KIRITIMATI

CLIMATE CHANGE and FISHERIES IMPACTS ON THE WORLD'S LARGEST ATOLL

BAUM LAB 2017 RESEARCH REPORT

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INTRODUCTION: In 2017, we conducted our 13th expedition to Kiritimati, continuing our long-term research on the atoll, which began in 2009. Our goals are:

- to understand the **impacts of the 2015-2016 El Niño event** on the reef and the i-Kiribati;
- to understand the community structure of Kiritimati's coral reefs, including the abundance and diversity of the corals, reef fishes, as well as the *Symbiodinium* (the microscopic algae that live in symbiosis with the corals) and other types of microbes;
- to understand how the coral reef community structure changes because of fishing pressure and pollution as one moves from Kiritimati's heavily fished reefs near the villages to the remote reefs that are far from villages;
- to understand how climate change is impacting the coral reefs;
- to understand how Kiritimati's coral reefs recover after a mass mortality that occurred during the 2015-2016 El Niño;
- to understand the connections between the people of Kiritimati and the coral reefs;
- to help teach Kiritimati's school children about coral reef biology and sharks;
- to help stimulate improved fisheries management and coral reef conservation on Kiritimati by working together with the Ministry of Fisheries and MELAD's Wildlife Conservation Unit

This report introduces our current research team and describes the work we have conducted over the past year. It also briefly describes our findings from last year as well as the work we propose to do during our research on Kiritimati in July 2018, and our previous projects.

MAJOR FINDINGS FROM OUR 2017 EXPEDITIONS TO KIRITIMATI:

- The major El Niño event that took place in 2015-2016 hit Kiritimati extremely hard, causing unprecedented heat stress on the atoll's coral reefs. Please find attached a compendium of some of the media coverage of this event;
- We are focusing most of our work on the lagged impacts of the major El Niño and the reefs recovery. For example, it is very likely that the loss of live coral will have impacts on Kiritimati's reef fish populations, but declines in reef fish may not occur until the structure of the reef has deteriorated, and this process could take several years;
- Following the 90% coral mortality there are small signs of recovery including the presence of coral recruits and we will be working hard this summer and in the coming years to understand how reef recovery proceeds;

We welcome the opportunity to discuss these changes to Kiritimati's coral reefs with you. We are currently conducting analyses of our other data and preparing several papers for publication. We will ensure that these are all shared in a timely manner.

PLAN for 2018: We plan to return to Kiritimati for three weeks in June 2018, with the aim of conducting ecological monitoring to track the recovery of the reef after the 2015-2016 major El Niño event.

2017 RESEARCH TEAM:

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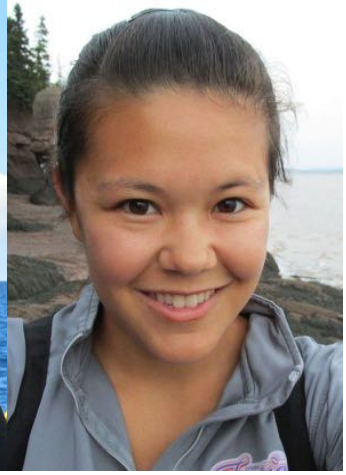

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Our research is conducted primarily in collaboration with Assistant Senior Environment Officer Ms. Ratita Bebe, Head of the Ministry of the Environment, Lands & Agricultural Development Wildlife Conservation Unit on Kiritimati, and with the support of Acting Senior Environment Officer Mr. Puta Tofinga and Environment Licensing officer Ms. Victoria Hnanguie, of the Environment and Conservation Division, Ministry of the Environment, Lands & Agricultural Development, Tarawa.

KIRITIMTI EXPEDITIONS RESEARCH OVERVIEW:

Over the past nine years, we have made the following trips to Kiritimati:

Fig. 1 | Diver surveying the reef on Kiritimati before the 2015-2016 El Niño

- **2017:** This four-week trip (July 5th – August 2nd) led by Kristina Tietjen and Julia Baum, focused on continuing the monitoring of the reef following the El Niño. We sampled for coral recruits, *Symbiodinium*, microbes and continued the ecological underwater monitoring. A full household survey was also conducted in May, by collaboration Laurence Romeo a Master's student at Imperial College in London, England, who was co-supervised by Julia.
- **2016:** Two trips (March 16th – April 6th, November 9th – 23rd) led by Kristina Tietjen and Julia Baum focused on underwater research assessing the state of the reef after the third ever major global coral bleaching event[1], including collecting *Symbiodinium* and microbe samples and photographing the reef. Coral recruitment tiles were also deployed during the November trip to characterize the recovery of the reef following the bleaching event;
- **2015:** Three trips (January 21st – February 4th, April 20th – May 13th, July 1st – 29th) led by Danielle Claar, which focused on underwater research to collect *Symbiodinium* and microbe samples and to photograph the coral communities. Additional data collection focused on surveys with aquarium fisherman during the January/February trip, which coincided with a large storm along the lagoon face of the atoll, and on fish and urchin surveys conducted during the July trip, which witnessed the onset of bleaching due to warming waters from the El Niño;
- **2014:** This three-week trip (August 20th – September 10th) was led by Julia Baum and Danielle Claar and focused on underwater research to assess coral reef health, including collecting *Symbiodinium* and microbe samples and photographing the coral communities;
- **2013:** This four-week trip (July 15th – August 14th) was led by Julia Baum. Our field team continued our ecological underwater monitoring (fish, urchin, coral surveys) and collaborated with Kiaueta, the Ministry of Fisheries and Aana to complete a full household survey. We also conducted outreach activities at the local primary schools;
- **2012:** This three-week trip (August 15th – September 5th) led by Julia Baum focused on underwater scientific research including fish collections, and a shark fisheries survey, as well as outreach activities.
- **2011:** Two trips (July 12 – Aug. 2nd, Aug. 16-30th) included the household surveys and our underwater monitoring program and fish collections;
- **2010:** This six-week trip (May 4th – June 15th) focused on underwater scientific research;
- **2009:** This three-week trip (July 23 – August 11th) led by Julia Baum and Sheila Walsh* focused on household surveys and underwater monitoring;

*Our research program on Kiritimati was initiated in 2007 by Sheila Walsh, who was a PhD student at Scripps Institution of Oceanography, University of California San Diego at the time. Sheila participated also in 2009 and 2011, but now works at The Nature Conservancy.

[1](http://www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coral-bleaching-event.html)

CURRENT PROJECTS: Our work on Kiritimati currently includes the following core elements:

1. ECOLOGICAL & SOCIOECONOMIC MONITORING:

Ecological Monitoring: We have 40 permanent fore-reef sites around Kiritimati, at which we conduct underwater scientific sampling (see maps Appendix A). We conduct the following monitoring using SCUBA (below, brackets show years in which each activity was previously conducted):

- underwater visual censuses (species, size) of fish [37 sites in 2007; ~30 sites in 2009; 14 sites in 2010; 25 sites in 2011; 20 sites in 2013; 17 sites in 2015; 34 sites in 2017]
- underwater visual censuses (species, size) of urchins [2009, 20 sites in 2010; 14 sites in 2011; ~ 25 sites in 2012; 18 sites in 2013; 17 sites in 2015]
- photographs of small (<1m2) randomly placed quadrats to quantify benthic composition [2007, 2009, 2011, 2013, 2014, 2015 (all three trips), 2016 (both trips), 2017]
- photographs of permanent mega-photoquadrats (4m x 4m) and coral settlement tiles to quantify dynamic processes (recruitment, growth, mortality) at 10 sites [2009, 2010, 2011, 2012, 2013]; in 2015 we started using an innovative method developed by Dr. John Burns (University of Hawai'i) to photograph the permanent mega-photoquadrats [2015, 2016 (both trips); 2017]
- monitoring tagged coral colonies via photos taken each trip [2014, 2015 (all three trips), 2016 (both trips); 2017]

Research Status: In June 2018, our team will conduct another year of underwater ecological monitoring, surveying the fish, urchins and coral community at as many of our monitoring sites as we can. We plan to analyze the data collected in this monitoring program from 2007 – 2017 by 2019. To date, we have analyzed hundreds of benthic (coral, algae, sand) photographs around the island and are currently working to analyze these data and write up a paper about the results to be submitted spring 2018. Benthic and structural complexity data from the mega-photoquadrats are currently being processed alongside the results of the fish surveys, and will be written up in two manuscripts to be submitted summer 2018.

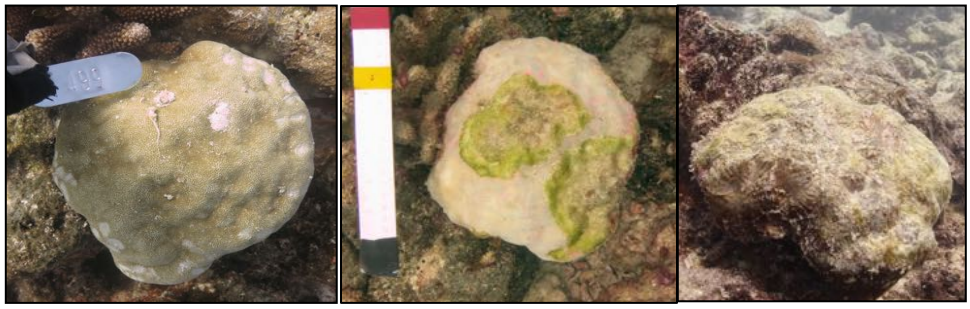


Fig. 2 | A *Porites lobata* colony in 2014 (left), March 2016 (middle), and November 2016 (right) showing the progression of the coral dying due to the El Niño

Socioeconomic Monitoring via Household Surveys:
In 2017, we conducted socioeconomic interviews at 120 households, following up on earlier interviews conducted in 2007, 2009, 2011, and 2013 to determine household income and assets, fishing pressure and how these factors are changing over time. We conduct surveys in all four villages, surveying the heads of households, after obtaining oral consent.

Fig. 3 | Fisherman being interviewed with his family

Our survey follows a semi-structured interview format that includes detailed questions about household demographics, capital, income sources (fishing and alternative economic activities, such as tourism, copra agriculture, government job), as well as fishing (effort, targeted species, gear, fishing grounds) and opinions on fisheries status and family welfare (see Appendix B). It was developed with input from officers from Kiribati's Ministry of Finance and Ministry of Fisheries in 2006. These core questions form the basis of our longitudinal study, and hence are repeated each monitoring year. In 2013 and 2017, our questions also focused on perceptions of local fishing pressure, and effects of climate change.

Fig. 3 | Reef fish catch on Kiritimati

Research Status: In May 2017, visiting Masters student, Laurence Romeo, conducted household surveys. The results of these surveys showed that while the copra subsidy did have a positive impact on household wealth, livelihood diversity and wealth distribution; it does not have a positive conservation benefit for the fishery and that fish stocks are perceived to be in decline. In addition they revealed that the current harvesting of coconuts may not be economically or environmentally sustainable. A manuscript of our 2013 household surveys is published in '*Ocean and Costal Management*' and has been previously shared with you. We would be happy to send additional copies if desired.

<u>3. SYMBIODINIUM DIVERSITY</u>: This is a study initiated in 2013, led by Danielle Claar and Julia Baum, and conducted in collaboration with Prof. Ruth Gates at the University of Hawaii's Hawaii Institute of Marine Biology (HIMB). The goals are to understand how *Symbiodinium* diversity varies across coral species, and across the atoll's gradients and how stressors influence coral partnerships.

Fig. 4 | Near-pristine reef on Kiritimati

At each of 18 sites, 8-10 colonies of each of the three focal species (*Pocillopora eydouxi, Porites lobata, Montipora foliosa*) were sampled. At a subset of sites, colonies of the three focal species and four additional focal genera (*Favia*, *Favites*, *Hydnophora*, *Platygyra*) were also sampled.

Research status: We have processed over 1000 samples for coral symbiosis analysis, and are currently drafting two manuscripts documenting the findings from these samples. These manuscripts will be presented as part of Danielle Claar's doctoral thesis, as well as submitted to scientific journals

by fall 2018. We have also submitted ~1800 samples to the Earth Microbiome Project (EMP) for microbial (bacteria and archaea) analyses, and these data are available open-access from the EMP website. These samples are included in a meta-analysis of global microbial communities that was published in the peer-review journal *Nature*. We will be submitting the first publication using a subset of these samples to *Science* early this year.

4. MICROBIAL COMMUNITY STRUCTURE: This study began August 2014, led by Jamie McDevitt-Irwin and Julia Baum, in collaboration with Dr. Melissa Garren, an adjunct research professor at California State University Monterey Bay and Dr. Becky Vega-Thurber, a professor at the Oregon State University. The goal is to understand the relationship between the coral-associated microbial communities (e.g. bacteria, archaea) at the micro scale and the coral community at the macro scale along the human disturbance gradient of Kiritimati.

To date, we have sampled at 18 sites, collecting coral tissue, coral mucus, water around the coral and sediment below the coral. We collected coral tissue and mucus samples from three focal species (*Pocillopora eydouxi, Porites lobata, Montipora foliosa*) and four additional focal genera (*Favia*, *Favites*, *Hydnophora*, *Platygyra*).

Research status: The microbial samples from August 2014, January 2015, May 2015 and July 2015 of the coral tissue, mucus, water and sediment have all been sequenced on Illumina Miseq using both 16S and 18S primers to evaluate the complete coral-associated microbial communities. We will be submitting the first publication from a subset of this data this summer to the journal *Coral Reefs*, demonstrating the impact of human disturbance and thermal stress on the community structure of the coral microbiome in both *Montipora foliosa* and *Porites lobata*.

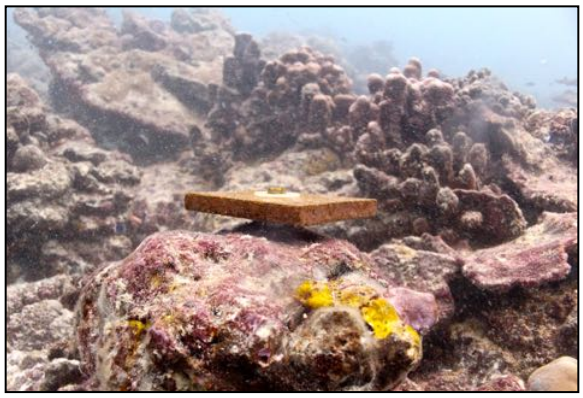


Fig. 5 | A recruitment tile deployed at a site

5. CORAL RECRUITMENT: In November 2016, we started a new study led by Kristina Tietjen and Julia Baum. Following the severe (~90%) coral mortality that occurred on Kiritimati due to the 2015-2016 El Niño event, we aim to characterize patterns of coral recruitment (settlement of young corals) as the reef begins to rebuild. This project will analyze reef recovery at a macro scale over the human disturbance gradient present on Kiritimati, allowing us to determine the effect of human impacts on reef recovery.

To date we have tiles deployed at 14 sites around the island and we have sampled them once. The coral recruits are photographed and sampled to be identified by DNA sequencing.

Research status: In July 2017 we sampled the recruitment tiles deployed at 12 sites around the island and are in the process of sequencing the DNA from the recruits. We also deployed tiles at two new sites. In June 2018 we will sample the tiles and the data will be analyzed and written up for Kristina Tietjen's master's thesis by summer 2019.

6. OUTREACH ACTIVITIES: We have communicated our research on Kiritimati through radio broadcasts (2007, 2009), village visits to conduct surveys (2007, 2009, 2011, 2012, 2013, 2017), in public talks in schools and/or churches (2007, 2012, 2013, 2016, 2017), and through meetings with government officials (each year). For example, in 2009 Sheila Walsh and Julia Baum met with Timon Manikaoti, Permanent Secretary of the Line and Phoenix Islands to discuss our research and the resettlement program to Kiritimati.

Fig. 6 | Baum Lab member, Jenn Magel, demonstrating the coral reef food web with students at Tennessee Primary School, July 2017

Fig. 7 | Dr. Julia Baum with Tennessee Primary School students and their drawings of ocean animals, July 2017

In 2012 and 2013, Baum Lab team member Maryann Watson prepared presentations and activities on coral reef ecology and shark biology, and gave presentations to many of the classes at the Tennessee Primary and Junior Secondary Schools. In 2017, the team again presented these to the students at the Tennessee Primary and Junior Secondary School. These were very well received, and we hope to continue this outreach this summer.

In July 2017, Kiritimati Island field team member, Tyler Phelps, met with local divers at Marine Beauties (Aquarium Fish business owned by Alfred Smith) to give a presentation about dive safety and a demonstration on how to use Emergency Oxygen in diving related medical issues.

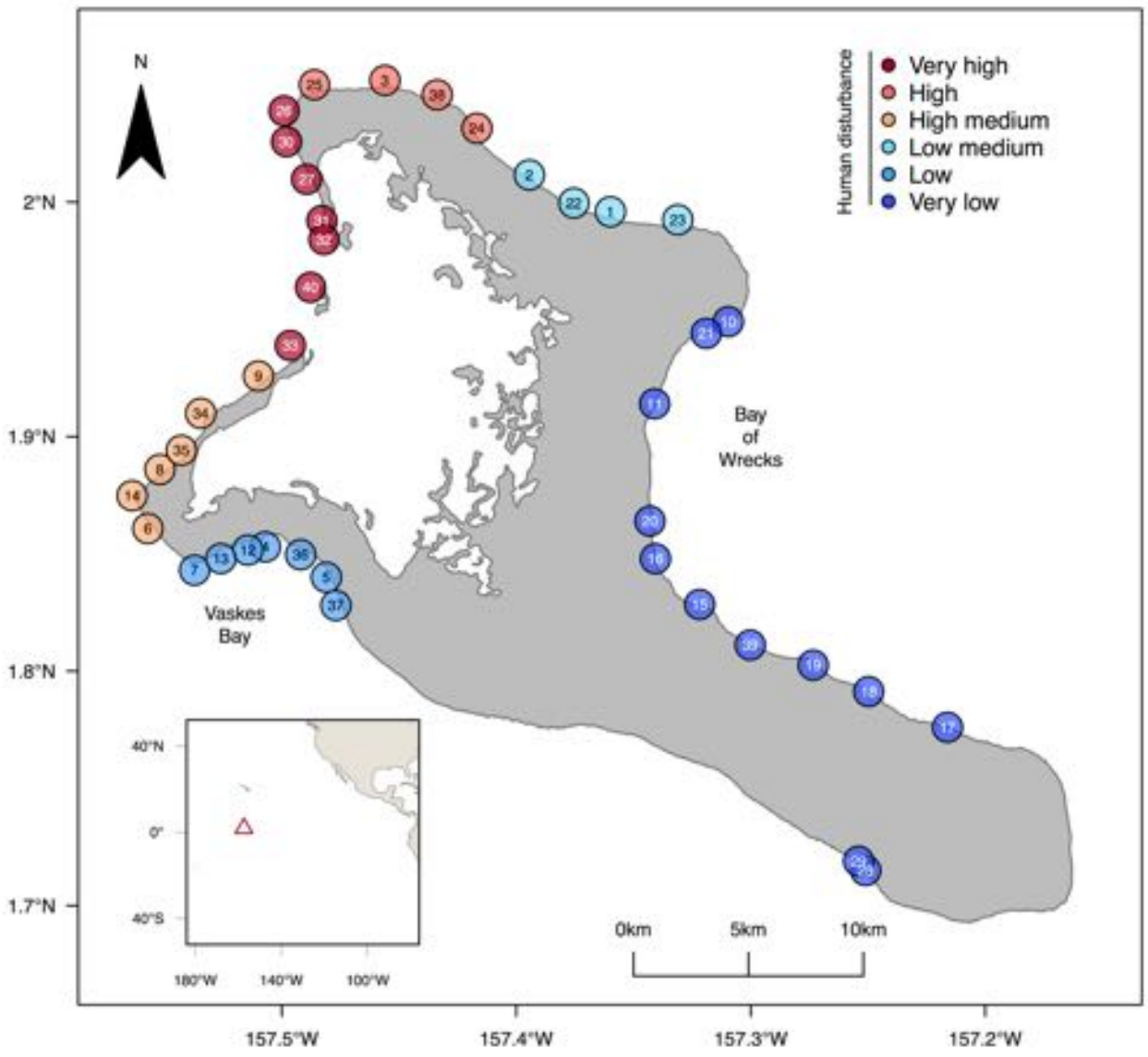
Fig. 8 | Field team member, Tyler Phelps, demonstrating how to use emergency oxygen, July 2017

FUTURE COLLABORATION: We would like to continue to develop our collaboration with the Ministry of Fisheries and the Wildlife Conservation Unit with the aim of helping to understand how fishing pressure on Kiritimati is affecting the coral reef ecosystem, how much fishing pressure the reef can withstand, and what fisheries management measures might help to conserve the coral reef resources so that they can provide productive fisheries for many years to come.
Please let us know how we can work together, and what information and activities would be most useful for us to work on together.

Fig. 9 Ph.D. student Danielle Claar demonstrating the size of some of the corals along Kiritimati's North coast.

Appendix A:
Maps showing ecological monitoring survey sites around Kiritimati atoll

Map 1. Kiritimati Research Study Sites, with fishing impact gradient around the atoll



Map 2. Sample sites since 2013

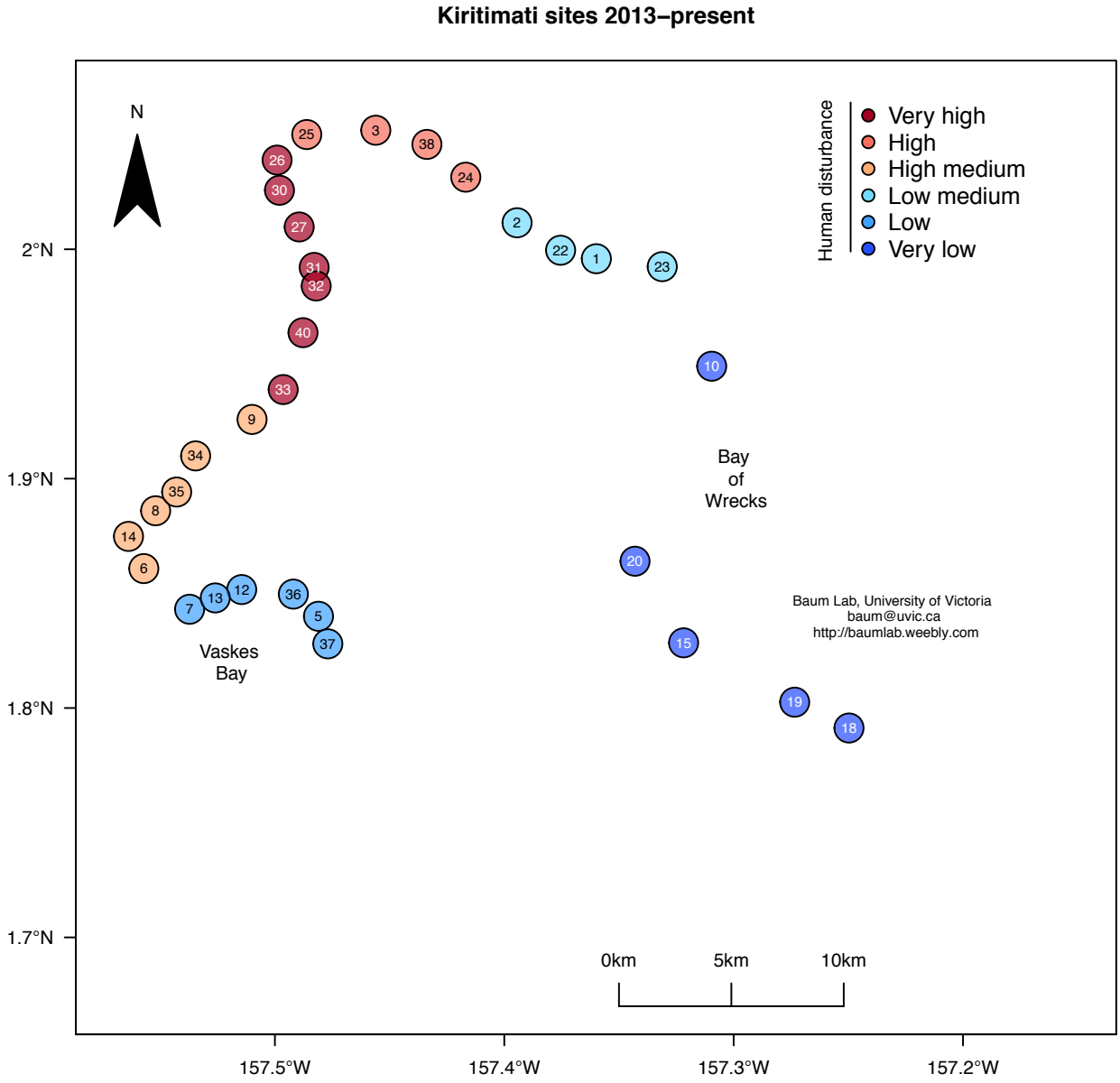
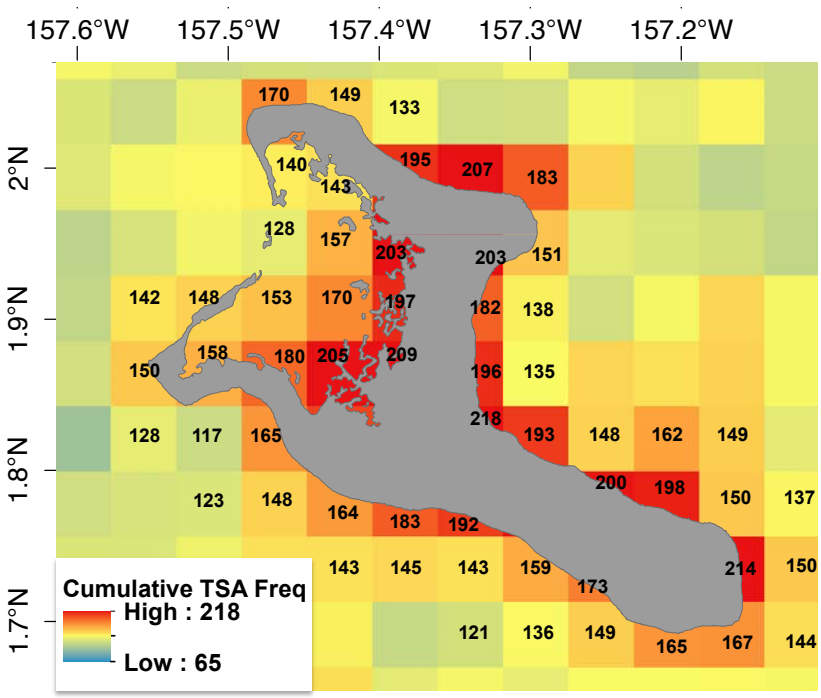
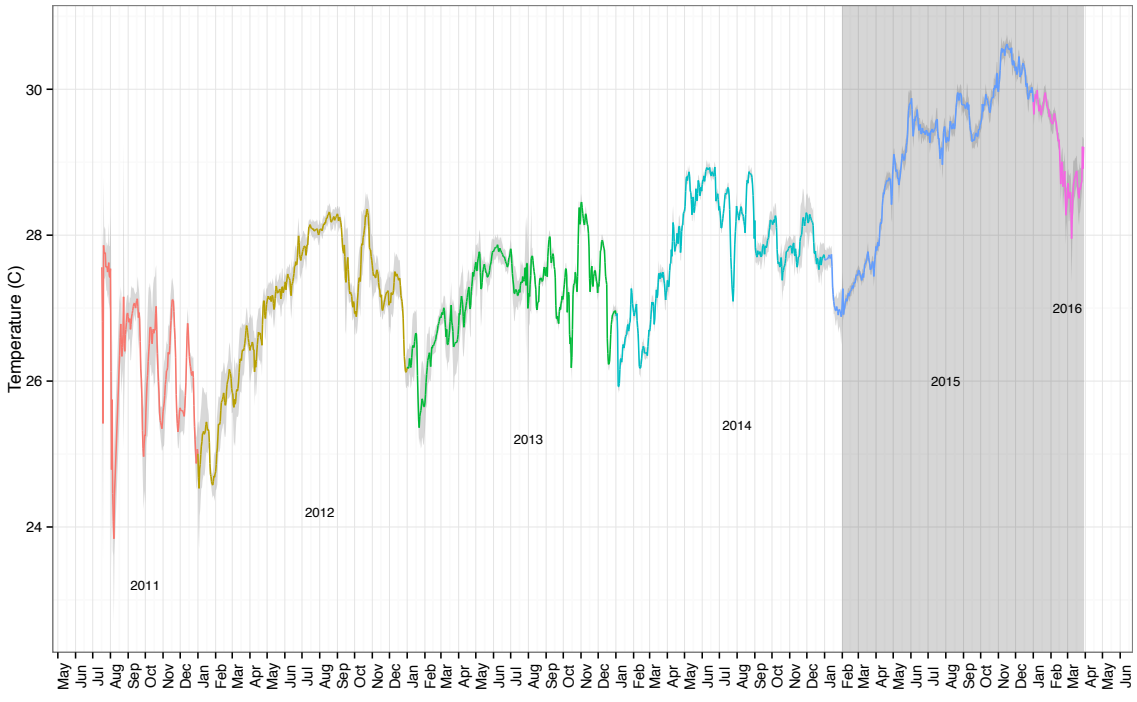


Figure 1. Historic temperatures around Kiritimati

a)



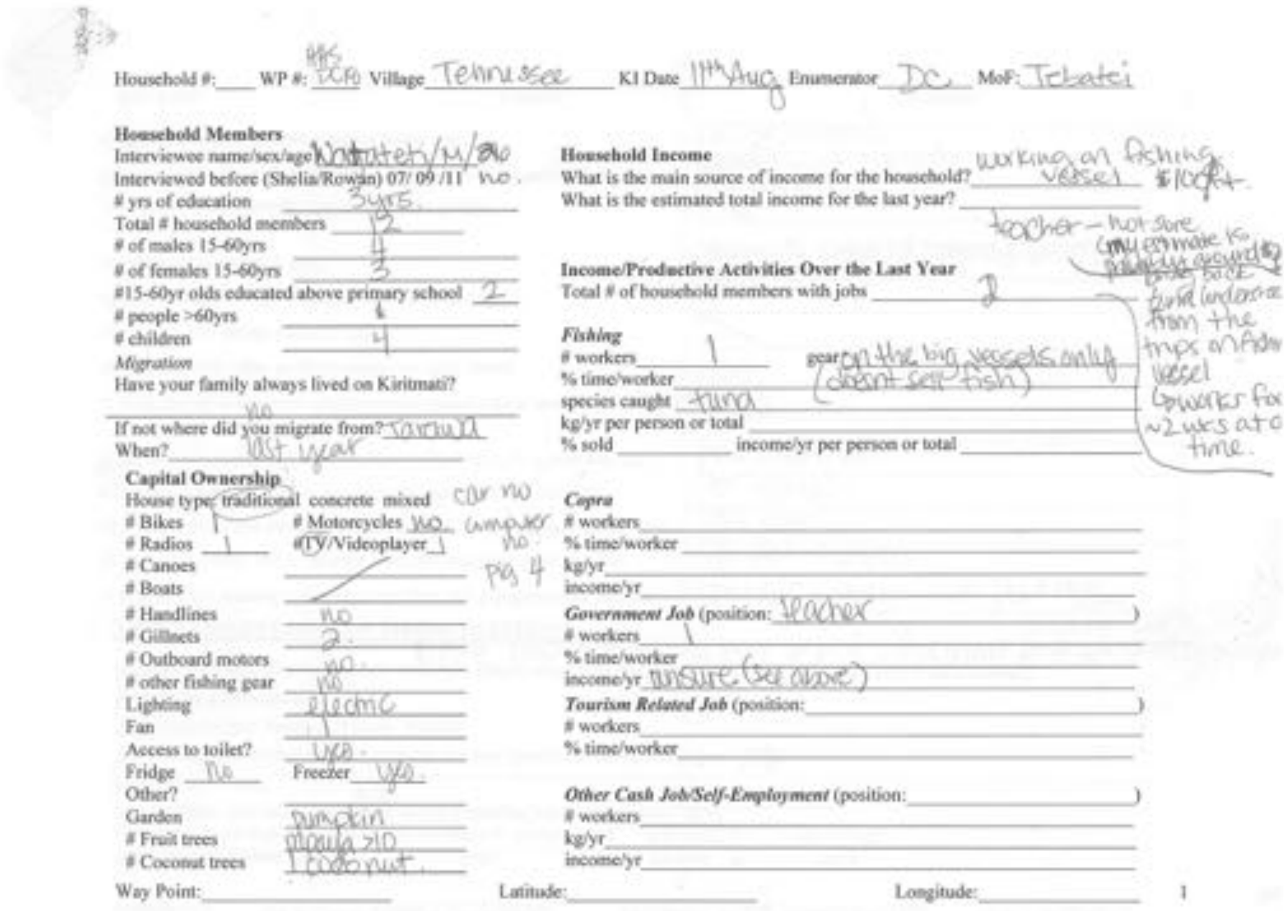
b)



b) Figure showing temperature around Kiritimati 2011- March 2016 with the 2015-2016 El Niño event highlighted in grey

Appendix B:
2013 Household Survey – Example of completed survey, showing survey questions and map

Figure 1. A completed first page of a household survey. There are eight pages including the map shown on the next page.


Household #:____ WP #: DCF0 Village Tennessee KI Date 11th Aug Enumerator DC MoF: Tebatei

Household Members
Interviewee name/sex/age Natatek/M/26
Interviewed before (Shelia/Rowan) 07/ 09 /11 no
yrs of education 3yrs
Total # household members 12
# of males 15-60yrs 4
# of females 15-60yrs 3
#15-60yr olds educated above primary school 2
people >60yrs 1
children 4
Migration
Have your family always lived on Kiritimati? no
If not where did you migrate from? Tarawa
When? last year

Capital Ownership
House type: traditional concrete mixed
Bikes 1 # Motorcycles no
Radios 1 #TV/Videoplayer 1
Canoes
Boats
Handlines no
Gillnets 2
Outboard motors no
other fishing gear no
Lighting electric
Fan 1
Access to toilet? yes
Fridge no Freezer yes
Other?
Garden pumpkin
Fruit trees
Coconut trees 1 coconut

Household Income
What is the main source of income for the household? working on fishing vessel
What is the estimated total income for the last year?

Income/Productive Activities Over the Last Year
Total # of household members with jobs 2

Fishing
workers 1 gear on the big vessels only
% time/worker (doesn't sell fish)
species caught tuna
kg/yr per person or total
% sold income/yr per person or total

Copra
workers
% time/worker
kg/yr
income/yr

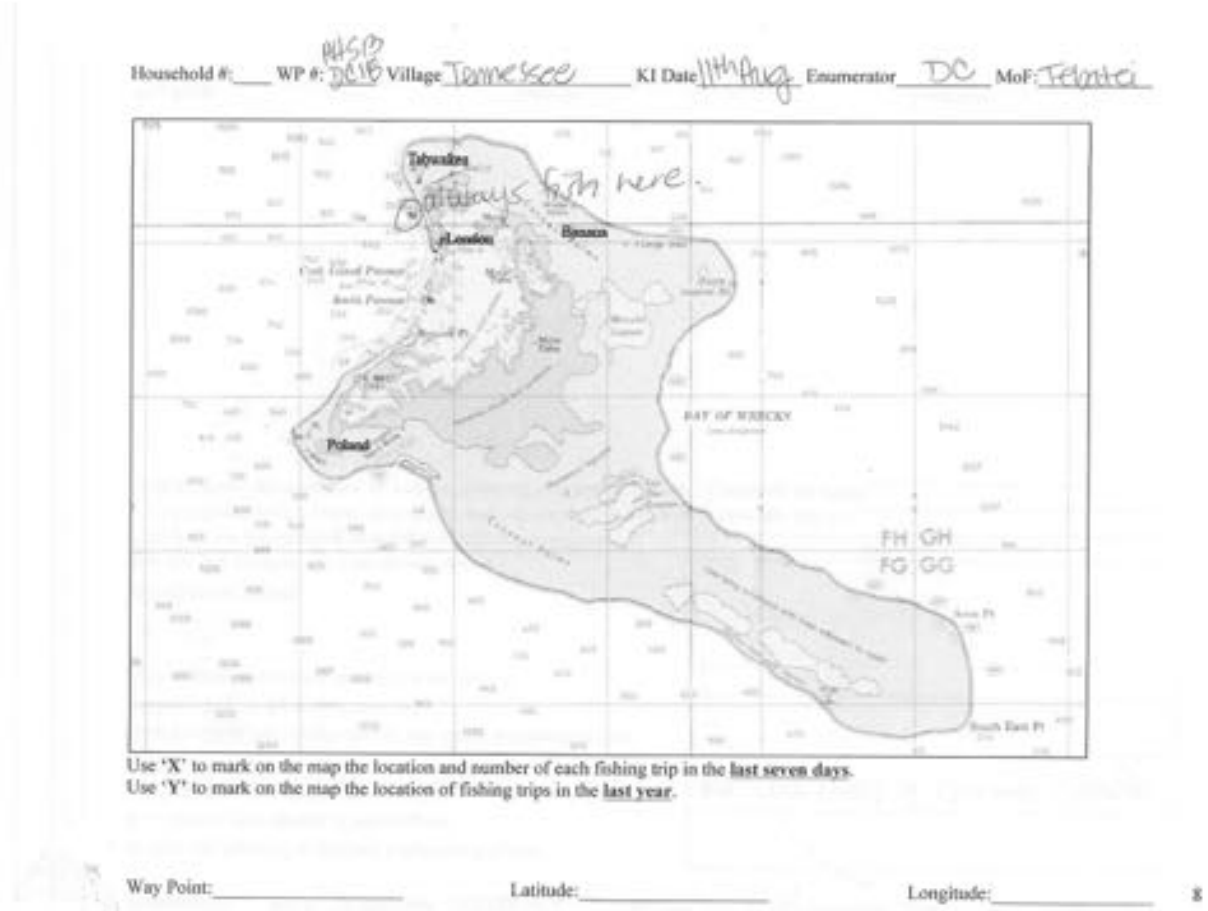
Government Job (position: teacher)
workers 1
% time/worker
income/yr unsure (see above)

Tourism Related Job (position:)
workers
% time/worker

Other Cash Job/Self-Employment (position:)
workers
kg/yr
income/yr

Way Point: Latitude: Longitude: 1

Figure 2. A completed map showing where the subject fishes as a part of the household survey



Publications from our research on Kiritimati

Hughes, T.P., K.D. Anderson, S.R. Connolly, S.F. Heron, J.T. Kerry, J.M. Lough, A.H. Baird, **J.K. Baum**, M.L. Berumen, T.C. Bridge, D.C. Claar, C.M. Eakin, J.R. Gilmour, N.A.J. Graham, H. Harrison, J-P.A. Hobbs, A.S. Hoey, M. Hoogenboom, R.J. Lowe, M.T. McCulloch, J.M. Pandolfi, M. Pratchett, V. Schoepf, G. Torda, and S.K. Wilson. 2018. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science* 359(6371): 80-83.

Thompson, L.R., J.G. Sanders, D. McDonald and 34 co-authors and the Earth Microbiome Project Consortium (includes J.K. Baum, D.C. Claar, J.M. McDevitt-Irwin). (2017) *Nature.* DOI: 10.1038/nature24621.

Dunic, J., and J.K. Baum. (2017) Size structuring and allometric scaling relationships in coral reef fishes. *Journal of Animal Ecology*. 86(3): 577-589.

Robinson, J.P.W. and J.K. Baum. (2016) Trophic roles determine coral reef fish community size structuring. *Canadian Journal of Fisheries and Aquatic Science.* 73(4): 496-505.

Watson, M.S., D.C. Claar, J.K. Baum. (2016) Subsistence in isolation: fishing dependence and perceptions of change on Kiritimati, the world's largest atoll. *Oceans and Coastal Management.* 123: 1-8.

Wood, C.L., J.K. Baum, S. Reddy, R. Trebilco, S. Sandin, B. Zgliczynski, A. Briggs, F. Micheli. (2015) Productivity and fishing pressure drive variability in fish parasite assemblages of the Line Islands, central equatorial Pacific. *Ecology* 96(5): 1383-1398.