KIRITIMATI

FISHERIES AND CONSERVATION ON THE WORLD'S LARGEST ATOLL

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BACKGROUND: I am a Canadian marine biologist, and have led research on Kiritimati each summer since 2009. Research in 2009 and 2011 was conducted in collaboration with Dr. Sheila Walsh. Sheila now has a full-time job at The Nature Conservancy, and cannot continue this research. In August and September 2012, I conducted research with a team of students and research assistants, in collaboration with the Ministry of Fisheries. In July and August 2013, my field team and I continued our ecological monitoring and collaborated with the Ministry of Fisheries and Ministry of Environment to complete a full household survey. I plan to return to Kiritimati for three weeks this August to early September, with the aim of conducting ecological monitoring to use as baseline data prior to the large El Niño event that is predicted to occur in January 2015. Herein, I summarize our research to date.

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

- 2009: Three week trip, from July 23 – August 11th focused monitoring;
- 2010: Six-week trip, from May 4th – June 15th focused on underwater scientific research;
- 2011: Two trips (July 12 – Aug. 2nd, Aug. 16-30th), focused on the household surveys and underwater monitoring program;
- 2012: A three-week trip (August 15th – September 5th) focused on underwater scientific research and shark fisheries survey.
- 2013: A four-week trip (July 15th – August 14th) focused on underwater monitoring, coral research, and household surveys.

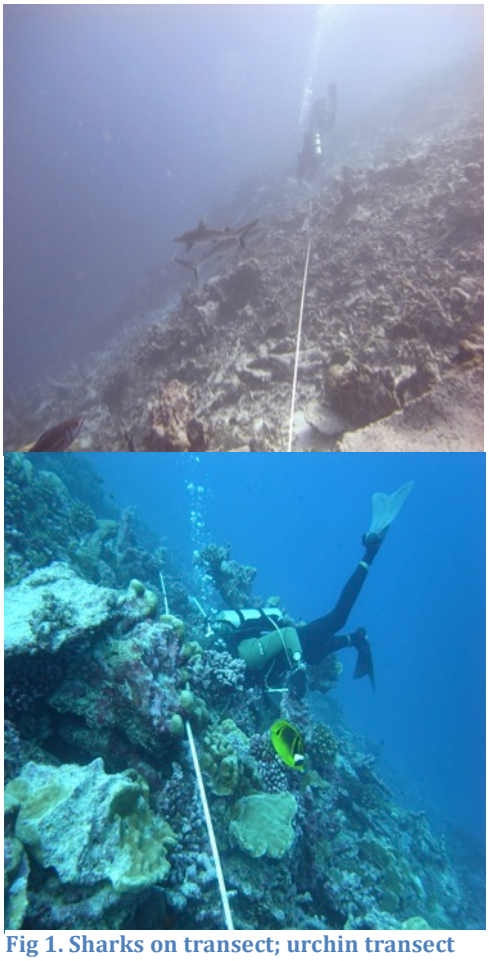


Fig 1. Sharks on transect; urchin transect

This project includes the following core elements:

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]
- 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.


Fig. 2 North coast shore entry

Research Status: We plan to analyze the data collected from 2007 – 2013 by the end of 2014.

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 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.


Fig. 3 Reef fish catch on Kiritimati

Research Status: A manuscript of our 2013 household surveys has been submitted to a journal for publication 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.

2. COLLECTIONS for STABLE ISOTOPE ANALYSIS: We have collected ~ 2000 fish, as well as urchins, turf algae, macroalgae and phytoplankton at ~30 sites around the atoll, which are divided into 6 levels of fishing pressure ranging from near pristine to heavily exploited. These samples, which span most trophic levels, will be used for stable isotope (SI) analyses to reconstruct the island's food web, and to parameterize models to estimate quantitative baselines for coral reef ecosystems. 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.

Research Status: Following collection of these samples, there is a lot of lab work to do (dissecting the samples, grinding, drying, weighing, and then running on mass spec to extract the stable isotope signals). Over half of this lab work has been completed but there is still a significant portion to do. Adrian Burrill completed his Master's thesis with stable isotope data in May 2014. Our goal from these data is to understand what the coral reef fish food web looks like and how fishing pressure changes it. I aim to have my students and research assistants complete analyses of these data and write research reports for publication within the next year.

3. 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. Sea urchin populations have been shown to be controlled by their fish predators, and levels of predation influence their population composition and the behaviour of individual urchins.

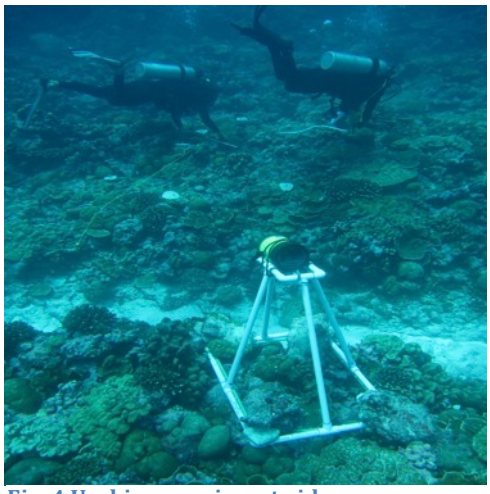


Fig. 4 Urchin experiment video cameras

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 urchin *Diadema savignyi*, we recorded urchin behavior and mortality, measures of habitat composition and complexity, and ran video to monitor predation events (Fig. 6).

Research Status: These data will be analysed by the end of 2014, and a report written up at that time.

4. 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 & 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). 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. My goal is to complete this study within the next year.

5. SYMBIODINIUM DIVERSITY STUDY

This is a new study initiated in 2013, led by my PhD student Danielle Claar, and conducted in collaboration with me 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.

At each of 18 sites, 8-10 colonies of each of the three focal species (*Pocillopora eydouxi, Porites lobata, Montipora foliosa*) were sampled.

Fig. 5 Coral sampling site

Research status: We have processed the samples from 4 of the sites and will be writing the paper from this study within the next six months.

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

Fig. 6 Maryann presenting coral reef talk at Tennessee Primary

In 2012 and 2013, my undergraduate student 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 (Figures 6, 7). These were very well received, and we hope to continue this outreach this summer.

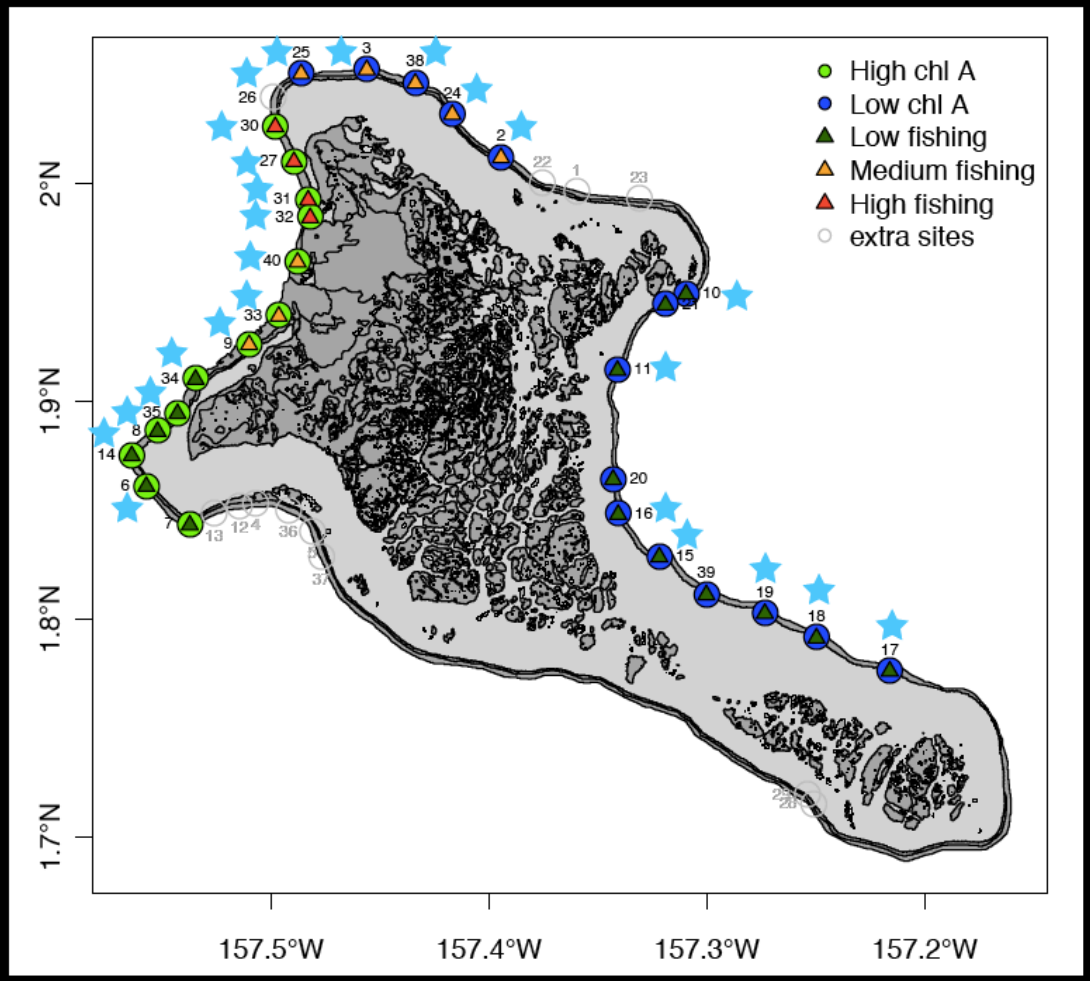
Fig. 7 Tennessee Primary school kids proudly displaying fish mosaics, summer 2013

FUTURE COLLABORATION: We would like to continue to develop our collaboration with the Ministry of Fisheries, 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 me know how we can work together, and what information and activities would be most useful for us to work on together.

Ph.D. student Danielle Claar demonstrating the size of some of the corals along the north coast.

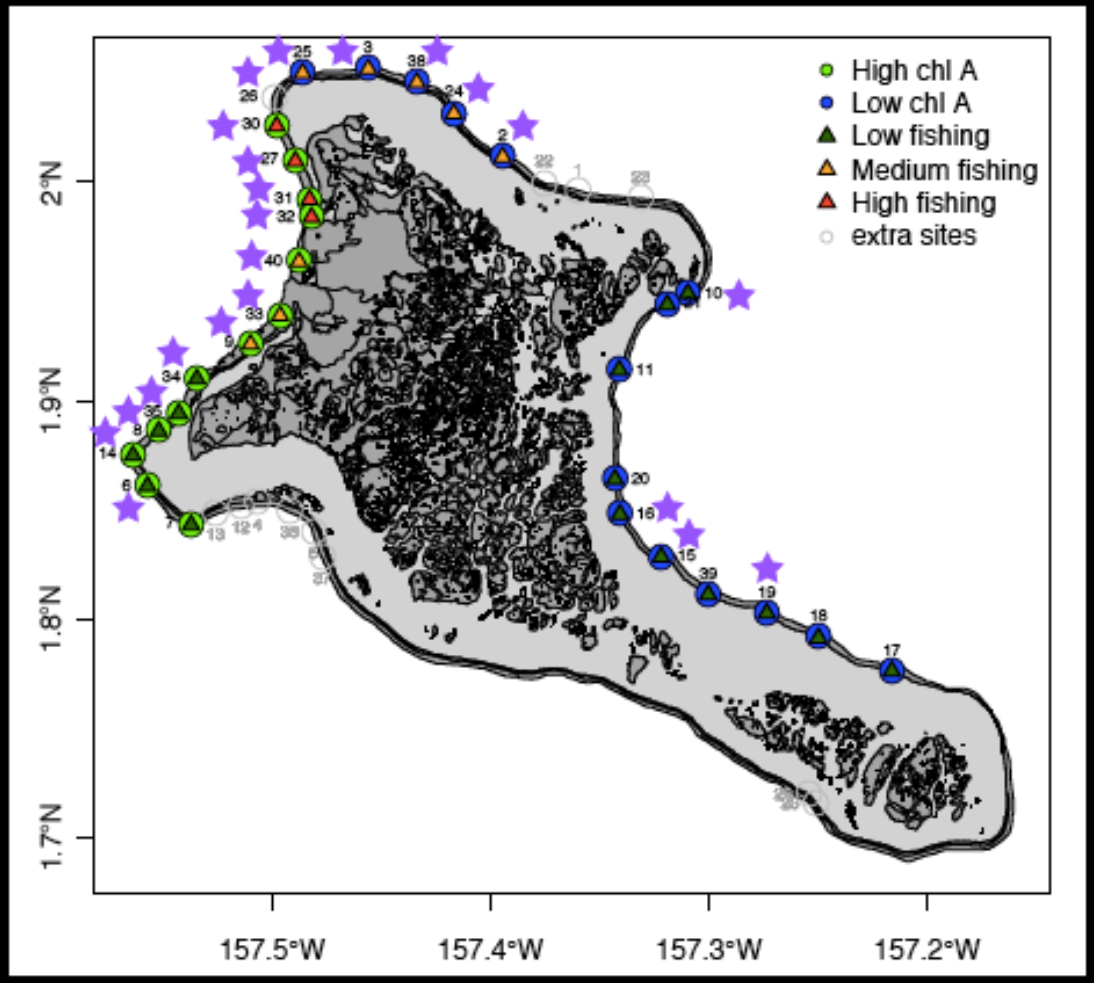
Appendix A:
Maps showing ecological monitoring survey sites around Kiritimati atoll

fish surveys



Category	sites
HP.HF	4
HP.LF	5
HP.MF	3
LP.LF	7
LP.MF	5
EXTRA	1
total	25

urchin surveys



Category	sites
HP.HF	4
HP.LF	5
HP.MF	3
LP.LF	4
LP.MF	4
EXTRA	1
total	21

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 MoF Tekeeti

Household Members

Interviewee name/sex/age Bua/F/32

Interviewed before (Shelia/Rosalie) 07/09 (1) 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?

Car/truck no

Computer no

CD player 1

Garden

Fruit trees breadfruit 2, papaya 1

Coconut trees 7

Household Income

What is the main source of income for the household? Copra >$10/day

What is the estimated total income for the last year? 6 /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 $10/day (works every day 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 #: XC24 (WS13) Village: Roland ____ KI Date: 12th Aug Enumerator: DC ____ MoI: Tetanke

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 mostly) — 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), 2ft, 710	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?	5 milkfish/day

Way Point: ____ Latitude: ____ Longitude: ____

Household # ____ WP # HH513 ID24 Village Bland KI Date 12th Aug Enumerator DC Mod Tablet

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	BCM	3hrs	2	Milkfish	~2	7			
3												
4												

Way Point: _____ Latitude: _____ Longitude: _____

Household #: ___ WP # IL24 (#151?) Village: Edward KI Date: 12th Aug Enumerator: DE MoF: Telesote

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

Trip	Type of Fishing	Gear	Location	Habitat	# hrs	# people	Species	Kg	Total kg's	Sold $	Earned
5											
6			Broke 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:_____ 4

Household #: ___ WP # #HS13 DC24 Village: Poland KI Date: 12th Aug Enumerator: DC Mof: Tawaka

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

(1) Would you change fishing gear *(to what)*, change location *(to where)*, change fishing depth *(to what)*, start fishing illegally?	always catch enough fish (don't understand)
(2) If you would **increase** your fishing effort, how so? More hours/day, more days/week *(how many)* - 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: ___ 5

Household #: ___ WP # PB13 DC24 Village: Abaiang KI Date: 12th Aug Enumerator: DC Mid: Teuraitei

FISHERIES MANAGEMENT & CONSERVATION

6. a) Are there any traditions or government regulations that limit fishing in any way?	Donation
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. follows 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's 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? yes.	

Way Point: _____ Latitude: _____ Longitude: _____

Household #: ____ WP #: ~~JC24~~ HH23 Village: Poland ____ KI Date: 12th Aug ____ Enumerator: JC ____ MoI: Tebwaki

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?	not sure.
f) Do you think that climate change will impact Kiritimati, or your whole country, in the future? How so?	
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: ____

Household #: ___ WP #: A0513 2024 Village: Poland KI Date: 12th Aug Enumerator: DC MoF: Tebaudei

Use 'X' to mark on the map the location and number of each fishing trip in the **last seven days**.
Use 'Y' to mark on the map the location of fishing trips in the **last year**.

Way Point:_____ Latitude:_____ Longitude:_____

Appendix C:
2013 Household Survey Submitted Manuscript – "Subsistence fishing dependence and perception of local and global threats on the world's largest atoll"

ENVIRONMENTAL CONSERVATION

CAMBRIDGE UNIVERSITY PRESS

Subsistence in isolation: fishing dependence and perceptions of change on Kiritimati, the world's largest atoll

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Manuscript Type:	Research Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Watson, Maryann; University of Victoria, Biology Claar, Danielle; University of Victoria, Biology Baum, Julia; University of Victoria, Biology
Keywords:	adaptive capacity, coral reef, subsistence fishery, Christmas Island, management, climate change

Subsistence in isolation: Fishing dependence and perceptions of change on Kiritimati, the world's largest atoll

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Article Type: Research paper

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SUMMARY

Millions of people worldwide depend on coral reef resources for their food and livelihoods. The people of Kiritimati, an island of the Republic of Kiribati, are among the most vulnerable to reef degradation due to high reef dependence and high exposure to threats. Here, we interview Kiritimati residents to evaluate perceptions of fishery status and dependence, and climate change effects. People believed fishery resources had declined, and attributed this to overfishing by Kiritimati's growing population. Continued immigration to Kiritimati has created a shifting baseline, with more recent immigrants perceiving the local fishery to be in better condition than long-term residents. In response to a hypothetical fishery decline, 70% of respondents anticipated continuing to fish because of their high dependence on fishery resources, and limited alternatives for food. This low adaptive capacity, driven by Kiritimati's poverty and isolation, suggests interventions are needed to avoid further reef degradation. Kiritimati residents were open to discussing new conservation policies that would conserve their fisheries, suggesting locally supported conservation strategies may aid in alleviating some of their vulnerability. Finally, recognition of climate change was common, and connectivity may play an role in awareness of impacts and adaptation programmes for those who will be most affected.

Key words: adaptive capacity; coral reef; subsistence fishery; Christmas Island; management; climate change

INTRODUCTION

Globally, coral reefs are under threat from the combined impacts of fishing, pollution, and climate change (Pandolfi *et al.* 2003; Hoegh-Guldburg *et al.* 2007). In many small-island nations, diminished reef resources also imperil the local communities who depend on these ecosystems for their sustenance and livelihoods (Wilkinson 2008; Bell *et al.* 2009; Teh *et al.* 2013). The Republic of Kiribati, a nation of 33 islands scattered over 5 million km^2 of the equatorial Pacific Ocean, is considered to be one of the world's most vulnerable countries to coral reef degradation owing to its high reef dependence, its high exposure to threats including overfishing and climate change, and its low capacity to adapt to changes (Burke *et al.* 2011). Fishing is deeply rooted in the culture of the Kiribati people, the I-Kiribati, and the nation's subsistence fishery produces nearly three times that of its commercial fishery, both in terms of weight and monetary value (Lovell *et al.* 2001). The I-Kiribati are estimated to have the highest per capita fish consumption in the world (75.2 kg per person per year; Sugiyama *et al.* 2004). A spectrum of dependence on subsistence activities exists within the population, with some households operating mainly by cash-based means, and others operating with minimal cash that is used to supplement subsistence activities (Thomas 2002). Kiribati's rapidly growing population, and increasing access to imported goods are resulting in a shift to higher consumption and reliance on imported food that is of poorer nutritional quality than the traditional seafood based diet (AusAid 2012). With increasing monetization and urbanization, the future health and independence of the I-Kiribati will require sustainable development of the subsistence fishery.

Kiritimati (pronounced "Christmas"), an island comprising over half of the Republic of Kiribati's total land area (01°52′N 157°24′W, Northern Line Islands), is the world's largest coral atoll by land mass (Fig. 1). Although it is one of Kiribati's least densely populated islands, Kiritimati's population is increasing rapidly because of a population re-settlement program from the nation's capital of South Tarawa to Kiritimati that was initiated in the 1980's (Asian Development Bank 2002). The program was an effort to reduce the population of South Tarawa, where very high population density (3,184 people per km^2; Kiribati National Statistics Office, 2012) has led to environmental degradation. This resettlement program continues today, and in the 2010 census, over 90% of the people on Kiritimati identified themselves as having migrated to Kiritimati. The island's population of approximately 5,500 (Kiribati National Statistics Office 2012) is highly reliant on the reef's resources for subsistence fishing, aquarium fish exports, and sport fishing tourism (Awira *et al.* 2004; Walsh 2011). The local fishery is artisanal, with fishers using hand lines, gillnets, and spears to fish on the reef along the coast and within the atoll lagoon. Most of Kiritimati's population is concentrated in a few villages on the northern end of the atoll (Fig. 1), and high fishing pressure in these areas has degraded the reef fisheries resources (Sandin *et al.* 2008; Walsh 2009).

Faced with a decline in fishery resources, fishers may choose to continue fishing as before, to leave the fishery, or to increase their fishing efforts; these individual actions cumulatively affect fish stocks and management outcomes. Fishers' vulnerability to declining reef resources is increased by low adaptive capacity (Burke *et al.* 2011) - the ability to modify behaviour to adjust to changes, risks, or opportunities - which in turn is influenced by socio-economic characteristics, and varies across scales, from country to the individual (Smit &

Wandel 2006). Previous studies suggest that the willingness of an individual fisher to exit or adapt to a declining fishery may be driven by the availability of other economic options (Cinner *et al.* 2009; Cinner *et al.* 2011), by factors influencing the perceived risk to the fisher (Daw *et al.* 2012), or by social aspects such as cultural attachment to their way of life (Muallil *et al.* 2011; Walsh 2009). We hypothesized that socioeconomic factors including personal wealth, current occupation, and migration status would influence Kiritimati fishers' perceptions of their local fishery and their individual capacity to adapt to resource changes.

Although Kiritimati's rapidly changing fishery requires effective management strategies and local support to secure long-term sustainability, the extent of agreement and compliance with local regulations is unclear. Kiritimati has recently implemented fishing regulations focused on preserving the local bonefish (*Albula sp.*) population, which is the focus of the atoll's growing sportfishing industry. A regulation prohibiting island residents from catching bonefish was implemented in 2008, and small areas of bonefish breeding habitat within the lagoon have been closed to fishing. Both fishers' perceptions of the state of their resource and the benefit they associate with management policies have been shown to influence their agreement with policies (Gelcich *et al.* 2005; McClanahan *et al.* 2009); we expected the latter to be the primary determinant of agreement and compliance with management policies on Kiritimati.

Localized fisheries impacts on coral reefs also act cumulatively with global climate change, and reef-dependent communities are expected to experience climate change effects more acutely than other countries (Barnett & Adger 2003; Cinner *et al.* 2012). The responses and adaptive capacity of reef-dependent people will thus be a critical factor in determining the future

of reef ecosystems. People's perceptions and awareness of climate change impacts influence their willingness and preparedness in adapting to changes (Patt & Schroter 2008). Recognizing this, the government of Kiribati has established national adaptation programmes for climate change that include community workshops and informative radio programmes. This initiative appears to have improved climate change awareness, and observations of climate change impacts (*e.g.* temperature changes, sea level rise) are common, but understanding of climate change processes is generally low (Kuruppu & Liverman 2011). We assessed climate change awareness and experiences of related impacts on Kiritimati, and hypothesized that awareness would be positively influenced both by education and media connectivity.

We interviewed residents of Kiritimati with the broad goals of characterizing local and global threats on the atoll. Specifically, we first evaluate fisheries practices including the distribution of current fishing pressure, as well as perceptions of fishery status, reliance on the fishery, responses to a hypothetical decline in the fishery, and attitudes towards fishery management. We then assess resident's awareness and associations of perceived changes in the local environment to climate change. Together, this information provides the first description of the status of Kiritimati's fisheries and the adaptive capacity of the atoll's people to local and global threats.

[FIGURE 1]

METHODS

Study design and socioeconomic assessment

We conducted semi-structured interviews with heads of households on Kiritimati in August 2013. We stratified our sampling effort across the atoll's villages, allocating effort approximately in proportion to the size of each village. Estimated village populations in 2010 were 1879 people in London, 2311 in Tabwakea, 955 in Banana, and 441 in Poland (Kiribati National Statistics Office 2012). We re-surveyed households from prior years' surveys (J.K. Baum and S.M. Walsh, unpublished data) where possible, otherwise we chose households haphazardly.

We gathered information on the economic and social characteristics of each household to evaluate how these related to focal questions on fishing and climate change. We collected information on each respondent's gender, age, years of education, and the number of people living in the household, as well as weekly household incomes and expenditures, the number of employed adults, diversity of jobs, and material assets. Social characteristics included social capital (whether the household belonged to a community group such as a church or fishing group), the number of income sources to the household, and migration.

Fishing pressure & perceived and hypothetical fishery changes

To assess the distribution and intensity of fishing pressure around the atoll, we collected fishing information from each respondent including: fish catches on normal fishing days, regular fishing locations, the importance of fishing to household income (whether fishing was a primary income source), and capital investment into the fishery by the household (ownership of nets,

boats, and other fishing gear). We calculated distances between households and their reported normal fishing location using QGIS (QGIS Development Team 2014).

We then assessed respondents' perceptions of changes in the local fishery over time. This included the length of time they had been fishing around the atoll, changes in the effort needed to catch fish over the previous 5 years, changes in the size or abundance of fish they caught, and whether they were able to consistently obtain enough fish to feed their families.

To determine how perceptions about the fishery may impact fishers' decisions to exit or remain in the fishery, we asked survey participants how they would respond to a hypothetical 50% reduction in their catch over a sustained time period. Responses were categorized as either: (1) continue to fish as before, (2) increase fishing efforts, (3) decrease fishing efforts, (4) stop fishing completely, or (5) temporarily switch jobs. We questioned respondents further as to the actions they would take to achieve these responses.

Fishery management

We evaluated perceptions of management policies by asking respondents about their awareness of, and agreement with, local fisheries management or conservation regulations. We further questioned those that were aware of regulations as to their agreement with the regulations, whether they complied with the regulations, and whom they perceived as benefitting from the regulation.

Climate Change

Finally, to assess awareness of climate change and its impacts, we surveyed participants on their basic knowledge of climate change, including whether they had heard of the term, and if they had perceived any climate change-related changes in Kiritimati's environment and economy (*e.g.* sea level rise, changes to rainfall, freshwater availability, and/or the price of food).

Analyses

All analyses were conducted in R Studio version 0.98.507 (R Development Core team 2012). Linear regressions were used to assess possible gains in fish catch (standardized by total estimated normal catch length in metres) or in time spent fishing each week. Fishers Exact Tests were used to compare the proportions of respondents who perceived changes in the fishery over time. An index of relative wealth was created using a principal components analysis of household structure and possessions (Table S1, see supplementary material at Journal.cambridge.org/ENC) in the vegan package for R (Oksanen *et al.* 2012); the resulting first principle component explained 29.2% of the variation (Table S1). A generalized linear model (GLM) was used to examine how fishers responses to a 50% decline in the fishery related to their characteristics; household income multiplicity, total weekly income per household member, the index of relative wealth, whether fishing provided income to the household, their perceived change in the fishery, age, years of education, and gender. Differences in the proportion of people who were aware of climate change and their age and education were evaluated with t-tests, and differences in the proportions of those who owned radios and were aware of climate change were assessed with a Fishers Exact Test.

196 # RESULTS

197 **Respondent background**

198 In total, we interviewed people in 103 households, covering 12% of Kiritimati's 857
199 households (Kiribati National Statistics Office 2012): London n = 35, Tabwakea n = 20, Banana
200 n = 21, Tennessee n = 9, Poland n = 15, copra settlements n = 3. Respondents included forty-four
201 women and fifty-nine men who ranged in age from 21 to 75 years (Fig. S1a, see supplementary
202 material at Journal.cambridge.org/ENC). Both the education level and household sizes (including
203 adults and children) of respondents ranged widely, from 0 to 18 years (Fig. S1b) and 1 to 27
204 people (Fig. S1c), respectively. A typical household contained an extended family; most often
205 two married couples and their children. Both women and men worked for household income;
206 however, only men were involved in fishing activities or selling fish. The number of jobs per
207 household ranged from 0 to 4 jobs (Fig. S1e) and weekly household incomes ranged from $0-
208 $750 AUD (Fig. S1d). Although income sources were diverse, with respondents identifying 44
209 different occupations overall, the most common source was selling fish (n = 23 respondents).
210 Weekly expenditures were predominantly on food, such as rice, sugar and flour, but some
211 respondents listed educational and church expenses as well.
212
213 About half (52%) of respondents had migrated to Kiritimati, with three-quarters of these
214 migrants coming from Kiribati's capital Tarawa, and the rest coming from other outer islands of
215 Kiribati. Respondents who had immigrated to Kiritimati had lived on the atoll for an average of
216 16 years (ranging from 1 to 42 years). The vast majority (87%) of respondents were members of
217 a community group, most of which were church communities; three respondents used to, or
218 currently belonged to community fishing groups.

Fishing pressure & perceived and hypothetical fishery changes

Ninety-five per cent of households were actively engaged in fishing. While 18% of these fishers relied on fishing as the primary income source for the household, and an additional 17% included fishing as one of multiple household income sources, the majority of fishers relied on fishing primarily for subsistence. All respondents described fish as a key part of their household's diet, being consumed at two or more out of three meals each day. In most households, fish was the only source of protein regularly consumed although some households supplemented their diet with chicken or land crabs. All but two fishers said they were always able to catch enough fish to feed their family.

The most commonly caught fishes listed by respondents were milkfish (*Chanos chanos*), snappers (Lutjanidae), trevally (Carangidae), tuna (Scombridae), and surgeonfishes (Acanthuridae). Fishing locations were highly concentrated around the villages (Fig. 1a), and on average fishermen travelled 6.5km ± 8.6km (±SD) to their daily fishing locations. People in the villages of Poland and London travelled the shortest average distance to their fishing locations (3.8km ± 2.4km, and 3.3km ± 3.9km respectively) and these areas also had the highest density of fishing sites (Fig. 1c). Fishers travelled to shore-based fishing locations on foot, by bicycle, by motorcycle or by car. Boat ownership, either canoes or boats with an outboard motor, was uncommon (13% and 15% ownership, respectively). Distance to fishing locations was not significantly related to total length of fish caught or to hours spent fishing each week (both $p > 0.05$).

Two-thirds of respondents reported that it was now harder to catch fish on Kiritimati than it had been in the past, 28% had not noticed any changes, and 6% found it easier to catch fish now (Fig. 2a). Of those who found it harder to catch fish, the majority (81%) attributed this change to overfishing, and cited the increasing human population on the island, a greater number of fishers, or decreasing fish populations as contributing factors. Still, a number of people (16%) were not sure why fishing had become harder, and 3% attributed the change to their fishing location. Few respondents had changed fishing location (14%) or gear (11%) in the last 5 years, suggesting that decreases in the catch can largely be attributed to a declining resource.

Perceptions of change in the fishery differed with the length of time the respondent had been fishing on Kiritimati (Fig. 2b). Most of those (82%) who had fished for more than thirty years on Kiritimati (n=11) reported that it was harder to catch fish now than in the past. Similarly, three-quarters (77%) of those who had been fishing for more than 20 years (n = 31) also perceived an increase in the effort needed to catch fish. In contrast, only 61% of those who had fished on Kiritimati for (10-20 years, n=25) and less than half (47%) of those who had been fishing for less than ten years (n=21) said it was harder to fish now. The proportion of fishers who reported fishing becoming harder was significantly greater in those who had been fishing for greater than 20 years, than in those who had been fishing on Kiritimati for less than 20 years (Fishers Exact Test, $p < 0.05$). Place of fisher origin (ie. whether they had migrated from an outer island, Tarawa or were born on Kiritimati) did not influence their perceptions of changes in fishing effort on Kiritimati (Fishers Exact Test, $p > 0.05$).

Although the majority of respondents (59%) did not report any changes in the sizes or abundances of the fish they had caught over the past five years, and a single respondent (1%) said there was a greater number of larger fish on Kiritimati, 40% of respondents did report a decrease in either the size or abundance (Fig. 2c). *"In the past"* a resident of Poland village noted *"we catch Koinawa [Convict surgeonfish] that were larger, now they are much smaller. In the past we could only cook two fish in the frying pan, now we can fit almost six in the pan."* Of fishers who had been fishing over the long-term (>20 years and >30 years) half (53% and 50%) perceived decreases in fish size or abundance. Among fishers who had been fishing for less time (<20 and <10 years) a smaller proportion reported declines in fish size (33% and 32%). Proportions reporting a decreased fish size between those who had fished for greater than 20 years for less than 20 years were not significantly different (Fishers Exact Test, $p > 0.05$).

[FIGURE 2]

In response to a hypothetical 50% decline in their fish catch, 29% of fishers said they would increase their fishing effort, 41% would continue to fish as before, 7% would fish less, 8% would stop fishing completely, and 14% were unsure of what they would do (Fig. 3). Many respondents noted their family's dependence on fishing, as did this resident of London village: *"We depend heavily on fish, so really not sure what we would do [if fish resources declined]. The supply from the store is so expensive."* Many of those who said they would reduce their fishing efforts said they would store the fish they caught for longer periods. The median weekly income of those who said they would stop or fish less was $31.80 AUD per household member, while those who would continue fishing as before or increase their fishing efforts was lower

($17.90 and $20.00 respectively). Responses were not, however, significantly related to income, relative wealth, perceived change in fishing effort, occupational multiplicity, age, education, or time spent in the Kiritimati fishery.

[FIGURE 3]

Fishery management

Most respondents (88%) were aware of Kiritimati's restriction on catching bonefish, and the areas closed to fishing within the lagoon. Nearly all respondents (89%) who were aware of a management policy also agreed with the policy. Agreement with policies was significantly related to respondents' years of education (GLM, $t = 2.291$, $p < 0.05$), with those agreeing having an average of 1.8 more years of education than those who disagreed. Agreement with policies was, however, not related to respondent age, their household's weekly income, or their perceived change in the fishery. Additionally, a high proportion of respondents (86%) said they would agree with the implementation of a new marine protected area on the island.

Of the small number of respondents who disagreed with management policies, some reported that they disagreed with the bonefish restriction because they enjoyed eating bonefish; one respondent suggested the implementation of additional closed areas to protect bonefish and that removal of the fishing ban would allow people to fish without worrying about catching bonefish accidentally. Another respondent, who agreed with the regulation, stated that the regulations were not being enforced properly. Fifteen respondents admitted to sometimes catching and keeping bonefish, mainly as bycatch within gillnets. Respondents rarely listed themselves or their community (Kiritimati Island) as benefitting from the bonefishing ban, and

most frequently listed the tourism industry, the government of Kiribati, and the people of Kiribati (Fig. 4).

[FIGURE 4]

Climate Change

Almost two-thirds of respondents (65% of 88 respondents) had heard of climate change. Although more of those who knew about climate change owned a radio (72%) than those who did not (55%), this difference was not significantly different (Fisher's Exact Test, $p = 0.16$). Nor was there a significant difference in awareness of climate change with respondent's age or years of education. Three-quarters of respondents (75%) stated that they had observed weather changes over the past 10 years, including increasing temperatures, and changes in the rainy and dry seasons. Similarly, 74% of respondents had observed increasing food prices. Half of respondents reported observing changes in sea level (50%) or freshwater availability (51%).

DISCUSSION

The ubiquitous dependence of Kiritimati residents on the fishery highlights their vulnerability to changes in their natural resources. The high dependence on fish among Pacific island nations has been described as a state of 'subsistence affluence' rather than due to lack of development (Bell *et al.* 2009), allowing for a good quality of life that is not measureable in monetary value. This view is important to maintain in the context of management, to both conserve fishery resources and to support local livelihoods. Fishing is a traditional practice to obtain food for the household, and has many non-monetary benefits associated with it; as an available resource, it reduces the expenditures for the household with relatively low effort and many enjoy the fishing lifestyle. Participation in fishing for enjoyment on Kiritimati was

observed by Walsh (2009), whose study revealed that a government subsidy on copra resulted in the unintended consequence of increased fishing pressure as a result of people having more leisure time to spend fishing.

Fishing pressure on Kiritimati was concentrated around the villages, areas which have been shown to have lower fish biomass due to fishing (Walsh 2011), but those who travelled farther to their fishing sites did not appear to have an advantage of increased regular fish catch, or a decrease in the amount of time spent fishing each week. Access to transportation appeared to be a limiting factor for fishers to go to the farthest fishing sites. Additionally, many fishers reported targeting only the number of fish that could feed their families until their next fishing trip, so traveling a greater distance to catch this same amount would increase their effort unnecessarily while they could still obtain this catch closer to home. This observation is consistent with findings that aggregation of fishing effort does not necessarily relate to patterns of fish abundance (Pet-Soede *et al.* 2001). Instead, small-scale fishermen may act to minimize risks instead of maximizing catch rates and travelling to farther fishing sites imposes greater risk (more time, money *etc.*) without certainty that they will be compensated in their catch. The current pattern of high fishing effort nearest to the villages, which has been observed in earlier surveys of fishing on Kiritimati (Walsh 2011), may change with pressure from future population growth, or declines in fishery resources.

Perceptions of the status of Kiritimati's fishery resources was dependent on the numbers of years spent fishing on the atoll, with newer fishers perceiving the resource to be in better condition, indicative of a 'shifting baseline' (Pauly 1995). This trend has serious implications for

Kiritimati; new fishers continually migrating to the island have a baseline for the local fishery at the time of their arrival, or may be using a baseline from their previous fishery, and do not have the perspective of those who may have witnessed declines in fish populations or sizes over a longer time. This will likely be an ongoing issue, as the population continues to grow and receive new arrivals to the island (Kiribati National Statistics Office 2012). Despite this difference across groups, the majority of respondents reported increasing effort required to catch the same amount of fish and recognized the growing island population as the driver of this change.

At a hypothetical 50% reduction in fish catch, the majority of respondents said they would continue to fish as before or increase their fishing pressure, and only a small proportion said they would decrease or cease their fishing efforts. This 'continue fishing' response differs from other studies in which the proportions of fishers who said they would exit the fishery at a 50% decline outweighed the proportion who would continue to fish (Cinner *et al.* 2011, Cinner *et al.* 2009). Although factors of income, occupational multiplicity, age, education, perceived change in the fishery, or time in the fishery have been found to influence the behaviour of subsistence fishers in other regions (Cinner *et al.* 2009; Cinner *et al.* 2011; Daw *et al.* 2012; Muallil *et al.* 2011), this was not the case on Kiritimati.

Kiritimati's isolation is a likely explanation for why it differs from subsistence fisheries in other parts of the world (*e.g.* Cinner *et al.* 2011; Muallil *et al.* 2011), since this results in low adaptive capacity and contributes to the high vulnerability to changes in the reef resources (Bell *et al.* 2009; Daw *et al.* 2009). There is little option but to continue to fish to provide the bulk of food for households; agriculture is constrained by the atoll's low rainfall and there is high

reliance on food imports, which are expensive, infrequent, and can be unreliable. In 2008, for example, Air Pacific (the only airline service to Kiritimati) suspended all flights to Kiritimati for twenty months due the condition of the island runway, creating problems with access and imports to the island. Also in 2008, the global financial crisis caused the prices of food and fuel to increase - Pacific Island countries are especially vulnerable to these changes due to their remoteness and dependence on imported food (Miskelly *et al.* 2011). Increases in food prices, especially rice, had been noticed by most I-Kiribati that we interviewed. On Kiritimati, targeted strategies to reduce fishing efforts, such as increasing affluence or alternative-employment opportunities, may increase reliance on imported food. Management of local fishing is needed in conjunction with economic development to enable sustainable use of the local reef resources.

Management policy effectiveness is dependent on local attitudes, and fishers' behavioural responses are influenced by their individual perceptions of a given policy (Gelcich *et al.* 2005). Our results showed a high awareness of, and agreement with, fishing regulations on Kiritimati, recognition of benefits to the economy through the development of sport fishing tourism, and also highlighted areas that could be improved to increase local agreement. Disagreement with the bonefishing ban occurred when fishers felt their individual needs were neglected, or they did not perceive any personal benefits from changing their fishing behaviour. Incorporating local needs and goals into policies could be achieved through community meetings, workshops, or household surveys. Education may have an important influence on positive attitudes to fishery management on Kiritimati by potentially increasing knowledge of resources and effects of management (McClanahan 2009). Increasing demand for reef resources from Kiritimati's growing population will require active management of fishery resources to continue to support the island, including

401 forecasting the future need for fish resources (Bell *et al.* 2009). Improving accessibility to
402 continuing education, or targeted outreach programmes may improve understanding of and
403 attitudes towards fishery management.
404
405 Raising public awareness of climate change impacts is a top priority of the Kiribati
406 National Adaptation Program of Action (NAPA; Government of Kiribati 2007), and should
407 positively influence people's preparedness and ability to adapt to changes (Lata & Nunn 2011).
408 Climate change is impacting both ecological systems (*e.g.* through coral bleaching and ocean
409 acidification) and human systems (*e.g.* coastal communities are threatened by sea levels rise and
410 extreme weather events) (Daw *et al.* 2009). Media connectivity may have a positive influence on
411 climate awareness; several respondents stated that they had heard of climate change and
412 adaptation programmes on the radio, suggesting that efforts of adaptation programs are effective
413 to some degree. Residents of Kiritimati described climate change-related impacts they were
414 experiencing, including rising sea level, changing weather patterns, increasing temperatures, and
415 changes to their freshwater supply such as an increased salt content. We may expect the severity
416 of these impacts to increase for the I-Kiribati in the near future, along with climate change
417 effects to their fishery resources. This underscores the importance of active adaptation initiatives
418 to assist those who will be most affected.
419
420 Our results demonstrate the high dependency of people in developing island nations on
421 their reef for their livelihoods, and their low adaptive capacity due to the inherent isolation of
422 their communities. This isolation sets this case apart from other studies that have examined
423 fishers' responses to resource declines (*e.g.* Cinner *et al.* 2011; Cinner *et al.* 2009). The response

424 of people to continue fishing in the face of a fisheries decline has potentially severe
425 consequences for the reef ecosystem. Coupled with the impacts of climate change, the future of
426 Kiritimati's fishery and those who rely on it is in jeopardy. We found that in general, people
427 were open to discuss and implement further conservation policies that would conserve their
428 fisheries. Thus, opportunity exists to engage the local community in conservation efforts and to
429 reduce vulnerability through protection of Kiritimati's reef resources.
430

431 **Supplementary material**

432 To view supplementary material for this article, please visit Journal.cambridge.org/ENC.
433
434

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CONFLICT OF INTEREST

None

ETHICAL STANDARDS

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human research ethics.

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559 FIGURE LEGENDS

560

561 Figure 1. (a) Map of Kiritimati, villages (blue triangles, size indicates relative populations), and
562 survey respondents' regular fishing locations (red circles). (b) Kiritimati's location within the
563 Pacific Ocean. (c) Density of reported fishing locations around the atoll (low density = blue, high
564 density = red).

565

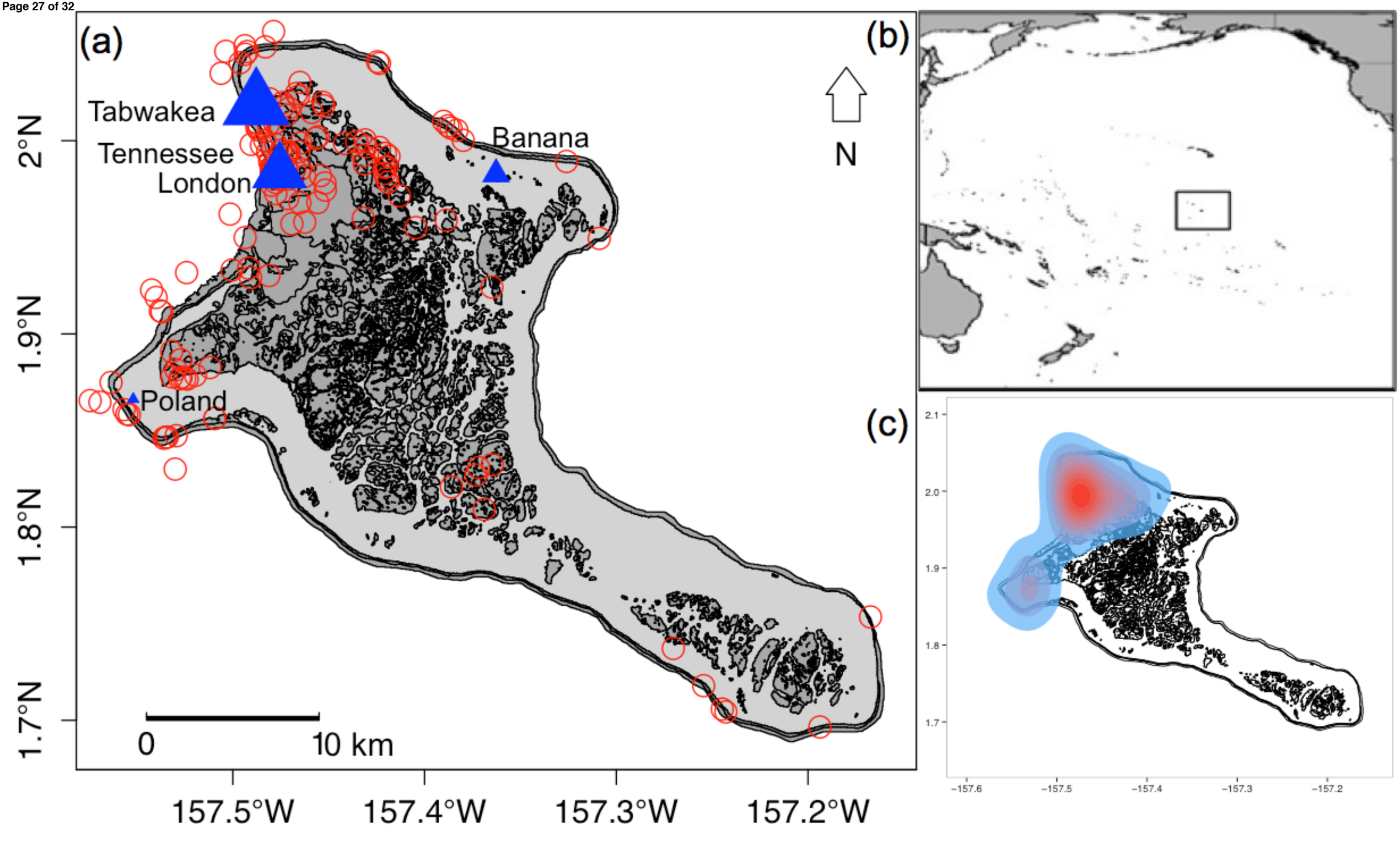
566 Figure 2. (a) Respondents perceptions of changes over the previous 5 years of effort required to
567 obtain their normal fish catches. (b) Responses were grouped into time categories of the length of
568 time the fisher had been fishing on Kiritimati: <10 years (n=25), >10 years (n=25), >20 years
569 (n=31), and >30 years (n=11). (c) Respondents perceptions of changes in the size of the fish they
570 caught over the previous 5 years.

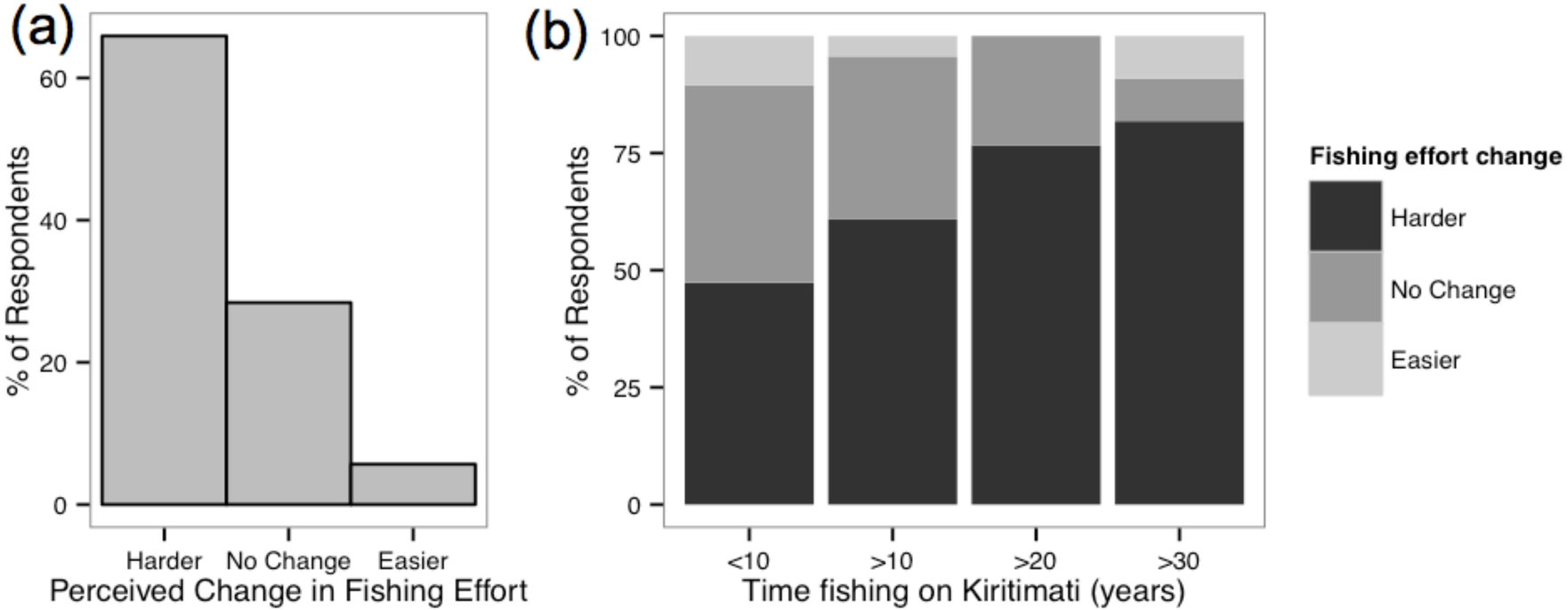
571

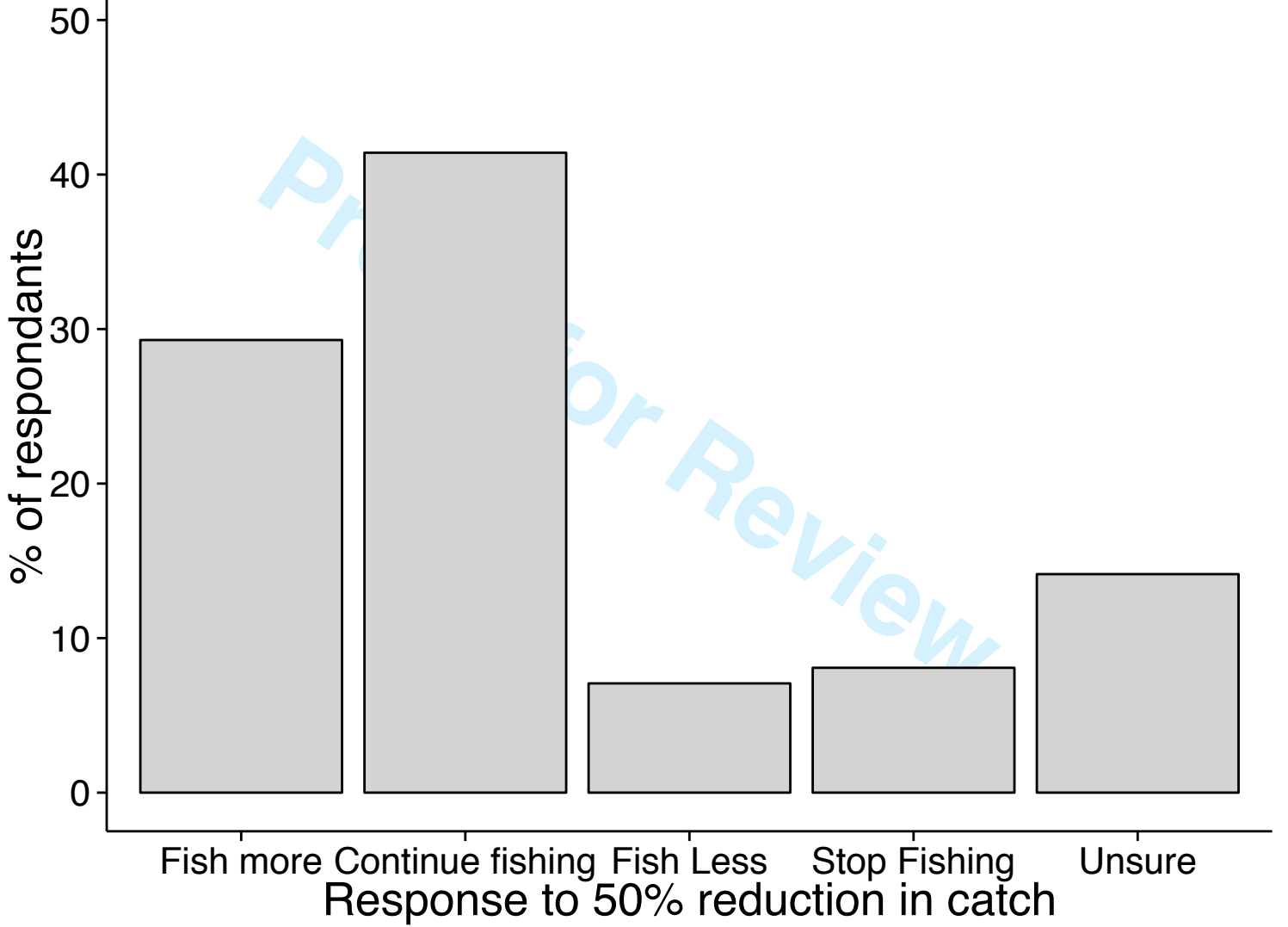
572 Figure 3. Distribution of responses of people on Kiritimati to a hypothetical 50% decline in fish
573 catches over a sustained period. Responses were categorized into (1) fish more, (2) continue
574 fishing, (3) fish less, (4) stop fishing, or (5) unsure.

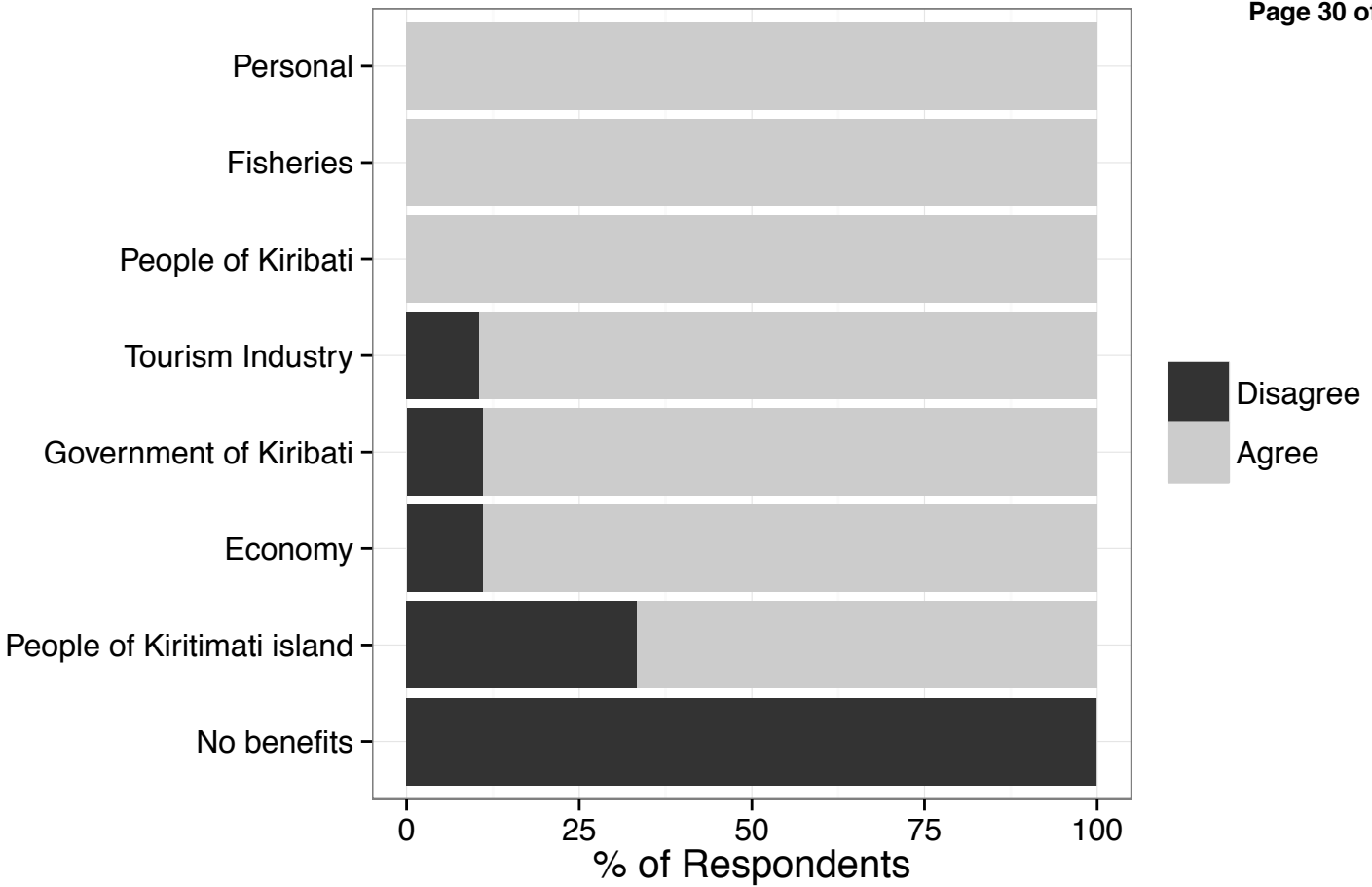
575

576 Figure 4. Proportions of respondents who agreed or disagreed with the Kiritimati bonefishing
577 regulation, and whom the respondent perceived as benefitting from the regulation.

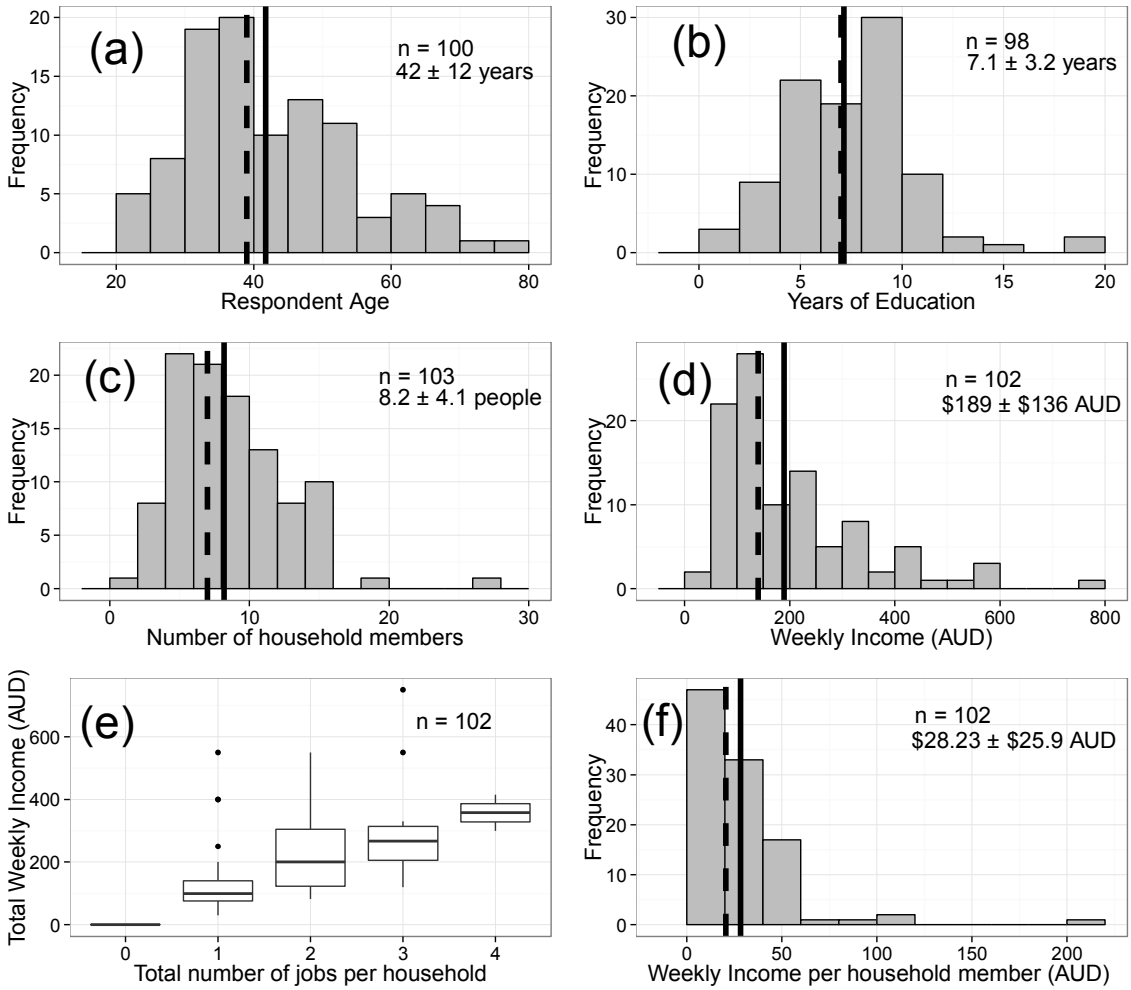

(a)
Tabwakea
Tennessee
London
Banana
Poland
2°N
1.9°N
1.8°N
1.7°N
0
10 km
157.5°W
157.4°W
157.3°W
157.2°W
(b)
N
(c)
2.1
2.0
1.9
1.8
1.7
−157.6
−157.5
−157.4
−157.3
−157.2


(a)
% of Respondents
0
20
40
60
Harder
No Change
Easier
Perceived Change in Fishing Effort
(b)
% of Respondents
0
25
50
75
100
<10
>10
>20
>30
Time fishing on Kiritimati (years)
Fishing effort change
Harder
No Change
Easier
(c)
% of Respondents
0
20
40
60
Decrease
No Change
Increase
Perceived Change in Fish Size


50
40
30
20
10
0
% of respondants
Fish more
Continue fishing
Fish Less
Stop Fishing
Unsure
Response to 50% reduction in catch


Personal
Fisheries
People of Kiribati
Tourism Industry
Government of Kiribati
Economy
People of Kiritimati island
No benefits
0
25
50
75
100
% of Respondents
Disagree
Agree

SUPPLEMENTARY MATERIAL



Supplementary Figure 1. Summary of respondent characteristics: (a) respondent ages, (b) number of years of education received by respondent, (c) number of household members at the respondents house, (d) weekly income of each household, (e) the weekly income per household by the number of income sources (jobs) per household, (f) weekly income per household member, calculated as the weekly income divided by the number of household members. Solid vertical lines indicate the mean of each variable and dashed lines indicate the median. Number of responses as well as the mean ± standard deviation for each characteristic indicated on each plot.

SUPPLEMENTARY MATERIAL

Supplementary Table1. Relative wealth index variables used in a Principal Components Analysis.

Variable	Description	PCA 1
House type	Traditional, concrete or mixed type houses	1.074
Electric lighting	Presence/absence of electric lighting	-1.27
Fan	Presence/absence of an electric fan	-1.19
Toilet access	Whether household has access to a toilet	-1.10
Refrigerator	Presence/absence of a refrigerator	-0.98
Freezer	Presence/absence of a freezer	-1.12
Bicycle	Ownership of a bicycle	0.23
Motorcycle	Ownership of a motorcycle	-0.84
Radio	Presence/absence of a radio	-0.35
TV/Video	Presence/absence of a TV/video player	-0.90
Variance Explained		29.2%