

The Rufford Foundation Final Report

Congratulations on the completion of your project that was supported by The Rufford Foundation.

We ask all grant recipients to complete a Final Report Form that helps us to gauge the success of our grant giving. The Final Report must be sent in **word format** and not PDF format or any other format. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work. Please be as honest as you can in answering the questions – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please complete the form in English and be as clear and concise as you can. Please note that the information may be edited for clarity. We will ask for further information if required. If you have any other materials produced by the project, particularly a few relevant photographs, please send these to us separately.

Please submit your final report to jane@rufford.org.

Thank you for your help.

Josh Cole, Grants Director

Grant Recipient Details	
Your name	Robert Lamb
Project title	Fish diversity in the Galapagos Islands: implications for marine reserve management and ecosystem functioning
RSG reference	12661-2
Reporting period	June 2014 – June 2015
Amount of grant	£6000
Your email address	Robert_lamb@brown.edu
Date of this report	6/30/15

1. Please indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Surveys of fish diversity			YES!	12 sites surveyed in June-August 2014, January 2015, and June-August 2015.
Description of physical drivers of fish diversity		Still in progress		Surveys will continue through El Niño peak (2015) to highlight species and locations most susceptible to diversity loss under changing climate
Manipulative experiment testing effects of wave exposure on fish diversity			YES!	Contrary to predictions and standard ecological theory, fish diversity <i>increased</i> with wave exposure, highlighting the ability of mobile consumers (fish) to affect ecosystem function in dynamic and stressful environments
Description of oceanographic drivers of fish consumer pressures		Still in progress		Video recordings of fish herbivory on the benthos started in January 2015, will continue through this summer to evaluate effects of temperature and productivity on consumer pressures
Technical report to Galapagos National Park			YES!	Oral presentation given in August 2014, initial report in January 2015, and a final report will be given in August 2015
Peer-reviewed publications		Still in progress		Three publications stemming from this work expected by 2017
Integration of Google Streetview into subtidal monitoring programme			YES!	See the Galapagos streetview underwater images and video
Identification of environmental indicator species			YES!	The yellowtail surgeonfish (<i>Prionurus laticlavus</i>) responds strongest to wave stress, while the long-nosed hawkfish (<i>Oxycirrhites typus</i>) requires vertical walls and black coral habitat

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled (if relevant).

One of the biggest difficulties in implementing this project was negotiating the political waters of the Galapagos conservation and science arenas. Because of its status as a global icon of pristine wilderness, rich natural history, and conservation priority, several major research and conservation entities have full-time staff stationed here on a variety of projects. The Galapagos National Park and Charles Darwin Research Station also maintain their own research and community outreach efforts. As a result, the community is somewhat saturated and in many

instances we were rebuked for venturing into the “territory” of another group. It is our belief that the most successful and long lasting conservation biology projects are borne of inter-disciplinary collaboration and open dialogue. The very nature of our field of work is also highly dynamic and adaptive, requiring exploratory forays to pursue a lead in a new direction. One such endeavour we sought to include in our work was to produce a documentary film highlighting fishermen in the Galapagos, their role within the local economy and culture, and the paradox of fishing to sustain the permanent local population and hundreds of thousands of tourists each year, all within a supposedly protected marine reserve. We also wanted to enhance the dialogue between fishermen, researchers, and park authorities in order to include traditional fishermen knowledge in our efforts. However, the proposal did not sit well with certain authorities, who preferred we did not hold conversations with the fishing sector for reasons unexplained. In the interest of maintaining our good standing with all involved we desisted.

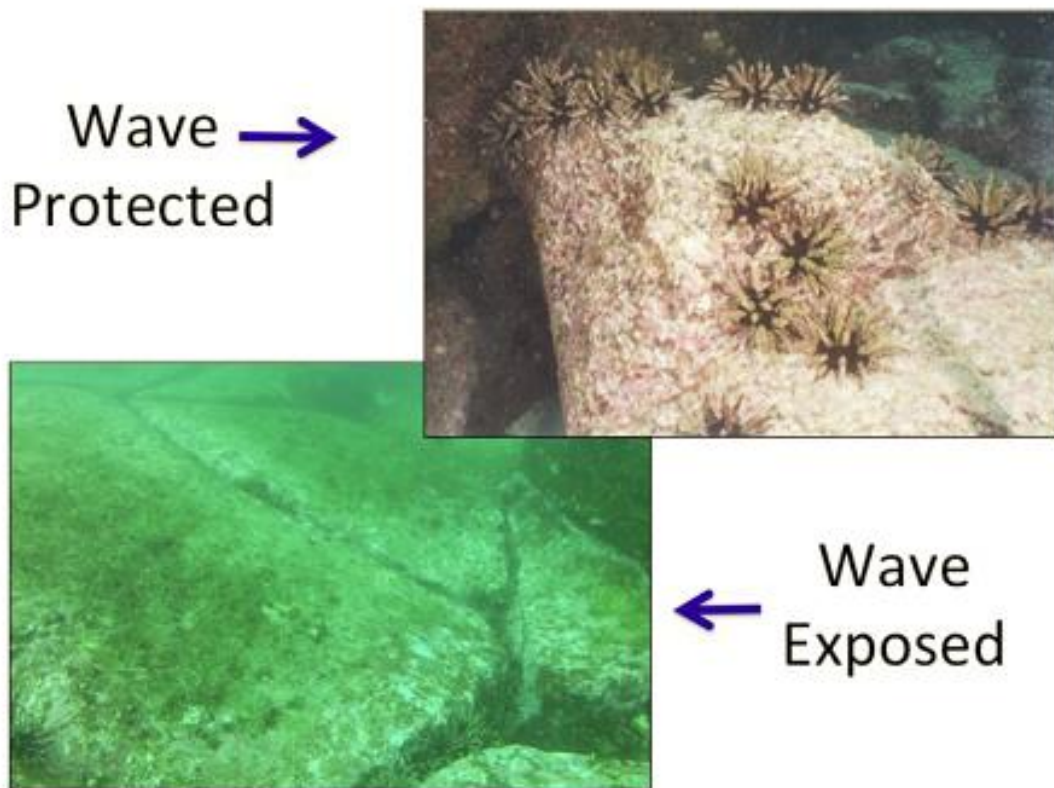
3. Briefly describe the three most important outcomes of your project.

1. A presentation and accompanying report was delivered to the Galapagos National Park and Charles Darwin Research Station authorities and staff this year. These outlined the major findings of the importance of individual species for ecosystem functioning, the effects of several environmental stressors and abiotic forces on fish and benthic community diversity, and the projected effects of El Niño cycles on these and other components of ecological stability.

2.



3. A novel and quite unexpected relationship was described between the strength/degree of exposure to oncoming waves and fish diversity and biomass. Whereas our original hypothesis was that fish communities would decrease in biomass and complexity with increasing wave stress, we observed a rapid *increase*. The south-facing side of islands, exposed to the predominating southerly swells, were full of fish, mostly large herbivores such as parrotfishes and surgeonfishes, which were grazing in the turbulent waters on a rich bed of turfy algae growing on the rocks. Just around the corner of a peninsula, not 200 m away, was a protected embayment. With all the same characteristics of rock type, water temperature and chemistry, etc., this side was an urchin barren, where pencil-sea urchins (*Eucidaris galapagensis*) reach densities surpassing 50/m², and they have completely grazed the algae down to a crustose coralline algal crust (not very nutritious or easy to bite into for fish).



There are also urchins on the exposed side, but there they are limited to persist in cracks between boulders. The chronic stress of water motion around them reduces grazing rates and they often cannot even walk out on the rock surfaces for risk of dislodgement. This frees up a food resource for fish grazers, which are highly mobile and can get in, feed, and get out because they are *faster than the return time of the physical stress* (waves). So essentially, when a limiting resource (such as algal food) is available in a stressful environment, consumers can access it and exert control over the food web/ecosystem as long as their mobility surpasses the periodicity of the stressor.

Here, the stress is hydrodynamic energy produced by wave turbulence. In sufficient numbers, urchins can completely graze down most of the rock substrate to these desert--like epilithic crusts. Wave turbulence reduces the capacity of urchins to graze, and enter the fish. The fish can get in, feed, and get out before the next set of heavy waves. The grazing strategies that fish use involve roving bites that have an effect of increasing benthic diversity and whole foodweb productivity. The analogy is a clear cut as compared to a pruned and constantly regenerating forest.



This presents a new outlook on the drivers of fish diversity and biomass on Galapagos rocky reefs, and changes our conception of how environmental stress affects consumer pressures on the benthos. This has far reaching implications for community diversity and overall productivity of the ecosystem, and will aid in the currently ongoing process of re-zoning the Galapagos Marine Reserve.

4. Our project created jobs, training opportunities, and environmental education on several avenues. We provided alternative income for four different fishing boats, which now spend a substantial portion of their time providing services to local scientists instead of extractive fishing. We trained staff from the Charles Darwin Foundation, the Galapagos National Park, and several Galapagos natives in underwater census and experimental research methodologies using SCUBA and snorkel, as well as in laboratory techniques for processing samples. We gave talks at the National Park, Brown University, the 2015 Benthic Ecology Meeting in Quebec, Canada, and the Rufford Small Grants Regional Conference in Valparaiso, Chile. We produced two documentary-style films during this period:

[The unique roles played by different species of grazers and their predators in subtidal rocky reefs of the Galapagos Islands](#)

[Marine Ecology in Easter Island](#)

We also organised and hosted a [marine film festival](#) at Brown University, which showcased 12

films on marine science and conservation from around the world, including our own productions. This was followed by a discussion panel hosted by Brown University professors Dr Jon Witman and Dr Heather Leslie, and Dr Jennifer Galvin, filmmaker and science communicator. This event was incredibly successful and we plan to hold future viewings both at Brown and in the Galapagos. We have also made regular posts to our lab website (www.witmanlab.com) highlighting our work in marine ecology and conservation in the Galapagos and elsewhere.

4. Briefly describe the involvement of local communities and how they have benefitted from the project (if relevant).

We worked with the local community of Puerto Ayora, Galapagos, where the Charles Darwin Research Station is located and where the majority of our field work took place. This involved three primary efforts:

1) We led a high school field course on marine biology at the Charles Darwin Foundation in Galapagos. Students from the Tomás de Berlanga high school came to learn about basic marine biology and we took them snorkeling and looking for critters in the bay outside the station. It was surprising that some of them, who have lived on Santa Cruz Island all their lives, had never seen the underwater world of the Galapagos before! We also invited the students to help us with the analysis of our algal samples, which were assessed for total biomass and diversity of plants. In this way, the students saw what marine ecology research was like and many expressed their interest in pursuing a natural sciences career in university.

2) We worked with four different fishermen's boats to carry out our field research in Galapagos. The Galapagos Islands are a National Park and Marine Reserve in their totality, but the presence of a permanent human population necessitates extractive and often damaging practices to sustain it. Working in crews of two or three, fishermen use scuba, hook and line, and small nets to catch a variety of groundfish and pelagic species. By working with the four boats and their crews to carry out our work, we held daily conversations with these fishers to open dialogue regarding the importance of fish diversity for ecosystem stability, the resilience of marine habitats in the Galapagos to climate change, and the incorporation of traditional fisherman knowledge into our scientific understanding of how the marine ecosystem functions. This also provided the fishermen with an alternative and non-extractive source of income that continues to play a major part in their economies.

3) Recurring community events to spread awareness and appreciation of the fragility of marine ecosystems and to educate the public on the basic ecology of marine organisms. One such event involved showing cartoon videos of the breeding habits and life cycle of the Bacalao grouper (*Mycteroperca olfax*), which is the 4th highest grossing fishery species in the Galapagos. Another was to bring several groups of elementary school children to a local beach and construct a lifesize whale shark sand sculpture.

5. Are there any plans to continue this work?

We are currently continuing this work in conjunction with ongoing research efforts at the Charles Darwin Research Station. In the coming months we will bring the experiment analysing wave stress and its effects on fish diversity and ecosystem functioning to a close, but this work has opened up new lines of questioning that we hope to explore with future funding. Namely, we are

interested in evaluating the capacity of individual species and families of herbivorous fishes (e.g., parrotfishes, surgeonfishes, and chubs) to respond to and resist environmental stress, thus maintaining high secondary productivity and bolstering ecosystem resilience to perturbation. In addition, the sharp temperature gradients produced by mixing deep and surface water currents provides an ideal system in which to test the effects of fish consumer pressures across a range of sea surface temperatures indicative of global climate change and local seasonal fluctuations. Finally, there is a moderate El Niño event that has been materializing for the past several months over the tropical Eastern Pacific. The NOAA [climate forecasts](#) predict a 90% chance that this will continue through the end of the year, which presents a unique opportunity to observe the effects of this climatic phenomenon on our study system. During El Niño years, westerly trade winds relax, slowing the flow of warm tropical surface waters across the Pacific. As a result, Eastern Pacific sea surface temperatures increase, stratifying the water column and reducing productivity in the euphotic zone. We are in a prime position to document the effects of these trends on fish and benthic communities, which is of vital importance for marine conservation strategies under the scenario of increased frequency and magnitude of these climatic anomalies. We hope to secure continued funding in order to produce an accurate report of these trends to the Galapagos National Park.

6. How do you plan to share the results of your work with others?

The efforts made to communicate the results and progress of our work include documentary videos, a continually updated web blog, reports and presentations for the Galapagos National Park and Charles Darwin Research Station, small workshops and educational seminars, and personal training. In the next two years, we also expect three publications in peer-reviewed journals as a direct result of this work:

1. The effects of El Niño, ocean productivity, and benthic topography on fish community structure in the Galapagos Islands.
2. Wave stress enhances fish grazing on a rocky subtidal reef: a test of the Stress-Mobility Hypothesis.
3. Ecomorphology and food availability drive spatial segregation of herbivorous fish communities along a wave exposure gradient.

7. Timescale: Over what period was The Rufford Foundation grant used? How does this compare to the anticipated or actual length of the project?

The RSG was used during the expected time period of June 2014-June 2015. However, the project continues as we have developed new lines of inquiry and conservation targets as a result of initial results. We expect to continue this project and its related fields of study through 2017.

8. Budget: Please provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Dive boat rental	2400	3050	+650	Extra days needed to fully set up manipulative experiment
Food and lodging	1260	524	-736	Lodging was arranged for free due to the generosity of the Charles Darwin Research Station
Air travel	960	1150	+190	Airfare prices have increased since budget was prepared
Tools and equipment	624	916	+292	A new SCUBA regulator was purchased to replace one stolen during the project
GoPro Cameras	540	360	-180	Only 2 cameras were needed for filming
Total	6000	6000	0	

9. Looking ahead, what do you feel are the important next steps?

The Galapagos National Park is currently in the process of redesigning the marine reserve surrounding the islands based on the provision of ecosystem services, preservation of unique marine fauna, and minimisation of the negative effects of artisanal fishing activities. By the end of August 2015, we intend to provide a comprehensive report on the primary findings of our project for inclusion in this legislative process.

Through 2017, we intend to actively continue our ecological monitoring programme (pending continued financial support) in order to comprehensively assess the effects of El Niño phenomena on marine fish and benthic communities in shallow rocky reefs.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the RSGF receive any publicity during the course of your work?

The RSGF logo was used during the showing of the Beneath the Waves Film Festival at Brown University in May 2014 as one of the sponsoring institutions. The logo was also featured in an oral presentation delivered at the 44th Benthic Ecology Meeting held in Quebec City, Canada, in March 2015. This is one of the largest marine ecology meetings in North America and signified exposure for the RSGF to more than 500 top marine scientists and conservationists. A presentation and poster were also delivered at the Rufford Small Grants Conference regional meeting held in Valparaiso, Chile in May 2015. Finally, the logo was presented as part of the informational seminar and technical report delivered to the Galapagos National Park and Charles Darwin Foundation

11. Any other comments?

This project would not have been possible without the constant support and assistance from the Charles Darwin Station and Galapagos National Park, as well as the boat captains, field assistants, and countless others who have helped along the way.

Thank you again for your generous support of our work!