

Final Evaluation Report

Your Details	
Full Name	Prof. Julia K. Baum
Project Title	Ecosystem Consequences and Recovery from a Globally Unprecedented Heat Stress Event
Application ID	27855-D
Grant Amount	£10,000
Email Address	juliakbaum@gmail.com ; baum@uvic.ca
Date of this Report	4 January 2022

1. 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
1. Coral Reef Ecosystem Monitoring				
a) quantify fish and invertebrate abundances				We mostly achieved this objective as we sampled 14 sites for fish surveys and seven for urchin surveys. We had hoped to sample 20 sites but due to poor weather we were unable to access some sites.
b) quantify benthic community composition/ coral recruitment				We mostly achieved this objective as we sampled 14 sites. We had hoped to sample 20 sites but due to poor weather we were unable to access some sites.
c) quantify reef structural complexity				We mostly achieved this objective, photographing all permanent mega-photo quadrats at 11 of the 14 sites. The three unphotographed sites were due to poor weather.
d) sample tagged coral colonies				We met expectations for the sites we were able to sample - sampling 238 tagged coral colonies, tagging and sampling 47 new ones, and collecting photographs to create 3D models of 122 corals to analyse coral growth.
e) coral recruitment tiles				We mostly achieved this objective, retrieving and redeploying tiles at 11 of the 14 sites. The three unsampled sites were due to poor weather.
f) changes to food web				We achieved this objective, collecting fish, invertebrate, plankton, and algae samples for stable isotope analysis at eight target sites. (Note: We substituted two of the originally planned sites for three others due to their inaccessibility due to bad weather).
2. Socioeconomic Monitoring				We mostly achieved this objective. We conducted interviews in only 89 households although we had aimed

				to survey 160 households.
3. Conservation Education and Outreach				
a) participatory research				We fully achieved this objective, conducting our socioeconomic surveys with our partners at the Ministry of Environment and training Ministry of Fisheries divers in our methods.
b) conservation education activities				We focused our activities on school groups, and successfully conducted our proposed presentations, interactive activities (crafts, games etc.) on coral reefs, climate change, sharks, and reef fishes.
c) reports				We prepared and disseminated the report in 2019 and early 2020.
d) global communications				We shared our project on our websites and via social media. In March 2020, the documentary about the impacts of climate change on coral reefs (filmed our work on Kiritimati in 2018) came out on the Nature of Things in Canada and several other platforms since then.

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

None apart from that we were unfortunate with the weather and unable to sample any of the sites in the Bay of Wrecks due to large waves. Aside from that, there were the usual challenges of working in such a remote field location, but we had a fantastic team, who worked incredibly hard, such that we had a successful expedition.

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

Our 2019 expedition was a success aside from the unfortunate weather, and my team of students at the University of Victoria have been working hard to process and analyse data, and write manuscripts based on our field data. We have made considerable progress, notably the following three outcomes, which relate to the four 'monitoring success' components of my application:

i) discoveries about the Impacts of the 2015-2016 El Niño: Based on data collected during the 2019 expedition supported in this grant (as well as our 2015-2018 expeditions), we have documented significant ecological impacts of the El Niño including:

- almost complete elimination of soft corals during the heatwave (Maucieri and Baum. 2021. Impacts of heat stress on soft corals, an overlooked and highly vulnerable component of coral reef ecosystems. *Biological Conservation* 262:109328).
- a novel mechanism of coral resistance to heat stress (Claar, Starko, Tietjen, Epstein, R. Cuning, Cobb, Baker, Gates and Baum. 2020. Dynamic symbioses reveal pathways to coral survival through prolonged heatwaves. *Nature Communications*. 11,6097.).
- the utility of different acoustic indicators on coral reefs (Dimoff, Halliday, Pine, Tietjen, Juanes and Baum. 2021. The utility of different acoustic indicators to describe biological sounds of a coral reef. *Ecological Indicators*. 124:107435.).
- impacts of chronic disturbance on *Symbiodiniaceae* and bacterial communities in corals (Claar, McDevitt-Irwin, Garren, Vega Thurber, Gates and Baum. 2020. Increased diversity and concordant shifts in community structure of coral associated *Symbiodiniaceae* and bacterial communities subjected to chronic human disturbance. *Molecular Ecology* 29: 2477-2491.).
- impacts of chronic disturbance on *Symbiodiniaceae* beta diversity (Claar, Tietjen, Cox, Gates and Baum. 2020. Chronic disturbance modulates symbiont (*Symbiodiniaceae*) beta diversity on coral reefs. *Scientific Reports* 10, 4492.).
- evidence of how heat stress directly impacts reef fish communities (Magel, Dimoff and Baum. 2020. Direct and indirect effects of climate change-amplified heat stress events on coral reef fish communities. *Ecological Applications* 30(6): e02124.).
- comparisons between remotely sensed and *in situ* temperature (Claar, Cobb and Baum. 2019. In situ and remotely sensed temperature comparisons on a Central Pacific atoll. *Coral Reefs* 38(6): 1343-1349.).
- heat stress induced changes to the coral microbiome, including increases in alpha and beta diversity (indicative of invasions by pathogenic bacteria (McDevitt-Irwin, Garren, Vega Thurber, McMinds, Baum, 2019. Variable interaction outcomes of local disturbance and El Niño-induced heat stress on coral microbiome alpha and beta diversity. *Coral Reefs* 38(2): 331-345).
- significant loss of reef habitat structure and volume (Magel, Burns, Gates, Baum. 2019. Effects of bleaching-associated mass coral mortality on reef structural complexity across a gradient of local disturbance. *Scientific Reports* 9: 2512., and Bruce, Burns, Baum. In advanced preparation for *Journal of Applied Ecology*).
- mass coral mortality (~90% coral cover loss around the atoll; Baum, Claar, Tietjen, Magel, Maucieri, Cobb, Lund, McDevitt-Irwin. In advanced preparation for *Scientific Advances*).

ii) discoveries about short-term recovery from the 2015-2016 El Niño: We have closely monitored coral recruitment (new corals ~0.5mm) around the island using settlement tiles and have documented almost total recruitment failure thus far. We are preparing this work for publication (Tietjen, Epstein, Baum in advanced prep for *Coral Reefs*).

- Additionally, we are quantifying the abundance of juvenile and sub-adult corals for signs of recovery. Our work shows significant losses, but also that there are still corals of these life history stages around the atoll (Tietjen, Perks,

O'Brien, Baum, in prep).

- We have also tagged and sampled new corals and continued to sample coral colonies that were tagged before/during the El Niño. These are providing important new information about how coral symbionts change with heat stress.

iii) Conservation Education and Outreach. In 2019, we made multiple presentations to, and conducted interactive activities with, the local school children to teach them about coral reef biology and conservation. These were well received. Additionally, in 2020, a documentary, Reef Rescue (<https://www.vulcanproductions.com/reefrescue>), was released, which followed the impacts of climate change on coral reefs and highlighted our Rufford-supported research on Kiritimati during the heatwave and in subsequent years (2016-2019). This documentary was first released on The Nature of Things (March 6, 2020, <https://www.cbc.ca/natureofthings/episodes/reef-rescue>) and has since been released on other platforms (e.g., PBS Nova). It was also awarded the Best Conservation Film from Jackson Wild Media Awards in 2020. These measures should increase awareness locally and globally, respectively.

4. What do you consider to be the most significant achievement of this work?

The most significant achievement of this work is that we have been able to document the impacts of, and initial recovery from, a globally unprecedented marine heatwave on a coral reef ecosystem that would not otherwise have been studied. Through this work we have made several important and novel discoveries about how climate change impacts coral reef ecosystems – including that some corals can recover from bleaching while still under heat stress (see profile in Science “In surprising sign of resilience, some corals can survive long heat waves”; <https://www.science.org/content/article/surprising-sign-resilience-some-corals-can-survive-long-heat-waves>), that soft corals (which are seriously understudied) are even more vulnerable to heat stress than hard corals, that reef fish also respond directly to heat stress, and that recovery from mass coral mortality will be a very slow process. We have also been able to bring these discoveries to a wide audience through the Reef Rescue documentary as well as many public talks.

5. Briefly describe the involvement of local communities and how they have benefited from the project.

At this stage, having conducted 15 expeditions to Kiritimati over the past decade, my team and I have strong connections with local communities, businesses, and government (Ministry of Fisheries, Ministry of Wildlife). We will continue to build on these connections and on community involvement in our future trips. In particular, during our 2018 and 2019 expedition one of the Ministry of Fisheries technicians started working with us on our boat. We are teaching him our protocols and will continue to work with him this coming year. The local community benefits through knowledge about the status of their coral reef ecosystem, as our monitoring program is the only one conducted on Kiritimati. I had planned to travel to Tarawa (the capital) to meet with government in 2020 but due to Covid-19 and the Kiribati

Government's ban on international travel I have had to delay that trip until it is safe and possible to travel there again.

6. Are there any plans to continue this work?

Yes. I feel deeply committed to Kiritimati (both the people and the environment) and I plan on continuing my work there for the foreseeable future. Due to Covid-19, my team and I have been unable to return to Kiritimati since this 2019 Rufford-supported expedition. The Republic of Kiribati will be re-opening to visitors in early 2022 and thus we have started to plan a research trip for August 2022 and would like to apply for the Completion Grant that would support our coupled socioeconomic-ecological monitoring program, and focal studies on coral reef recovery dynamics.

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

We shared the results of our 2019 expedition with the local government on Kiritimati (Ministry of Fisheries, Ministry of the Environment) through the 2019 Research Report. When we can travel to Kiritimati again then we will share our work with the local government by meeting with them in person. The research report was also sent to the federal Government of Kiribati in Tarawa (in early 2020); we send copies of our publications to both as well, as they come out.

I have presented research from this expedition in nine invited scientific talks: University of Victoria (2021), Western Washington University (2020), Duke University (2020), Bamfield Marine Science Centre (2020), Verena Tunnicliffe Symposium at University of Victoria (2020), G.E.H. Barrett-Hamilton Memorial Lecturer at University of Manitoba (2019), Riser Lecture at Northeastern University (2019), University of New Brunswick (2019), Shedd Aquarium (2019)

I have also delivered seven public talks about this research: Aviso Wealth investing company (online across Canada, 2021), Canadian Society of Petroleum Geologists (online across Canada, 2021), NSERC Science Literacy Week Guest Speaker (online, 2020), NerdNite (Victoria, 2019), Public lecture University of Manitoba (2019), UVic Division of Continuing Studies lecture series (2019), Explore UVic presentation (2019)

We have published peer-reviewed papers from this work and presented it in five talks and/or posters at the 2021 International Coral Reef Symposium conference.

This work was also highlighted in the award-winning Reef Rescue film, a coral reef and climate change documentary (Merit Motion Pictures/Vulcan Productions (<https://www.vulcanproductions.com/reefrescue>); Aaron Floresco (Producer) and Su Rynard (Director); Best Conservation Film from Jackson Wild Media Awards in 2020). It was first released on The Nature of Things (March 6, 2020, <https://www.cbc.ca/natureofthings/episodes/reef-rescue>) and has since been release on other platforms (e.g., PBS Nova).

Lastly, we share our work via social media on Twitter and Facebook: @BaumLab, which now has >6500 followers and on our websites. We have also uploaded a

selection of the 3D models to Sketchfab (<https://sketchfab.com/baumlab/models>) to share these models publicly.

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

The period of the work for this Rufford Foundation grant was April - August 2019, with funds all spent supporting our four-week expedition to Kiritimati. This is the same as the anticipated timeline. Note: some work remains to analyse and write-up the data, and my students and I will continue working hard on this this year.

9. Budget: 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. It is important that you retain the management accounts and all paid invoices relating to the project for at least 2 years as these may be required for inspection at our discretion.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Research Permit	£188	£194	+£6	Foreign wire transaction fee increased
Shipping/excess luggage charges	£1125	£1188	+£63	We checked one more bag than we budgeted for
Dive safety supplies	£230	£363	+£133	Ended up needing more than originally thought
Underwater equipment	£375	£20	-£355	Did not end up needing as many materials as expected
Dive tank rental	£145		-£145	We received a different source of funding that allowed us to purchase our own dive tanks, so we did not have to rent anymore
Boat rental	£3038	£3844	+£806	Used more fuel than anticipated
Outreach materials	£188	£49	-£139	There were school supplies that were donated from other individuals at UVic, but we only had a certain amount of room for the supplies, so we ended up not purchasing as much as originally planned
Household survey	£75	£51	-£24	Materials were less than

supplies				anticipated
Transportation costs for household surveys	£1050	£408	-£642	Rental car on Kiritimati was cheaper than anticipated
Salary for interpreters for household surveys	£525	£265	-£260	Ended up only requiring 10 days' work total
Flights (to/from Kiritimati via Honolulu)	£3061	£3619	+£558	Flights were more than anticipated
Total	£10000	£10001	+1	Exchange rates used: \$1.56CAD = £1GBP (this was the exchange rate UVic used when the grant money was deposited into the account at UVic.)

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

The most important next step ecologically is to assess the status of Kiritimati's coral reef recovery following the 3-year hiatus that we have had due to Covid-19. It is important to document natural reef recovery to discover key mechanisms to ensuring reef resilience.

As travel opens back up and we return to Kiritimati, I will continue to strengthen my ties with local government and communities. Important next steps are to determine what conservation policies might be feasible on Kiritimati, both in terms of fisheries resource management and climate change adaptation.

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

Yes. The RF logo has been shown (as an acknowledgement to our RF funding) on all talks about this research and is included in my students' theses. We also acknowledged The Rufford Foundation in tweets about the expedition, and we acknowledge the foundation in each of our Kiritimati publications.

12. Please provide a full list of all the members of your team and briefly what was their role in the project.

Canadian/U.K. Team:

Kristina Tietjen: Kiritimati Project Manager, Coral field team member

Sean Dimoff: Fish team lead and dive safety specialist

Hannah Epstein: Coral field team member, post-doctoral fellow (conducted analyses on coral microbiome).

Niallan O'Brien: Research Technician, Socioeconomic surveys

Blake Hamilton: Coral field team member

Kevin Bruce: Coral field team and fish team member

Scott Clark: Fish team member

Kiritimati Team:

Rebeka Abaiota: Socioeconomic surveys, Wildlife Office, Ministry of Wildlife

Taratau Kirata: Senior Fisheries Officer

Ratita Bebe: Head of MELAD, Ministry of Wildlife

Alfred Smith: Dive team support

13. Any other comments?

I am grateful for Rufford's continued support of my project on Kiritimati and look forward to continuing this work.