over time, sampling the kelp periodically to note shifts in chemical and structural defense by using the Denis-Coicalteu method. Results will illustrate the impact of increasing grazer density on individual *M. pyrifera* and associated plasticity in chemical and structural defense production.

Project Rationale

As ocean conditions shift worldwide, we can expect this investigation to have applied implications for management and protection of key species including sea otters, temperate marine mammals, and recreationally important fish species. Tropicalization of temperate ecosystems has already impacted kelp forests globally. These marked impacts have been quantified in Tasmania, where 95% of the iconic kelp forests have been lost. Along with the loss of kelp forest habitat, many commercially and recreationally important fish species and crustaceans are no longer viable in this region. Tropicalization is impacting other temperate areas, including Maine and California. The Patagonian region of South America is at risk of tropicalization as well, but is more protected from seawater warming by the consistent westerly currents of the polar Southern Ocean. This presents an opportunity to conduct research on stable *Macrocystis* forests in South America, which may employ robust strategies and increased resiliency to survive in unfavorable conditions. By better understanding functional mechanisms of South American *Macrocystis pyrifera* forests, the scientific community will be more prepared moving into a future where prevention and mitigation of disturbance is key in these important ecosystems.

Project Outcomes and Application

As a Ph.D. student in Dr. Brian Silliman's lab at Duke University's Marine Science and Conservation program, I am able to continue development of my research and formal education. Additionally, I will disseminate research findings while working through local STEM outreach program Sci-REN, under Dr. Avery Paxton. I plan to continue my dissertation research through 2026, answering these questions as comprehensively as possible. I will publish my results in peer-reviewed scientific journals throughout the duration of my Ph.D. program and beyond. As

kelp forest ecosystems face the challenges of climate change and increasing seawater temperature, I expect my research will enable management teams to better understand how cross-hemispherical *Macrocystis* forests respond to stressful conditions. Additionally, I collaborate with Lindblad Expeditions and the National Geographic Society. This partnership allows me to utilize Lindblad Expedition's eco-tourism vessels as a research platform in southern Patagonia. Collaboration with Lindblad Expeditions and the National Geographic Society will allow me to disseminate my research to laymen, presenting research-focused lectures to shipboard guests, and using my videography skills to extend the reach of this work past the scientific community, offering folks a stronger understanding of STEM research.

Project Budget

Funds Requested	Units	Cost/Unit ($USD)	Total Cost ($USD)
30m Transect Tape	2	55.96	111.92
Dive Slates	4	26.50	106.00
Dive Slate Hardware	4	8.50	34.00
Dive Slate Taxes/Shipping	1	25.00	25.00
Waterproof Paper	2	64.00	128.00
Handheld GPS	1	349.99	349.99
GoPro Hero 10	2	449.98	899.96
GoPro Housing	2	49.99	99.98
Housing @ Field Site ($10/night)	24	10.00	240.00
Dive Boat Charter ($400/day)	20	400.00	8000.00
Total Funds Requested			**9994.85**