KIRITIMATI

FISHERIES AND CONSERVATION ON THE WORLD'S LARGEST ATOLL

BAUM LAB RESEARCH REPORT – APRIL 2015

Dr. Julia K. Baum, Danielle C. Claar, Jamie M. McDevitt-Irwin
Department of Biology, University of Victoria (UVic), Victoria, BC, Canada
baumlab.weebly.com, kiritimati.weebly.com

INTRODUCTION: We are marine ecologists and conservation biologists based in the Baum Lab at the University of Victoria in Canada. Our group has conducted research and outreach activities on Kiritimati each year since 2009. Our goals are:

- 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 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 improve the safety of aquarium divers on Kiritimati
- 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 the work we propose to do over the next three months, and our previous projects.

CURRENT RESEARCH TEAM:

Julia Baum
Assistant Professor of Biology
baum@uvic.ca

Danielle Claar
PhD Student
Symbiodinium Lead
dclaar@uvic.ca

Jamie McDevitt-Irwin
MSc Student
Microbe Lead
jmcdevit@uvic.ca

Kristina Tietjan
Symbiodinium Team
kristina_tietjen@yahoo.com

Kieran Cox
Dive Safety Specialist
kcox@uvic.ca

Scott Clark
Fish Team Lead
scott.clark@ucsb.edu

Our research is conducted in collaboration with Mr. Taratau Kirata and Mr. Kiaueta T. Tarau of the Ministry of Fisheries, and with Ms. Aana T. Berenti of the Ministry of the Environment.

RESEARCH OVERVIEW: Over the past seven years, we have made the following trips to Kiritimati:

- **2015:** A two-week trip (January 21st – February 4th) led by Danielle Claar, which focused on surveys with aquarium fishermen as well as underwater research to collect *Symbiodinium* and microbe samples and to photograph the coral communities. This trip coincided with a large storm along the lagoon face of the atoll;
- **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:** Six-week trip, from 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 has not been involved since because she now works at The Nature Conservancy.

Current Plans: Our team plans to return to Kiritimati for two weeks at the end of April to May 2015, and again for four weeks in July 2015, with the aim of conducting ecological monitoring to use as baseline data and to survey the reef for signs of recovery from the January 2015 storm, as well as for signs of coral bleaching. We also will continue our aquarium trade study and conduct new household surveys, as well as dive safety training.

Current Projects: Our work on Kiritimati currently includes the following core elements:


Fig. 1 Diver surveying the reef on Kiritimati

1. ECOLOGICAL & SOCIOECONOMIC MONITORING:

Ecological Monitoring: We have 37 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]
- underwater visual censuses (species, size) of urchins [2009, 20 sites in 2010; 14 sites in 2011; ~ 25 sites in 2012; 18 sites in 2013]
- photographs of small (<1m2) randomly placed quadrats to quantify benthic composition [2007, 2009, 2011, 2013, 2014]
- 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]

Challenges: The fishing gradient on Kiritimati atoll presents an extraordinary research opportunity, but also a major challenge: sampling at the remote end of the atoll where the reefs are near-pristine has usually been limited to shore diving (i.e. it is inaccessible to the small fishing boats found on Kiritimati, and hence unfished). In most years, rough weather has presented considerable challenges to shore diving, thus limiting our ability to conduct research on this rare near-pristine reef. In 2013, we were very fortunate that the water was very calm and we were able to access the Bay of Wrecks by boat. Boat access to this part of the island in future years is crucial in order to answer fundamental ecological questions about the role of top predators on coral reefs, and the structure and function of coral reef ecosystems with intact food webs.

Research Status: In July 2015, our team will conduct another year of underwater ecological monitoring, surveying the fish, urchins and coral community at as many of our 37 permanent monitoring sites as we can get. We plan to analyze the data collected in this monitoring program from 2007 – 2015 by 2016. 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.

Socioeconomic Monitoring via Household Surveys: In 2013, we conducted socioeconomic interviews at 103 households, following up on earlier interviews conducted in 2007, 2009, and 2011 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. 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, our questions also focused on perceptions of local fishing pressure, and effects of climate change.

Research Status: In July 2015, our team will conduct additional household surveys. A manuscript of our 2013 household surveys is in review at a peer-reviewed journal and is included here in Appendix C. We will also mail copies of the paper once it is published and we have the final version of it.

Fig. 2 Top: Fisherman being interviewed with his family; Bottom: Reef fish catch on Kiritimati

<u>2. AQUARIUM FISH COMPANY AND DIVER SURVEYS</u>: In January 2015 we initiated surveys of the aquarium fish company employees and divers. Our goal is to describe and quantify key characteristics of the aquarium (i.e. ornamental) fish trade on Kiritimati. We aim to determine the socioeconomic importance of the aquarium fishery, the nature and magnitude of the aquarium fishery, conservation impacts, potential management solutions and increase dive safety among the aquarium divers.

Research Status: In July 2015, we will complete this study. Working in collaboration with the Ministry of Fisheries, we will conduct interviews with members of the aquarium trade including current and former aquarium fish divers, company employees (e.g. boat drivers and fish packagers), company owners, and Ministry of Fisheries employees. Furthermore, we will obtain contact information of other international members of the trade to conduct further interviews. We will obtain any formal records of the trade that members are willing to give us. Additionally, we will obtain U.S. import records of aquarium fishes.

We also will give <u>dive safety presentations</u> and lessons to the aquarium divers to increase dive safety through awareness and prevention. Finally, with permission, we will take photographs of the divers, their gear, boats and the fish to use in publications, talks and websites.

Fig. 3 Flame Angelfish from Aquarium Fishery

<u>3. SYMBIODINIUM DIVERSITY</u>: This is a new study initiated in 2013, led by Danielle Claar, and conducted in collaboration with Dr. Julia Baum and Prof. Ruth Gates at the 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.

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.

Fig. 4 Near-pristine reef on Kiritimati

Research status: We have processed the samples from four of the sites and are currently drafting the paper from this study, which will be submitted for publication within the next six months. We have prepared samples for four other sites and three different time points (2013, 2014, 2015), and will be analyzing these and writing the manuscript for this research in the next year. We will share copies of all resulting publications as soon as they are ready.

<u>4. MICROBIAL COMMUNITY STRUCTURE</u>: This study began August 2014, led by Jamie McDevitt-Irwin in collaboration with Dr. Julia Baum and Dr. Melissa Garren, a post-doctoral researcher at MIT. The goal is to understand the relationship between the coral-associated microbial communities (e.g. bacteria, archaea, viruses) 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 11 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: In April 2015, we will return to Kiritimati with the goal of sampling microbes from 4-5 additional sites. We have already begun processing the samples we collected in 2014 in our laboratory at UVic and we will be writing up a paper from all of these samples, to be submitted for publication within the next two years. We will share copies of all resulting publications as soon as they are ready.

<u>5. OUTREACH ACTIVITIES</u>: We have communicated our research on Kiritimati through radio broadcasts (2007, 2009), village visits to conduct surveys (2007, 2009, 2011, 2012, 2013), in public talks in schools and/or churches (2007, 2012, 2013), and through meetings with government officials. 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. 5 Lab member Maryann Watson giving presentations to Tennessee Primary and Junior students

Fig. 6 Tennessee Primary school kids proudly displaying fish mosaics, summer 2013

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. These were very well received, and we hope to continue this outreach in the future.

Previous Projects:

FISH COLLECTIONS for STABLE ISOTOPE and PARASITE ANALYSES: Our goal in this project is to understand what the coral reef fish food web looks like and how fishing pressure changes it. Between 2010 and 2012, we collected ~ 2000 fish, as well as urchins, turf algae, macroalgae and phytoplankton at ~30 sites around the atoll. These sites were divided into 6 levels of fishing pressure ranging from near pristine to heavily exploited. We are using these samples, which span most trophic levels, for stable isotope (SI) analyses to reconstruct the island's food web. Stable isotopes are biological tracers that can provide information about the energy source that an organism is feeding from (for example, whether it is feeding from the reef benthos or whether it is feeding up in the water column, pelagically), as well as the trophic level that an organism feeds at (for example, whether it eats plants, invertebrates, or fish). We have also examined the stomachs of each of the collected specimens, to see directly what they had eaten. Following collection and dissection of these samples on Kiritimati, we processed the samples back at the University of Victoria. This included grinding, drying, weighing, and running the samples on mass spectrometer to extract the stable isotope signals). We have completed this for approximately half the samples.

Research Status: Our first manuscript from this research has been accepted for publication in the journal Ecology. We also recently submitted a manuscript based upon these data as well as our underwater fish surveys. We hope that this paper will be published later this year and we will share copies of it as soon as we have a final version of it. Dr. Baum's student Adrian Burrill completed his Master's thesis based upon this stable isotope data in May 2014. Abstracts of these papers and thesis are included as Appendix D. We will be writing a manuscript based upon this work later this year, and will share this manuscript as soon as it is completed.

PREDATION EXPERIMENT: Sea urchins are important grazers on coral reefs as they have strong influences on algal cover and biomass. Changes in urchin populations can affect the balance between algae and coral cover on reefs. Fish predators have been shown to control sea urchin populations, and levels of predation influence their population composition and the behaviour of individual urchins.

In 2010, we conducted a successful manipulative in-situ experiment at 14 sites (representing the gradient of urchin predator biomass present at boat-accessible dive sites on Kiritimati) testing the hypothesis that predators control urchin populations through direct predation and indirect behavioral effects. Using tethering manipulations on the dominant urchin species on Kiritimati, the long-spined sea

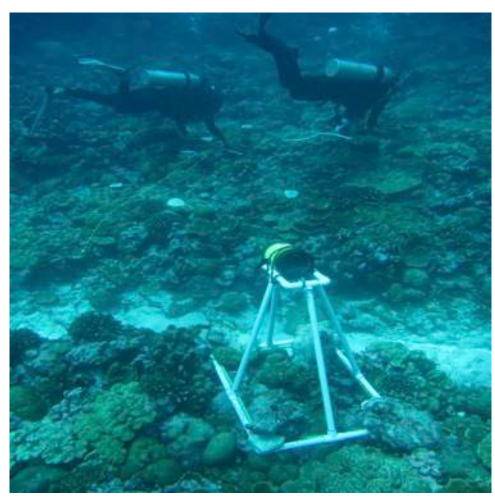


Fig. 7 Urchin experiment video cameras

urchin *Diadema savignyi*, we recorded urchin behavior and mortality, measures of habitat composition and complexity, and ran video to monitor predation events (Fig. 7).

Research Status: We aim to have these data analyzed and a report written by the end of 2015.

TROPHIC INTERACTIONS STUDY: The overall aims of this study are to determine the feeding interactions of herbivores, how these vary across Kiritimati's fishing and productivity gradients, and whether these interactions have cascading effects down the food web (e.g. whether herbivores control macroalgae, which in turn may mediate competition between coral and macroalgae and thus determine coral cover, composition, and recruitment).

In 2013, at each of 18 study sites, we collected several types of data aimed at answering these questions, including a) video and in-situ observations of herbivores grazing, b) coral recruit video and benthic composition photos, c) site characterization data (slope, aspect, rugosity).

Research Status: These data will be used in combination with our fish, urchin, and benthic monitoring data from this year (as well as previous years) to develop an integrated 'picture' of Kiritimati's trophic interactions. Our goal is to complete this study within the next two years.

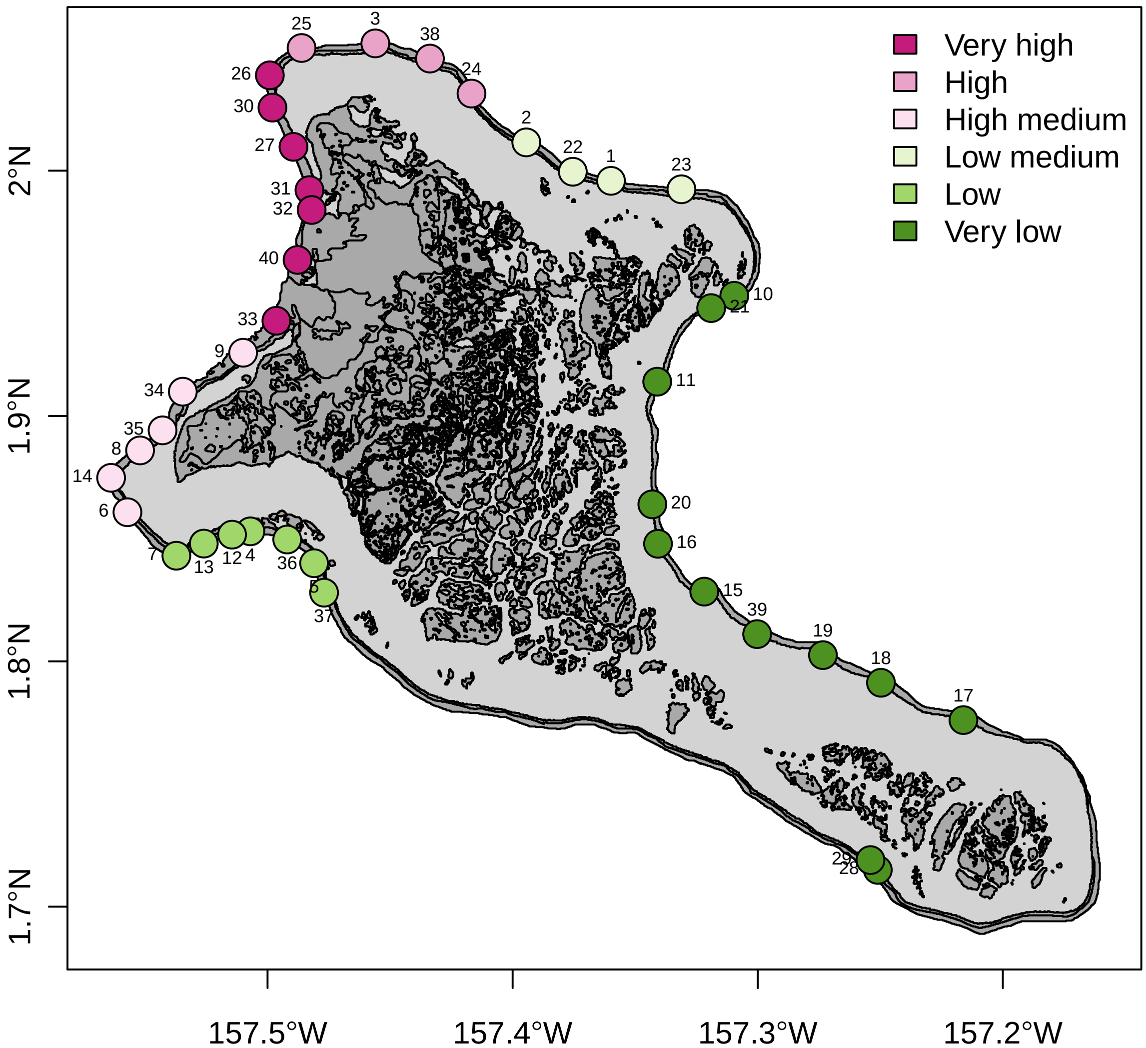
FUTURE COLLABORATION: We would like to continue to develop our collaboration with the Ministry of Fisheries and the Wildlife Conservation Unit with the aim of helping to understand how fishing pressure on Kiritimati is affecting the coral reef ecosystem, how much fishing pressure the reef can withstand, 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. We also hope to continue to collaborate with the aquarium fish divers and company owners to help make them safer and to work toward making the aquarium trade more sustainable.

Please let us know how we can work together, and what information and activities would be most useful for us to work on together.

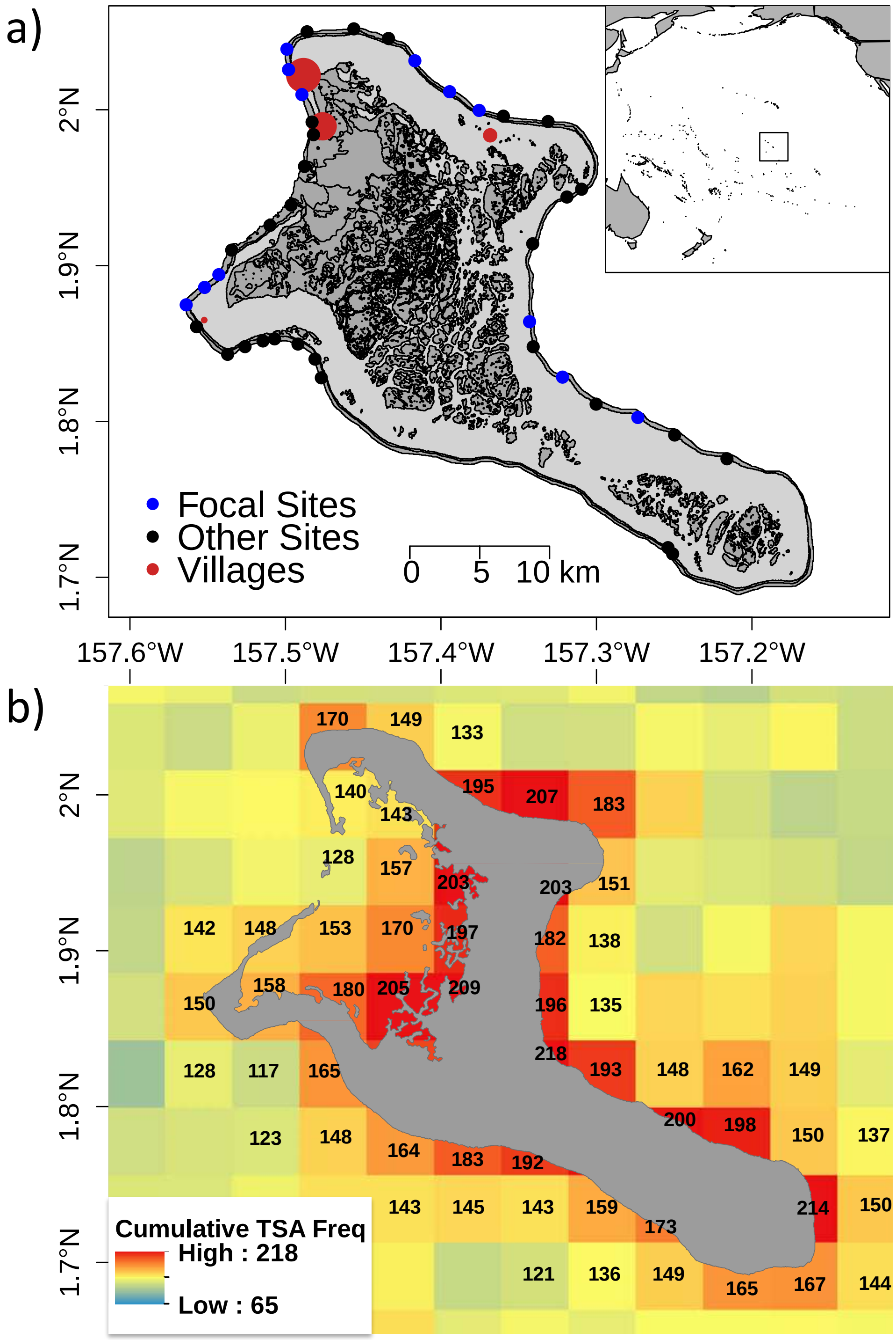
Fig. 8 Ph.D. student Danielle Claar demonstrating the size of some of the corals along Kiritimati's North coast.

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. Proposed focal sites for *Symbiodinium* and microbe studies, and historic temperature stress around Kiritimati



a) Map of Kiritimati showing focal sites, other sites that have been surveyed previously, and villages. Village marker size is proportional to human population size.
b) Historical thermal stress anomaly map for Kiritimati (1982-2009).

Appendix B:

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

MAS13
Household #: ____ WP #: DC24 Village: Poland KI Date: 2nd Aug Enumerator: DC Mol: Teboteb

Household Members
Interviewee name/sex/age: Buta/F/32
Interviewed before (Sheila/Rowan) 07/09: 11 yrs.
yrs of education: class 9
Total # household members: 10
# of males 15-60yrs: 2
# of females 15-60yrs: 3
#15-60yr olds educated above primary school: 1
people >60yrs
children: 4
Migration
Have your family always lived on Kiritimati?
yes. always Poland
If not where did you migrate from?
When?

Capital Ownership
House type: traditional concrete mixed
Bikes: 2 # Motorcycles: 1
Radios: 1 #TV/Videoplayer: no
Canoes
Boats
Handlines: 1
Gillnets: 1
Outboard motors: no.
other fishing gear: no.
Lighting: electric
Fan: no.
Access to toilet?: yes.
Fridge: no Freezer: no.
Other?
Garden
Fruit trees: breadfruit 2, papaya 1
Coconut trees: 7

Car/truck no
Computer no
DPlayer 1

Household Income
What is the main source of income for the household? Copra $140/day
What is the estimated total income for the last year?
a week
6 days

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

Fishing
workers ____ gear ____
% time/worker
species caught
kg/yr per person or total
% sold ____ income/yr per person or total ____

Copra
workers: 2
% time/worker
kg/yr
income/yr: $40/day (works everyday but Sunday)

Government Job (position: ____)
workers
% time/worker
income/yr

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

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

Way Point: ____ Latitude: ____ Longitude: ____

Household #:____ WP #: HBS13 3C24 Village: Roland ____ KI Date: 12th Aug Enumerator: DC Mel: Tekoka

Non-Labour Income Rent: x Gifts: x Pension: yes \$50/Month from government – for people >70 yrs old Other:

Community Are you a member of any groups? e.g. church, fishing: church, Catholic

Job Mobility Has anyone in your household changed jobs in past 5 yrs? no

From what to what? N/A

Why? age/health, migration, lack of catch, lost job, changes in legislation, other: N/A

Which job did they prefer? Previous Current

Household Expenditures

How much money does your family spend in a typical week/fortnight? What is typically purchased each week/fortnight?

\$5/day on rice (don't buy sugar, cut back)

husband out now to spear the puffer

FISHERY PRODUCTIVITY & EFFORT QUESTIONS

1. a) What is a 'normal' day's catch for you? (kg fish/fisherman, species)	milkfish (gillnet), 2-4, 7-10	Puffer, ~18", 1 bucket ~20.
b) What is a 'great' day's catch for you? (kg fish/fisherman, species)	always same.	always same
c) When was the last time you had a great day's catch? d) *Where was this?*		
e) What is a bad day's catch for you? (kg fish/fisherman, species)		
f) When was the last time you had a bad day's catch? g) *Where was this?*		

2. a) Where do you usually fish? (*location/distance from shore, **map***)	map
b) Are there any other location where you fish? ***(map)***	no
c) How do you decide where to fish?	
d) Has your fishing changed at all over the past 5 years?	Same.
e) When do you usually fish?	morning

3. a) Do you catch enough fish to feed your family?	yes.
b) How much time do you need each week to do so? *(# hrs/day, #days)*	3x/wk; 3hrs/trip
c) What proportion of your family's diet is fish?	3 milkfish/day

Way Point:________ Latitude:________ Longitude:________

Household #: ____ WP #: HHS/3 DC24 Village: Island ____ KI Date: 12th Aug Enumerator: DC MoI: Tebantei

Fishing Activities in the Last Seven Days

Trip	Type of Fishing	Gear	Location	Habitat	Time & # hrs	# people	Species	#	kg	Total kg	% Sold	$ Earned
1	today	spear	lagoon	still out fishing						puffer		
2	Saturday	gillnet	lagoon		noon 3hrs	2	milkfish			~2ft	7 keep all for family	
3												
4												

Way Point: ____ Latitude: ____ Longitude: ____

Household #: ___ WP #: [illegible] Village: [illegible] KI Date: 12th Aug Enumerator: DE MoF: [illegible]

Fishing Activities in the Last Seven Days (Cont'd)

Trip	Type of Fishing	Gear	Location	Habitat	# hrs	# people	Species	#kg	Total kg	% food	$ Earned
5											
6		Only 2x this wk									
7											
8											

Were last week's fishing activities typical, or was there anything unusual about it? If yes, how did it differ from a typical week?

___

Way Point: ___ Latitude: ___ Longitude: ___

Household #:____ WP #: KHS13 3029 Village: Poland KI Date: 12th Aug Enumerator: DC MoF: Taualea

FISHERY CHANGES

4. a) How many years have you been fishing on Kiritimati? since they came here

b) With the same amount of effort, is it harder or easier to catch fish now than it was 5 years ago (i.e. 2008)? Same.

c) Why do you think this is?

In the past 5 years (i.e. since 2008), have you:

d) continued to fish in the same areas? Same

e) continued to use the same types and amount of gear? Same

f) continued to catch the same types of fish? Same.

g) Are there any particular fish that have changed in abundance or size in this time? (i.e. since 2008)? No change.

FISHERY HYPOTHETICALS

What would you do if your 'normal' fisheries catch declined by 50% over a sustained period?

(1) Continue to fish as before/suffer losses in catch **(2)** Increase effort **(3)** Decrease effort **(4)** Stop fishing **(5)** Temporarily switch jobs also eat land crab

(1) Would you change fishing gear *(to what)*, change location *(to where)*, change fishing depth *(to what)*, start fishing illegally?	always catch enough fish
(2) If you would **increase** your fishing effort, how so? More hours/day, more days/week *(how many)*	(don't understand)
- More gear *(how much more)* - How much would your catch have to decline before you would stop fishing?	
(3) If you would **decrease** your fishing effort, how so? Less hours/day, less days/week	
(4) If you would **stop fishing** when catch declined by 50%. What would you have done when your catch declined by 25%? – Would you first have tried to increase fishing effort? How?	
What would you do to support your family you **decreased** your fishing effort or **stopped** fishing?	

Way Point:________ Latitude:________ Longitude:________

Household #: ____ WP #: ~~1513~~ 2024 Village: Poland ____ KI Date: 12th Aug Enumerator: DC Mol: Tebonteiti

FISHERIES MANAGEMENT & CONSERVATION

6. a) Are there any traditions or government regulations that limit fishing in any way?	bonefish
b) If so, do you agree with these regulations?	yes.
c) Do you follow these fisheries rules? Why/why not?	yes scared of government
d) Who do you think these fishing limitations benefit?	People.
e) Do you think the current fisheries regulations are helping to ensure that Kiritimati's fishery will be healthy in the future?	yes.
f) If not, what would you like to see done?	not sure. follow the government (only they make the regulations)
g) Many other countries in the Pacific Ocean have implemented small marine reserves, to help protect some parts of the coral reef while others are fished. Do you think this could work on Kiritimati? Why/why not?	not sure.

CLIMATE CHANGE

7. a) Have you heard of Climate Change? If so, what have you heard / what do you know about it?	yes. from the radio not sure what she heard
b) Do you think climate change is occurring on Kiritimati? Why?	no.
c) Have you noticed any changes in the weather in the past 5 years?	more dry season

Differences in rainfall, rainy season/dry season yes.
Changes in storms? Frequency, severity no.
Changes in freshwater availability? no.
Changes in food prices? same.
Changes in sea level? no.
Any new sea life observed/caught? no.
Do you think these changes may be caused by climate change? ~~no~~ yes.

Way Point: ____ Latitude: ____ Longitude: ____

Household #: ____ WP #: 9K73 JC24 Village: Poland ____ KI Date: 12th Aug ____ Enumerator: JC ____ Mol: Tekabee

d) Have you heard of the Kiribati Adaptation Program? NO.
If so, what is your opinion of this program?
e) Do you think that climate change will impact your family in the future?
f) Do you think that climate change will impact Kiribati, or your whole country, in the future? How so?

not sure.

g) If so, what do you think should be done about it? (joking) just wait for tsunami to come.

INCOME OPTIONS

8 a) Are you satisfied with your income options? ____
b) If no, are you planning on doing anything new or different? ____
c) All things taken together, do you feel better off now than in you were 2 years ago (2011)? ____
d) All things taken together, do you feel better off now than in you were 4 years ago (in 2009)? ____

Way Point: ____ Latitude: ____ Longitude: ____

Appendix C:
2013 Household Survey Submitted Manuscript – "Subsistence in isolation: fishing dependence and perceptions of change on Kiritimati, the world's largest atoll"

Appendix D: Abstracts of papers and theses from 'Fish Collections for Stable Isotopes and Parasite Analyses' Study

Productivity and fishing pressure drive variability in fish parasite assemblages of the Line Islands, equatorial Pacific

Chelsea L. Wood[1,2], Julia K. Baum[3], Sheila M.W. Reddy[4], Rowan Trebilco[5], Stuart A. Sandin[6], Brian J. Zgliczynski[6], Amy A. Briggs[7], and Fiorenza Micheli[1]*
[1]Department of Biology, Stanford University, Stanford, CA, USA
[2]Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, CO USA
[3]Department of Biology, University of Victoria, Victoria, BC, Canada
[4]The Nature Conservancy, Arlington, VA, USA
[5]Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada
[6]Scripps Institute of Oceanography, University of California, San Diego, CA USA
[7]Department of Biology, California State University, Northridge USA
[*] corresponding author, chelsea.wood@colorado.edu

Status: Accepted in the journal '*Ecology'*

Abstract
Variability in primary productivity and fishing pressure can shape the abundance, species composition, and diversity of marine life. Though parasites comprise nearly half of marine species, their responses to these important forces remain little explored. We quantified parasite assemblages at two spatial scales: (*i*) across a gradient in productivity and fishing pressure that spans six coral islands of the Line Islands archipelago and (*ii*) within the largest Line Island, Kiritimati, which experiences a west-to-east gradient in fishing pressure and upwelling-driven productivity. In the across-islands dataset, we found that increasing productivity was correlated with increased parasite abundance overall, but that the effects of productivity differed among parasite groups. Trophically transmitted parasites increased in abundance with increasing productivity, but directly transmitted parasites did not exhibit significant changes. This probably arises because productivity has stronger effects on the abundance of the planktonic crustaceans and herbivorous snails that serve as the intermediate hosts of trophically transmitted parasites than on the higher-trophic level fishes that are the sole hosts of directly transmitted parasites. We also found that specialist parasites increased in response to increasing productivity, while generalists did not, possibly because specialist parasites tend to be more strongly limited by host availability than are generalist parasites. After the effect of productivity was controlled for, fishing was correlated with decreases in the abundance of trophically transmitted parasites, while directly transmitted parasites appeared to track host density: we observed increases in the abundance of parasites using hosts that experienced fishing-driven compensatory increases in abundance. The within-island dataset confirmed these patterns for the combined effects of productivity and fishing on parasite abundance, suggesting that our conclusions are robust across a span of spatial scales. Overall, these results indicate that there are strong and variable effects of anthropogenic and natural drivers on parasite abundance and taxonomic richness. These effects are likely to be mediated by parasite traits, particularly by parasite transmission strategies.

Keywords: primary productivity, upwelling, fishing, parasites, disease, human disturbance

Size structuring and distinct energy channels in a minimally disturbed coral reef food web

James P.W. Robinson[1], *Julia K. Baum*[2*]
1 Department of Biology, University of Victoria, PO BOX 1700 Station CSC, Victoria British Columbia, V8W 2Y2, Canada; Email: jamespwr@uvic.ca
2 Department of Biology, University of Victoria, PO BOX 1700 Station CSC, Victoria British Columbia, V8W 2Y2, Canada; Email: baum@uvic.ca Fax: 250-721-7120
*Corresponding Author

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Abstract
Relationships between abundance – body size and trophic position – body size can reveal size structuring in food webs, and may be used to test for the presence of distinct energy channels. Although there is considerable evidence of size structuring and energy channels in temperate aquatic food webs, little is known about the structure of tropical aquatic food webs. Here, we use underwater visual census data and nitrogen stable isotope analysis from a minimally impacted ecosystem to test if coral reef fish communities are 1) size structured and 2) composed of distinct energy channels. Examining individuals from over 160 species spanning four orders of magnitude in body size, we show that abundance scaled negatively with body size and, as predicted, individuals sharing energy through predation (carnivorous fishes) scaled more steeply than those individuals sharing a common energy source (herbivorous fishes). In both carnivores and herbivores, trophic position scaled positively with body size across species and across individuals, such that larger fish occupied higher trophic positions. Our results provide novel evidence of size structuring in a diverse tropical food web that also reflect properties of coupled food webs, thus indicating directions for further empirical analysis of the structure and stability of coral reef ecosystems.

Ecological niche metrics of coral reef piscivorous fishes:
The effects of fishing revealed through stable isotope analyses

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Abstract

Coral reefs are highly complex and also highly threatened ecosystems. Population growth and the unsustainable use of coral reefs have resulted in 55% of the world's reefs being considered degraded. Fishing, the primary 'local' threat on most reefs, has altered the composition of most reef communities. As a result, very few pristine coral reefs remain. Typically, coral reef research is done via underwater visual censuses, providing abundance estimates but no indication of trophic interactions, therefore we know relatively little about the structure of intact reef food webs. Understanding how human activities affect trophic structure and feeding interactions among resident reef species may be important for coral reef conservation.

Here, I apply stable isotope analysis to coral reef piscivorous fishes from Kiritimati (Republic of Kiribati), the world's largest atoll. I examine dietary niche metrics of five focal species (*Cephalopholis argus, Cephalopholis urodeta, Aphareus furca, Lutjanus bohar,* and *Lutjanus fulvus*) and of the piscivore functional group as a whole, across an anthropogenic disturbance gradient that results from the atoll's heavily skewed geographic population distribution. Using bootstrapped stable carbon (δ13C) and nitrogen (δ15N) isotope values, controlled for body size effects and analysed with Bayesian methods using the SIAR (Stable Isotope Analysis in R) program, I provide evidence of isotopic niche differentiation in *C. argus* and *L. fulvus* relative to other sampled species in terms of niche width metrics and mean δ13C and δ15N values. I also analyse the effect of fishing pressure at an individual level (controlling for body size effects on stable isotope signatures for each species), population level (accounting for observed differences in body size distributions across the fishing pressure gradient for each species), and the 'community' level (accounting for body size and relative abundance differences of the five piscivores across the fishing pressure gradient). These metrics reveal species-specific changes in niche metrics of three of the focal species at the individual level: *C. urodeta*, showed regionally distinct niche width metrics but no apparent correlation with fishing pressure, while *A. furca* and *L. bohar*, both had broader niche width metrics in heavily fished areas. No significant effect of fishing pressure was found at population or community levels. This study provides the first evidence using stable isotopes that fishing can alter the diets of coral reef fishes. The mechanism by which it can do so, while not entirely clear, would most likely be by expanding a given species' dietary diversity by either forcing it to switch to non-preferred prey items or changing the diet and/or body size of its prey items, both of which would reflect significant ecological changes within a community. This thesis provides evidence of the utility of stable isotope analyses in answering important ecological questions in coral reef food webs, and reveals that fishing can affect reef communities at the most fundamental level of trophic interactions.