Hum Ecol (2014) 42:75–86
DOI 10.1007/s10745-013-9605-9

The Influence of Science Communication on Indigenous Climate Change Perception: Theoretical and Practical Implications

Peter Rudiak-Gould

Published online: 16 August 2013
© Springer Science+Business Media New York 2013

Abstract Citizens receive information on global climate change through both observation of local impacts and reception of climate science. This article presents a quantitative analysis of the interplay of these two sources of information in an indigenous population: residents of Majuro, the capital city of the Republic of the Marshall Islands. While Majuro residents' reports of local environmental change are partly the result of firsthand observation of changing conditions, survey data robustly demonstrates that environmental change reports are also strongly influenced by awareness of climate science; scientific awareness is a better predictor of environmental change reports than exposure to the environment. This provides a rare quantitative demonstration of the openness of 'local' knowledge to foreign scientific information; challenges research methodologies for the study of indigenous climate change perceptions that exclude the role of scientific communication; and suggests a novel, and overlooked, rationale for the dissemination of climate science to frontline communities.

Keywords Climate change · Science communication · Environmental observation · Local ecological knowledge · Small Island States

Introduction

Broadly speaking, citizens have two sources of information about global climate change (Bravo 2009; Marino and Schweitzer 2009; Marx *et al.* 2007). The first source can be termed 'observation': the firsthand perceiving of local climatic or environmental changes that can be construed, by citizens or scientists or both, to be related to global climate change. The second can be termed 'reception': the uptake of scientific theories, measurements, and predictions of global warming as disseminated by journalists, teachers, government officials, and other science communicators. While many studies of 'local', 'frontline', or indigenous climate change attitudes focus on observation (see for instance Byg and Salick 2009; Crate 2008; Hitchcock 2009; Jacka 2009; Petheram *et al.* 2010), and some on reception (González and da Silveira 1997; Lahsen 2007; Mortreux and Barnett 2009), the literature is not yet well endowed with studies of the interplay of the two (but for exceptions see Connell 2003; Nuttall 2009). Furthermore, many studies of climate change perceptions treat local reports of change as purely the product of observation, rather than stemming from both observation and reception (in particular see Marin and Berkes 2013; Marino and Schweitzer 2009); while this assumption is reasonable in cases where reception (scientific awareness) is weak (Crate 2008) or non-existent (Byg and Salick 2009), it may not hold in more scientifically aware populations. A further limitation of the literature is that most, though not all (see for instance Byg and Salick 2009), of the studies of local climate change reports are entirely qualitative: they yield richly contextualized portraits but encounter difficulties in making empirically robust claims about the relation of various 'observation' and 'reception' factors to locals' reports of climate change. In the wider literature on ecological knowledge systems, numerous works investigate the interaction of indigenous and scientific knowledge (analogous in many ways to the interplay of climate change observation and reception), demonstrating that so-called 'traditional', 'local' understanding of the environment is in fact dynamic and open to outside input (Barsh 2000; Fulsås 2007; Iskandar and Ellen 2007; Suarez and Patt 2004), but quantitative investigations of this have been rare.

This article seeks to fill the gaps by quantitatively investigating the confluence of climate change observation and reception in an indigenous, frontline setting. More specifically,

P. Rudiak-Gould (✉)
Institute of Social and Cultural Anthropology, Oxford University, 51/53 Banbury Rd., Oxford OX2 6PE, United Kingdom
e-mail: peterrg@gmail.com

this interplay will be studied via investigating the factors that are related to citizens' reports of local climate change impacts. The population is the indigenous lay public of the Marshall Islands, more specifically residents of the country's capital and largest urban center, Majuro Atoll's D-U-D area (informally, and hereinafter, referred to as 'Majuro').

Study Site

The Republic of the Marshall Islands is a Micronesian nation of approximately 60,000 citizens, almost all indigenous Marshallese.[1] Composed entirely of low-lying coral atolls and single coral islands, the archipelago is considered severely threatened by even the best-case scenarios of climate change (Australian Government 2011; Barnett and Adger 2003; Kench *et al.* 2011); sea level rise, in conjunction with increased droughts, extreme weather, storm activity, and coral death from increased water temperatures and acidification endangers the country with uninhabitability within the present century (Barnett and Adger 2003). Majuro is particularly at risk due to its high population density, its positioning on narrow, windward islands (Spennemann 1996), and local development exacerbation of erosional impacts (Xue 2001).

Majuro residents have opportunities to learn about this burgeoning threat through both observation and reception. In the category of observation, Majuro residents have daily opportunities to monitor environmental conditions. No dwelling is farther than 250 m from the sea, and the vast majority are within 100 m. Most households have no air conditioning, rendering temperatures noticeable. Many men fish and collect octopus on the ocean-side reef. Locals must stay apprised of environmental conditions: residents must be wary of drought and wave damage during the *añōneañ* (winter) season, seawalls must be built if erosion becomes severe, and sea levels must be monitored for the purposes of fishing and boating. The Marshall Islands is also home to a long tradition, faltering but still extant today, of close monitoring of meteorological conditions for the purposes of ocean navigation. Moreover, environmental change, fitting the prediction of global climate change (though not necessarily straightforwardly attributable to it), is unquestionably occurring in Majuro. Majuro Atoll's temperatures have increased by 0.12 °C per decade since 1956 (Australian Government 2011: 4). Sea levels in the Marshall Islands as a whole have risen by an average of 7 mm per year since 1993 (Australian Government 2011: 4), while rainfall has been decreasing since 1950 (Australian Government 2011: 4), with droughts in the dry (*añōneañ*) season becoming more common. Coastal erosion may have increased in Majuro Atoll (Xue 2001), though accretion is also in evidence (Ford 2012). Majuro has been struck by several floods and high wave events, including one in December 2008 which flooded several neighbourhoods, broke seawalls, damaged more than two hundred houses, temporarily displaced hundreds of Majuro residents, and caused the Marshallese government to briefly declare a state of emergency.

In the category of reception, Majuro residents are exposed to several forms of media. Radios are widely owned and zealously listened to; the local radio station V7AB broadcasts programming in both the Marshallese language and English. The country's national newspaper, the Marshall Islands Journal, is widely read in Majuro, though its articles are primarily in English. Cable television and Internet are available to a minority. Other potential sources of reception include primary, secondary, and tertiary educational institutions; various workshops, conferences, and training sessions; and discussions of the country's Nitijela (Parliament) (witnessed firsthand or through radio and newspaper reporting). All of these outlets have communicated scientific discourses of global warming to Majuro residents, in particular since the beginning of 2009. Survey respondents (see next section) reported learning about global climate change from the radio (37 % of mentions); word of mouth (15 %); television (14 %); newspaper (10 %); school and university classes (9 %); workshops, conferences, and training sessions (9 %); discussions in the Nitijela (5 %); and the Internet (2 %).[2] The year 2009 witnessed a spike in climate change-focused awareness-raising activities, including the Ministry of Education's Education Week, forums hosted by a women's advocacy NGO, and presentations at the Marshall Islands Youth for Christ National Youth Convention. These events were conducted in Marshallese and broadcast on the radio, thus reaching a large segment of the urban (as well as rural) population. While the climate change messages were varied in terms of blame narrative and degree of alarmism, all encouraged citizens to believe that local environmental change (in particular rising sea levels, increasing temperatures, and worsening drought) were occurring, to link these changes to a worldwide anthropogenic phenomenon called 'global warming'/'climate change' (English) or *oktak in mejatoto* (Marshallese), and to be concerned about the severe impacts these changes will precipitate in the future.

Methods

Fieldwork in 2003–4, 2007, 2009, and 2012 totaled 21 months and mixed methods, including general ethnographic participant-observation, participant-observation at climate change educational sessions (2009), approximately 50 h of recorded open-ended interviews (2007, 2009, and 2012), and

[1] 92.1 % of the country's citizens have entirely Marshallese (indigenous) ancestry, while 5.9 % have mixed Marshallese and non-Marshallese ancestry (CIA World Factbook 2013).

[2] 97 individuals answered this question, with 130 total mentions of information sources.

a survey (September 2009) of 146 adult Majuro residents of indigenous Marshallese ancestry. It is the survey on which the quantitative portion of this study relies. I read a questionnaire orally in the Marshallese language (except for a very small number of individuals who preferred to speak in English) without an interpreter and wrote down the answers. Subjects were recruited by convenience sampling: I toured the streets in every neighborhood of Majuro, asking individuals if they were willing to participate. 76 men and 70 women participated. Participants ranged in age from 18 to 84 (Mean=42). Education ranged from none to 16 years (Mean=11). 76 % were Protestant and 10 % were Catholic. These figures are fairly representative of the country as a whole (CIA World Factbook 2013; Freedom Report 2009), indicating that the self-selection bias in the sampling procedure was not severe.

The questionnaire comprised three parts. Part 1 elicited the subject's reports of environmental change, for instance by asking whether the *mejatoto* (roughly 'climate') had changed or stayed the same since the past and, if it had changed how. Part 2 asked about the subject's awareness of the scientific notion of global climate change, such as whether s/he could define the English phrase 'climate change'. The third part elicited various demographic and personal information, such as how close the subject's home was to the sea. For the first 100 respondents, the survey was administered in the order indicated above: Part 1 preceded Part 2 so that discussion of climate science would not prime the subject to report environmental change. 46 additional surveys were administered with Part 2 preceding Part 1. No statistical evidence was found that this question-ordering variable was related to any outcome variable, so this study's statistical analysis will include all 146 respondents.

This methodology follows best practices in measuring climate change perceptions. As in Mortreux and Barnett (2009: 107), I did not announce myself as a climate change researcher, and only administered the survey to those who were unaware of my research topic, so as not to bias responses. Following West and Vásquez-León (2003: 242–244), I began with the most general questions and became more specific, and avoided asking direct questions about particular environmental changes (for instance, sea level rise), instead tallying whether these changes were *spontaneously* reported. There is good post hoc evidence that my subjects were not biased to report environmental change merely in order to please me: even when subjects were asked first about their awareness of climate science (thus implicitly 'outing' myself as a climate change researcher), they were not significantly more likely to report environmental change.

The outcome variables were: 'Reports change of climate', 'Reports sea level rise', 'Reports increased temperature', 'Reports decreased rainfall', 'Reports altered seasons'. These were chosen because they are among the most important climate change impacts in the Marshall Islands by any criterion: they are frequently mentioned in local awareness-raising activities, they are considered by scientists to pose the most severe threats to the country (Barnett and Adger 2003), they have been measured to be currently occurring in this country as well as predicted to intensify in the future by scientists, and they are reported by many locals. (The only outlier here is altered seasons, which is not as often emphasized in local awareness-raising activities, nor is it frequently highlighted in scientific measurements, predictions, or warnings, but it is included because many Marshall Islanders report it).

The independent variables included the following 'reception' variables (measures of awareness of the scientific concept of global climate change): 'Can define [the English phrase] "climate change"', 'Can explain causation of [the English phrase] "climate change"', 'Has attended climate change educational session', 'Years of education'. These measures are, of course, imperfect: 'Years of education' is indirect, while 'Can define "climate change"' and 'Can explain causation of "climate change"' likely underestimate awareness of the scientific concept of climate change, since subjects could have been exposed to the notion without having heard or retained any of the English phrases.

The independent variables also included the following 'observation' variables (measures of the degree of exposure to the environment and thus the amount of opportunity to eye-witness climate change impacts): 'Frequency of fishing/food-gathering on reef', 'Witnessed 2008 flood', 'House damaged in 2008 flood', 'Distance of home from shore', 'Age', 'Gender'. 'Frequency of fishing/food-gathering on reef' measures how often the subject engages closely with the ocean and reef environment. 'Witnessed 2008 flood' measures whether the subject witnessed an event that could be construed as a dramatic sign of burgeoning sea level rise. 'Distance of home from shore' measures how noticeable the ocean is to the subject during time spent in and around the home. Age measures exposure to the environment, as older people have had more years in which to observe their surroundings, and thus may have seen larger changes in their longer lives. Gender indirectly measures observation: Majuro women's tasks tend to be centered on the home, while men in general range more widely to, for instance, go fishing and boating and to drive taxis along the length of the city, so potentially men are more exposed to signs of environmental change. (The opposite is also possible, as women are more intimately involved with procuring water resources on a day-to-day basis).

Given that the sample is relatively small and derived from a single community, more extensive studies from a wider variety of frontline populations—including those facing *immediate* existential threats—would be required before the findings of this paper can be considered well established.

Qualitative Results

Survey respondents and other interviewees gave detailed accounts of a wide variety of negative environmental changes. Very few individuals reported that ecological conditions were stable or improving. The most commonly mentioned alterations were increased temperatures and sunniness, decreased rainfall and more frequent droughts, higher tides, extensive shoreline erosion (expressed as the ocean "eating" the land), dwindling fish and coral in the lagoon, the breakdown of the usual seasonal pattern of a calm summer (*rak*) and windy winter (*añōneañ*), pandanus trees producing fruit at unexpected times of year, and plants suffering from drought, heat, and saltwater intrusion. Residents' statements combined generally noted changes with idiosyncratic observations based on individual experience. Rostina[3], a middle-aged female Majuro resident, described a variety of changes:

> In Majuro, there are problems with water supply. There's not enough water….Families see that their water catchments are empty….Plants are dying in Majuro because of the sunny [rainless] weather….It used to rain at least once a week. The plants grew well. Nowadays it's really hot.…The islands are getting smaller. You see them getting smaller and smaller….It started around 1985. When I came here from the outer islands, I saw the tip of Laura [a semi-rural community in Majuro Atoll] and it was very long. Now it's not.

Mercy, a middle-aged female educator and long-time Majuro resident, focused on erosion and seasonal perturbation:

> There is a concern. My husband [and I], we were going to build our son's house on a piece of land that we [rented] from some landowners here [in Ajeltake, a village in Majuro Atoll], and 2 years ago the shoreline was way down there. Nowadays there is this big tree, it has fallen down….We acquired the land 2 years ago. In 2 years, that's really fast [for the erosion to happen]….The seasons are changing. The harvests are changing. We used to have *bōb* [pandanus fruit] during December. Now we're having *bōb* season right now [June], which is different from before….That's something that's very noticeable. We used to know when it's the breadfruit season, when it's the pandanus season. But no longer.

Many respondents and interviewees had some familiarity with the scientific discourse of human-caused global climate change, in particular the disturbing prediction of nationwide inundation. A minority dismissed this scientific discourse, saying that God had promised to Noah in the Book of Genesis that the earth would never again be flooded, and that scientists had proven themselves dangerously overconfident in their predictions in the past. Most residents, however, found the discourse sadly believable, and their accounts of change combined local observation with scientific predictions and concepts. Clanthy, an elderly woman from Laura (a semi-rural community in Majuro Atoll), linked her observations to the scientific concept of climate change:

> A lot of [Laura] has disappeared from the ocean. The pandanus trees are gone. There used to be coconut trees, but they've fallen from erosion….I can confirm it. The wind is strong. Not like in the past. It has started to rain less…Now when I go to Laura and look at the water, I can see that the water is rising….Perhaps soon it will reach the level of the road….The islands are thinner now….Not just in Majuro but in outer islands too there are problems. It's happening very much, from what they call *oktak in mejatoto* ("climate change")….On Utrik Atoll, I've heard that there are few breadfruit now. There used to be lots. And all the coconut trees have died. We see what the scientists are saying. Now in Laura, there are wells that used to have lots of water. It would never run out. But now it does. And I think this is part of *oktak in mejatoto* too.

Terina, a young female school administrator, and Matty, a middle-aged former Bible studies teacher, had recently attended a climate change workshop:

> Matty: They talked about how the atmosphere is changing—how people are causing this….There was also a man from the College of the Marshall Islands who told us about how stuff goes up into the sky and heats up the world. The climate changes, the ice melts, it gets hotter, and low islands are flooded….These islands will be covered and then there will be nothing….In the old days, people would say, "*Añōneañ*, *rak*," but not now. They could expect that December and January would be the times of big waves, but not now. This change is due to climate change….
> Terina*:* It used to be that the summer was hot, with hardly any wind, and then in Christmas and January or February, it was called *añōneañ* and we expected storms during this time. But now it has changed. And it's getting really hot now.
> Matty*:* And you see erosion nowadays too, on the small islands….Bikirin and Enemanit [islets in Majuro Atoll].

Patrick, a young Majuro man, was particularly concerned with sea level rise and erosion:

> My wife has land in Laura—at the end of the island. We built a shower and little house there, so people could take a shower after they went for a swim. The shower is still okay, but the waves have destroyed so much—they destroyed the little house. It's gone from the erosion…There used to be many graves [in the Jenrōk graveyard]. Then it was severely damaged. The land used to go much further out. That's not the only cemetery that this has happened to. There's one in Uliga [a Majuro neighborhood]. There used to be lots of graves there too. Now it's all gone….The ocean is higher. It wasn't that way before—it was very good….The ozone [sic] is broken, so it is sunnier

[3] Names have been changed.

now….They emit things into the atmosphere. I don't understand it too well. It's not just America but all countries…damaging the atmosphere, making the sun stronger, so the ice is melting. The Marshall Islands will disappear.

Quantitative Results

Univariate Analysis

Results of a univariate analysis are shown in Table 1.

Outcome variables Quantitative analysis confirms that sizeable proportions of respondents reported environmental change (a majority in the case of a changing climate and increased temperatures). 75.3 % of subjects reported at least one of the four types of changes and almost half, 43.2 %, reported two or more; and virtually no one reported the opposite trends of sea level *fall*, *decreased* temperature, or *increased* rainfall. Thus, Majuro residents are quite consistent with each other in terms of the existence, type, and direction of environmental change, and agree with both current measurements and future predictions for climate change impacts. All of these findings accord well with the literature on rural and indigenous climate change perceptions (BBC World Service Trust 2010; Byg and Salick 2009; Crate and Nuttall 2009; Krupnik and Jolly 2002; Petheram *et al.* 2010).

Reception Variables In agreement with qualitative impressions, subjects had a moderate overall level of awareness of the scientific concept of climate change. Few had attended a climate change educational session, and less than a third could give some account of the scientific causation of climate change. But a (bare) majority could give a definition of the English phrase 'climate change'. (In addition, 57.5 % had heard of the English phrase 'climate change' and 60.3 % had heard of at least one of the following English phrases: 'climate change', 'global warming', 'greenhouse effect').

Observation Variables Many subjects had extensive opportunity to witness environmental change firsthand, even in this urban environment: a majority collected food on the reef, witnessed the 2008 flood, and lived close to the shore.

Bivariate Analysis

The results of a bivariate analysis are presented in Table 2.

Table 1 Univariate analysis

Outcome variables	N (%)	Independent variables (reception)	N (%)	Independent variables (observation)	N (%)
Reports change of climate		Can define 'climate change'		Frequency of fishing/food-gathering on reef	
No	41 (28.1)	No	69 (47.3)	Never	57 (39.6)
Yes	105 (71.9)	Yes	77 (52.7)	Once a week or less	45 (31.3)
				More than once a week	42 (29.2)
Reports sea level rise		Can explain causation of 'climate change'		Witnessed 2008 flood	
No	97 (66.4)	No	105 (71.9)	No	42 (28.8)
Yes	49 (33.6)	Yes	41 (28.1)	Yes	104 (71.2)
Reports increased temperature		Has attended climate change educational session		House damaged in 2008 flood	
No	56 (38.4)	No	131 (89.7)	No	100 (68.5)
Yes	90 (61.6)	Yes	15 (10.3)	Yes	46 (31.5)
Reports decreased rainfall		Years of education		Distance of home from shore	
No	113 (77.4)	Less than 9	30 (20.7)	Next to the shore	53 (37.3)
Yes	33 (22.6)	9 to 12	72 (49.7)	Near the shore	25 (17.6)
		More than 12	43 (29.7)	Far from the shore	64 (45.1)
Reports altered seasons				Age	
No	115 (78.8)			Young adults (18–29)	35 (24.0)
Yes	31 (21.2)			Adults (30–49)	61 (41.8)
				Elderly (50–84)	50 (34.3)
				Gender	
				Male	76 (52.1)
				Female	70 (48.0)

Table 2 Bivariate analysis (effects in expected directions, and statistically significant P values [at the 95 % level], are indicated in bold)

	Reports change of climate		Reports sea level rise		Reports increased temperature		Reports decreased rainfall		Reports altered seasons	
	N(%)	P value	N(%)	P value	N(%)	P value	N(%)	P value	N(%)	P value
Reception										
Can define 'climate change'		**0.0003**		**0.0038**		**0.0000**		0.0660		**0.0000**
No	**40 (58.0)**		**15 (21.7)**		**28 (40.6)**		**11 (15.9)**		**4 (5.8)**	
Yes	**65 (84.4)**		**34 (44.2)**		**62 (80.5)**		**22 (28.6)**		**27 (35.1)**	
Can explain causation of 'climate change'		**0.0048**		**0.0438**		**0.0000**		0.2371		0.1469
No	**69 (65.7)**		**30 (28.6)**		**53 (50.5)**		**21 (20.0)**		**19 (18.1)**	
Yes	**36 (87.8)**		**19 (46.3)**		**37 (90.2)**		**12 (29.3)**		**12 (29.3)**	
Has attended climate change educational session		0.1519		0.2218		0.3147		0.3392		0.0796
Not attended	**92 (70.2)**		46 (35.1)		**79 (60.3)**		31 (23.7)		**25 (19.1)**	
Attended	**13 (86.7)**		3 (20.0)		**11 (73.3)**		2 (13.3)		**6 (40.0)**	
Years of education		0.6900		0.6476		**0.0021**		0.6416		0.7295
Less than 9 years	22 (73.3)		12 (40.0)		**13 (43.3)**		5 (16.7)		6 (20.0)	
9–12 years	50 (69.4)		22 (30.6)		**42 (58.3)**		18 (25.0)		14 (19.4)	
More than 12 years	33 (76.7)		15 (34.9)		**35 (81.4)**		10 (23.3)		11 (25.6)	
Observation										
Frequency of fishing/food-gathering on reef		0.4468		0.3043		0.5835		0.7705		0.8897
Never	43 (75.4)		17 (29.8)		37 (64.9)		14 (24.6)		13 (22.8)	
Once a week or less	29 (64.4)		13 (28.9)		25 (55.6)		9 (20.0)		9 (20.0)	
More than once a week	31 (73.8)		18 (42.9)		27 (64.3)		8 (19.1)		8 (19.1)	
Witnessed 2008 flood		0.2475		0.7271		0.2380		0.8287		0.3590
No	33 (78.6)		15 (35.7)		29 (69.1)		**9 (21.4)**		11 (26.2)	
Yes	72 (69.2)		34 (32.7)		61 (58.7)		**24 (23.1)**		20 (19.2)	
House damaged in 2008 flood		0.4429		0.8324		0.1125		0.5480		0.0896
No	**70 (70.0)**		**33 (33.0)**		66 (66.0)		24 (24.0)		25 (25.0)	
Yes	**35 (76.1)**		**16 (34.8)**		24 (52.2)		9 (19.6)		6 (13.0)	
Distance of home from shore		0.5379		0.6137		0.3753		0.6038		0.0719
Far from shore	43 (67.2)		**20 (31.3)**		36 (56.3)		16 (25.0)		19 (29.7)	
Near shore	19 (76.0)		**8 (32.0)**		18 (72.0)		7 (28.0)		3 (12.0)	
Next to shore	40 (75.5)		**21 (39.6)**		33 (62.3)		10 (18.9)		8 (15.1)	

Table 2 (continued)

	Reports change of climate		Reports sea level rise		Reports increased temperature		Reports decreased rainfall		Reports altered seasons	
	N(%)	P value	N(%)	P value	N(%)	P value	N(%)	P value	N(%)	P value
Age		0.1334		0.1756		0.3589		0.2951		**0.0000**
Young adults (18–29)	**21 (60.0)**		**8 (22.9)**		22 (62.9)		10 (28.6)		**1 (2.9)**	
Adults (30–49)	**44 (72.1)**		**20 (32.8)**		41 (67.2)		10 (16.4)		**7 (11.5)**	
Elderly (50–84)	**40 (80.0)**		**21 (42.0)**		27 (54.0)		13 (26.0)		**23 (46.0)**	
Gender		0.5407		**0.0080**		0.9591		0.9438		**0.0160**
Female	52 (74.3)		**16 (22.9)**		43 (61.4)		16 (22.9)		**9 (12.9)**	
Male	53 (69.7)		**33 (43.4)**		47 (61.8)		17 (22.4)		**22 (29.0)**	

Reception Variables 'Can define "climate change"' was related to all outcome variables, with those who could define 'climate change' much more likely to report environmental change. For instance, 80.5 % of those who could define 'climate change' reported increased temperature, whereas only 40.6 % who could not define it reported increased temperature. This effect was statistically significant in all but one case. 'Can explain causation of "climate change"' was related to all outcome variables, with those who could give some account of the scientific causation of climate change much more likely to report all categories of environmental change. For instance, 46.3 % of those who could explain the causation of 'climate change' reported sea level rise, while only 28.6 % of those who could not explain it reported sea level rise. This effect was statistically significant in three out of five cases. In general, 'Has attended climate change educational session' was related to outcome variables, with those who had attended somewhat more likely to report environmental change in three out of five categories. For instance, 86.7 % of those who had attended a session answered that the climate had changed, while only 70.2 % of those who had not attended a session answered that the climate had changed. However, this effect was not statistically significant. In general, 'Years of education' was not related to outcome variables. However, in one case, that of sea level rise, a relation was found: the more educated were much more likely to report sea level rise, and this effect was significant. The relation of 'Can define "climate change"' and 'Can explain causation of "climate change"' to outcome variables is shown in Figs. 1 and 2.

Observation Variables In general, 'Frequency of fishing/food-gathering on reef', 'Witnessed 2008 flood', 'House damaged in 2008 flood', and 'Distance of home from shore' were unrelated to outcome variables. In general, age was related to outcome variables, with older people more likely to report environmental change than younger people. However, this gradient was found in only three out of five outcome variables. For instance, 22.9 % of young adults reported sea level rise, while 32.8 % of adults did so, and 42.0 % of the elderly did so. However, this relationship was statistically significant in only one case, that of altered seasons. Gender was related to reports of environmental change: in two cases (that of sea level rise and altered seasons) men were considerably more likely than women to report the change (for instance, 29.0 % of men reported altered seasons, while only 12.9 % of women did so), while in one case (change of climate), women were slightly more likely than men to report the change. This effect was significant in the case of men's increased reports of sea level rise and altered seasons. The relation of 'Gender' and 'Age' to outcome variables is shown in Figs. 3 and 4.

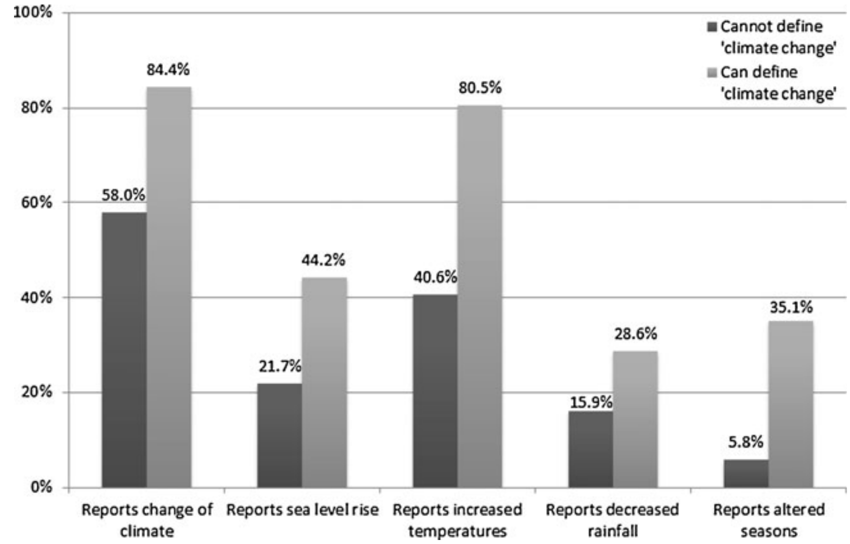


Fig. 1 Relation of the reception variable 'Can define "climate change"' to outcome variables

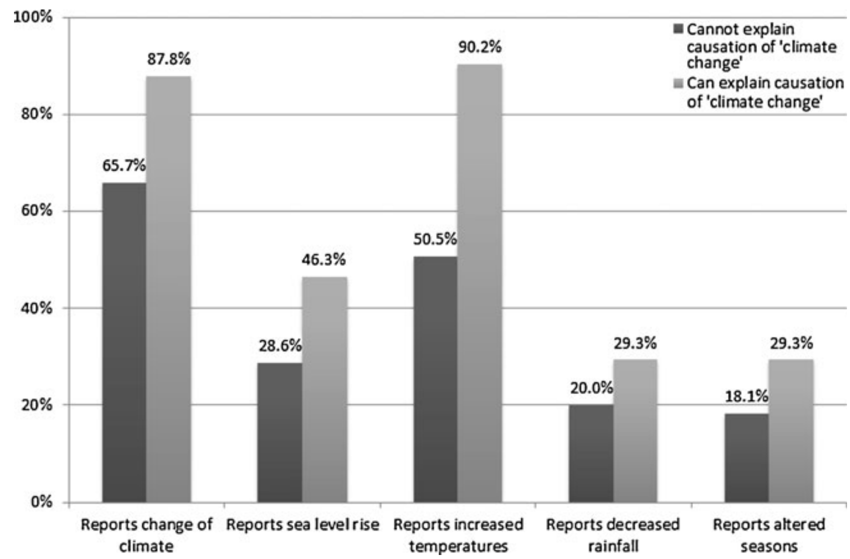


Fig. 2 Relation of the reception variable 'Can explain causation of "climate change"' to outcome variables

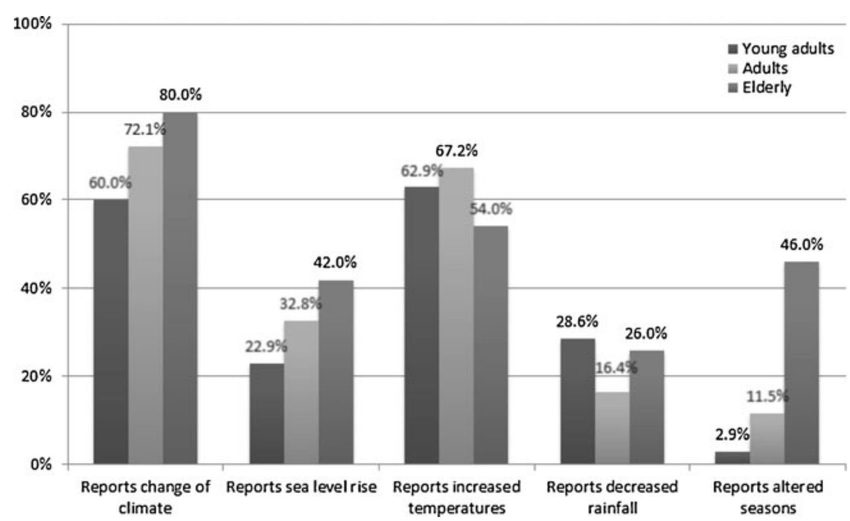
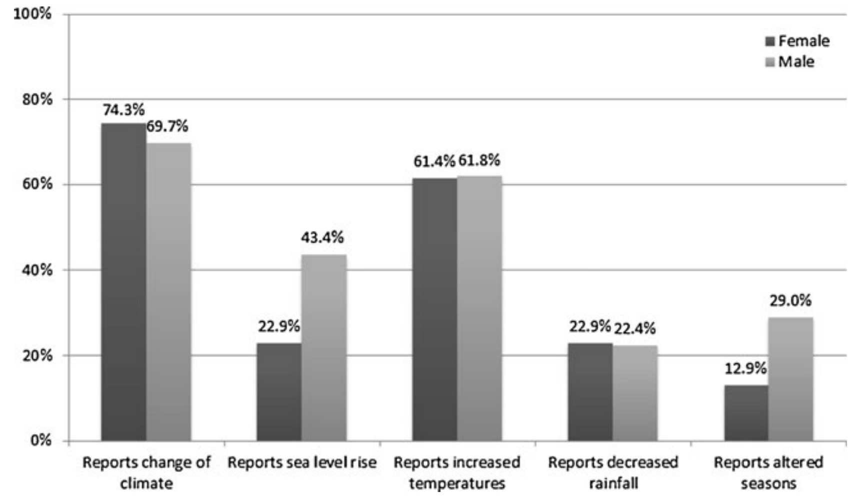


Fig. 3 Relation of the observation variable 'Age' to outcome variables

Fig. 4 Relation of the observation variable 'Gender' to outcome variables



Multivariable Analysis

A logistic regression analysis was performed for each outcome variable. Only the variables that showed statistical significance in bivariate analysis were entered into the regression model. (No regression analysis was performed for the outcome variable 'Reports decreased rainfall' because no independent variables were significantly correlated with it). The results of these analyses are shown in Tables 3, 4, 5, and 6, with statistically significant P values (at the 95 % level) indicated in bold. 'Can define "climate change"' was significant in all four outcome variables that were tested. 'Gender' was significant in the case of sea level rise, 'Can explain causation of "climate change"' in the case of increased temperature, and 'Age' in the case of altered seasons.

Discussion

This study found some evidence for the effect of observation on reports of environmental change. Age was a predictor of outcome variables. Older people were more likely to report a changed climate, sea level rise, and altered seasons; the relation in the final case was very robust. This is likely explained by the fact that older people have had more time to observe larger environmental changes.[4] Men were more likely than women to report sea level rise and altered seasons, with the first effect being very robust and the second only moderately so. In the first case one may surmise that men, spending more time engaging with the ocean, are more likely to observe sea level. Thus, using the observation proxies of age and gender, observation seems to play a large role in two categories of environmental change reports: sea level rise and altered seasons. However, the analysis found no compelling evidence of the influence of observation on reports of a changed climate, increased temperature, or decreased rainfall. In addition, there was no evidence that other proxies for observation—exposure to the 2008 flood, frequency of fishing or food-gathering on the reef, and the distance of the home from the shore—were related to reports of environmental change. The influence of observation is therefore only a sporadic, moderately strong, and moderately robust effect.

This study found much evidence for the effect of reception. Only moderately compelling evidence was found for the influence of the two more indirect measures of reception: years of education, and attendance at a climate change educational session. But strong evidence was found for the

Table 3 Logistic regression analysis of the outcome variable 'Reports change of climate'

	Odds ratio (CI 95 %)	*P* value
Can define 'climate change'	3.0 (1.2, 7.5)	**0.020**
Can explain causation of 'climate change'	1.8 (0.5, 6.1)	0.325

Statistically significant *P* values at the 95 % level are indicated in bold

[4] An alternate explanation is that elders report more environmental change not because they have observed more change but because they are more preoccupied, for other reasons, with societal change. But interview and ethnographic evidence, which I do not have the space to review here, would seem to refute this, as young and old are equally convinced of pervasive change. Moreover, if older people were reporting environmental change merely out of a prior conviction in change, one would expect their reports to be resolute, yet scattered and inconsistent; instead, we find that people's reports are remarkably consistent.

Table 4 Logistic regression analysis of the outcome variable 'Reports sea level rise'

	Odds ratio (CI 95 %)	*P* value
Can define 'climate change'	2.4 (1.0, 5.7)	**0.050**
Can explain causation of 'climate change'	1.2 (0.5, 3.0)	0.676
Gender	0.4 (0.2, 0.9)	**0.022**

Statistically significant *P* values at the 95 % level are indicated in bold

Table 6 Logistic regression analysis of the outcome variable 'Reports altered seasons'

	Odds ratio (CI 95 %)	*P* value
Age	1.1 (1.0, 1.1)	**0.000**
Gender	0.5 (0.2, 1.3)	0.165
Can define 'climate change'	12.2 (3.2, 46.3)	**0.000**

Statistically significant *P* values at the 95 % level are indicated in bold

influence of the more direct measures: ability to define, and ability to explain the scientific causation of, 'climate change'. By far the best predictor of reports of environmental change was ability to define the English phrase 'climate change'. This result is easily interpretable: as locals become aware of global warming discourses, they are told that local manifestations of this phenomenon are occurring and are encouraged to perceive them. Another explanation for this correlation is that the causation runs in the opposite direction: those who are convinced for other reasons that environmental change has occurred are more motivated to seek out information about climate science, for instance by attending educational sessions on climate change. But this hypothesis is refuted by the lack of correlation between reports of environmental change and attendance at climate change educational sessions.

In summary, both observation and reception appear to influence reports of environmental change, but reception more so. Science communication powerfully influences local reports of climate change impacts.

Implications

One implication that does *not* follow from this study—though it could easily be misconstrued to do so—is that Majuro residents are simply parroting what they hear in the media when they report local manifestations of global warming, and that therefore their reports (and by extension, perhaps, the reports of indigenous and frontline residents in general) are compromised, unreliable, or simply redundant. This interpretation is contradicted by the evidence that this study has found

Table 5 Logistic regression analysis of the outcome variable 'Reports increased temperature'

	Odds ratio (CI 95 %)	*P* value
Can define 'climate change'	2.9 (1.2, 6.9)	**0.016**
Can explain causation of 'climate change'	3.7 (1.1, 12.9)	**0.039**
Years of education	1.5 (0.8, 2.8)	0.179

Statistically significant *P* values at the 95 % level are indicated in bold

for the influence (however moderate) of observation, and the fact that some subjects who were completely unaware of the scientific notion of climate change nonetheless reported change consistent with it. It is also contradicted by the fact that, in survey answers as well as open-ended interviews, Majuro residents report environmental change in much more specificity and detail than the climate change science they are exposed to (as is clearly shown in the 'Qualitative results' section). For instance, they point not only to general sea level rise but to specific distributions, patterns, and impacts of erosion. Thus Marshallese observation of the environment is genuine and informative even if strongly influenced by science communication (see Marin and Berkes 2013).

This study refutes assumptions of 'traditional' or 'local' ecological knowledge as static, hermetically sealed, or categorically distinct from foreign scientific knowledge. I am by no means the first to make such a claim (see Agrawal 1995; Barsh 2000; Fulsås 2007; Iskandar and Ellen 2007; Suarez and Patt 2004), but I know of no other quantitative demonstration of the openness of 'local' ecological knowledge. This finding also demonstrates that in at least one frontline indigenous community, the *idea* of climate change is currently more powerful, in a sense, than the physical impacts; others have speculated at this (Hulme 2009: 328; Moser 2010: 36; Swim *et al.* 2009: 91), but quantitative confirmation has never before been furnished. This study also shows that, even among indigenous communities known for keen awareness of local environmental conditions, reports of climatic change may be strongly mediated by prior expectations; this has been demonstrated in Western populations (Kupperman 1982; Weber 1997), but less frequently investigated in indigenous contexts. Studies of local climate change perceptions must take to heart the fact that indigenous environmental reports, while genuine, informative, and largely reliable, are not perfectly 'pure'; yet this point is frequently neglected by journalistic, activist, and scholarly writings that treat local reports of climatic alteration unproblematically as 'indigenous observations of climate change' (Nuttall 2009). While psychologists (Swim *et al.* 2009) and geographers (Bravo 2009) seem well aware of reception's influence, anthropologists often persist in focusing, sometimes exclusively, on observation (Rudiak-Gould 2011); some anthropologists have even argued explicitly against studying reception (Marino and Schweitzer 2009) or taking seriously its influence on indigenous reports of climate change (Marin and Berkes 2013). In any community intensively exposed to the scientific discourse of climate change, such an approach is untenable.

This study also points to a rationale for climate science communication in indigenous and frontline communities. It is obvious that such dissemination may be useful for informing locals of the global, anthropogenic, technological origins of climate change; for absolving small communities of responsibility for causing the problem; for offering long-term climatic predictions on a time scale beyond that of local ecological knowledge; for suggesting adaptation measures unfamiliar to locals; and (perhaps most importantly) for initiating the scientist-citizen or Western-indigenous dialogues that are so needed for both practical and philosophical engagement with climate change (Leduc 2011). What is less obvious is that such communication may also help communities to perceive changes already afoot in their local environments. Attuning citizens to burgeoning climate change impacts that might go unremarked upon may be important in low-lying communities like Majuro where future prognoses are extremely severe yet present impacts are, thus far, only moderate. If such a suggestion sounds paternalistic, it is important to note that in most cases the communicators can, and should, themselves be locals—as climate change communicators in the Marshall Islands usually are. If the suggestion appears to denigrate indigenous environmental expertise, it is important to note that science communication is just one half of the necessary dialogue; that climate change impacts are not yet dramatic in all areas, even those considered highly vulnerable; that gradual changes like sea level rise are hugely obscured by fluctuations on the daily, monthly, yearly, and inter-yearly level; and that frontline communities have much else besides climate change to concern themselves about (in Majuro, the salience and concern-worthiness of a moderate rise in sea level, occurring over decades, pales in comparison to a month-to-month rise in the cost of rice). This particular value of climate change communication has been entirely neglected in the literature, and implicitly dismissed by scholarly, journalistic, and activist writings that emphasize the ability of indigenous actors to perceive local climate change impacts, recognize them as concern-worthy, and proactively respond to them, with no need for a citizen-scientist dialogue (see for instance Cherrington 2008). If this study's findings are extendable beyond Majuro, climate change communication is even more, and more widely, important than we have realized.

Acknowledgments The author acknowledges Josepha Maddison and Iroij Mike Kabua for granting fieldwork permission; the many Marshall Islanders who agreed to participate; and Vahid Ravaghi and Nassim Mojaverian for assistance with quantitative analysis. Various phases of research were supported by the Andrew W. Mellon Foundation; Dr. Alun Hughes; Oxford University; All Souls College, Oxford; St. Hugh's College, Oxford; Jesus College, Oxford; and the Institute of Social and Cultural Anthropology, Oxford.

References

Agrawal, A. (1995). Dismantling the Divide Between Indigenous and Scientific Knowledge. Development and Change 26(3): 413–439.

Australian Government (2011). Current and future climate of the Marshall Islands. International Climate Change Adaptation Initiative/Pacific Climate Change Science Program/Australian AID/Australian Bureau of Meteorology/Australian Department of Climate Change and Energy Efficiency/CSIRO/Marshall Islands National Weather Service. http://www.cawcr.gov.au/projects/PCCSP/pdf/8_PCCSP_Marshall_Islands_8pp.pdf. Accessed 13 June 2012.

Barnett, J., and Adger, W. N. (2003). Climate Dangers and Atoll Countries. Climatic Change 61: 321–337.

Barsh, R. L. (2000). Taking Indigenous Science Seriously. In Bocking, S. (ed.), Biodiversity in Canada: Ecology, Ideas and Action. Broadview, Peterborough, pp. 153–173.

Bravo, M. T. (2009). Voices from the Sea Ice: The Reception of Climate Impact Narratives. Journal of Historical Geography 35(2): 256–278.

Byg, A., and Salick, J. (2009). Local Perspectives on a Global Phenomenon: Climate Change in Eastern Tibetan Villages. Global Environmental Change 19(2): 156–166.

Cherrington, M. (2008). Indigenous Peoples and Climate Change. Cultural Survival Quarterly 32(2): 10–12.

Connell, J. (2003). Losing Ground? Tuvalu, the Greenhouse Effect and the Garbage Can. Asia Pacific Viewpoint 44(2): 89–107.

Crate, S. A. (2008). Gone the Bull of Winter? Grappling with the Cultural Implications of and Anthropology's Role(s) in Global Climate Change. Current Anthropology 49(4): 569–595.

Crate, S. A., and Nuttall, M. (eds.) (2009). Anthropology and Climate Change: From Encounters to Actions. Left Coast Press, Walnut Creek.

Ford, M. (2012). Shoreline Changes on an Urban atoll in the Central Pacific Ocean: Majuro Atoll, Marshall Islands. Journal of Coastal Research 279(1): 11–22.

Freedom Report (2009). International religious freedom report 2009. Bureau of Democracy, Human Rights, and Labor. http://www.state.gov/g/drl/rls/irf/2009/127278.htm. Accessed 14 February 2011.

Fulsås, N. (2007). What did the Weather Forecast do to Fishermen, and What did Fishermen do to the Weather Forecast? Acta Borealis 24(1): 1–25.

González, L. E., and da Silveira, P. (1997). The People's Attitudes Towards Global Environmental Phenomena: A Case Study. Climate Research 9: 95–100.

Hitchcock, R. K. (2009). From Local to Global: Perceptions and Realities of Environmental Change Among Kalahari San. In Crate, S. A., and Nuttall, M. (eds.), Anthropology and Climate Change: From Encounters to Actions. Left Coast Press, Walnut Creek, pp. 250–261.

Hulme, M. (2009). Why We Disagree about Climate Change: Understanding Controversy. Inaction and Opportunity. Cambridge University Press, Cambridge.

Iskandar, J., and Ellen, R. (2007). Innovation, 'Hybrid' Knowledge and the Conservation of Relict Rainforest in Upland Banten. In Ellen, R. (ed.), Modern Crises and Traditional Strategies: Local Ecological Knowledge in Island Southeast Asia. Berghahn, Oxford, pp. 133–142.

Jacka, J. (2009). Global Averages, Local Extremes: The Subtleties and Complexities of Climate Change in Papua New Guinea. In Crate, S. A., and Nuttall, M. (eds.), Anthropology and Climate Change: From Encounters to Actions. Left Coast Press, Walnut Creek, pp. 197–208.

Kench, P., Owen, S., Resture, A., Ford, M., Trevor, D., Fowler, S., Langrine, J., et al. (2011). Improving understanding of local-scale vulnerability in atoll island countries: Developing capacity to improve in-country approaches and research. Final report to the Asia-Pacific Network for Global Change Research. http://www.apn-gcr.org/resources/archive/files/c54841d9632f99c90e37bb8e8fc208e6.pdf. Accessed 24 January 2013.

Krupnik, I., and Jolly, D. (eds). (2002). The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Arctic Research Consortium of the United States & Arctic Studies Center, Smithsonian Institution.

Kupperman, K. (1982). The Puzzle of the American Climate in the Early Colonial Period. The American Historical Review 87(5): 1262–1289.

Lahsen, M. (2007). Trust through Participation? Problems of Knowledge in Climate Decision-Making. In Pettenger, M. E. (ed.), The Social Construction of Climate Change: Power, Knowledge, Norms, Discourses. Ashgate, Aldershot, pp. 173–196.

Leduc, T. B. (2011). Climate, Culture, Change: Inuit and Western Dialogues with a Warming North. University of Ottawa Press.

Marin, A., and Berkes, F. (2013). Local people's Accounts of Climate Change: To What Extent are They Influenced by the Media? Wiley Interdisciplinary Reviews: Climate Change 4(1): 1–8.

Marino, E., and Schweitzer, P. (2009). Talking and Not Talking About Climate Change in Northwestern Alaska. In Crate, S. A., and Nuttall, M. (eds.), Anthropology and Climate Change: From Encounters to Actions. Left Coast Press, Walnut Creek, pp. 209–217.

Marx, S., Weber, E. U., Orlove, B., Leiserowitz, A., Krantz, D., Roncoli, C., and Phillips, J. (2007). Communication and Mental Processes: Experiential and Analytic Processing of Uncertain Climate Information. Global Environmental Change 17(1): 47–58.

Mortreux, C., and Barnett, J. (2009). Climate Change, Migration and Adaptation in Funafuti, Tuvalu. Global Environmental Change 19(1): 105–112.

Moser, S. C. (2010). Communicating Climate Change: History, Challenges, Process and Future Directions. Wiley Interdisciplinary Reviews: Climate Change 1: 31–53.

Nuttall, M. (2009). Living in a World of Movement: Human Resilience to Environmental Instability in Greenland. In Crate, S. A., and Nuttall, M. (eds.), Anthropology and Climate Change: From Encounters to Actions. Left Coast Press, Walnut Creek, pp. 292–310.

Petheram, L., Zander, K. K., Campbell, B. M., High, C., and Stacey, N. (2010). 'Strange changes': Indigenous Perspectives of Climate Change and Adaptation in NE Arnhem Land (Australia). Global Environmental Change 20(4): 681–692.

Rudiak-Gould, P. (2011). Climate Change and Anthropology: The Importance of Reception Studies. Anthropology Today 27(2): 9–12.

Spennemann, D. H. R. (1996). Non-Traditional Settlement Patterns and Typhoon Hazard on Contemporary Majuro Atoll, Republic of the Marshall Islands. Environmental Management 20(3): 337–348.

Suarez, P., and Patt, A. G. (2004). Caution, Cognition, and Credibility: The Risks of Climate Forecast Application. Risk Decision and Policy 9: 75–89.

Swim, J., Clayton, S., Doherty, T., Gifford, R., Howard, G., Reser, J., Stern, P., and Weber, E. U. (2009). Psychology and global climate change: Addressing a multi-faceted phenomenon and set of challenges. http://www.apa.org/science/about/publications/climate-change-booklet.pdf. Accessed 29 February 2012.

Weber, E. U. (1997). Perception and Expectation of Climate Change: Precondition for Economic and Technological Adaptation. In Bazerman, M. H. (ed.), Environment, Ethics, and Behavior: The Psychology of Environmental Valuation and Degradation. New Lexington Press, San Francisco, pp. 314–341.

West, C. T., and Vásquez-León, M. (2003). Testing farmers' Perceptions of Climate Variability: A Case Study from the Sulphur Springs Valley, Arizona. In Orlove, B., and Strauss, S. (eds.), Weather, Climate, Culture: Building Anthropological Bridges from Past to Future. Berg, Oxford, pp. 233–247.

CIA World Factbook (2013). Marshall Islands. https://www.cia.gov/library/publications/the-world-factbook/geos/rm.html. Accessed 18 February 2013.

BBC World Service Trust (2010). Africa Talks Climate research report: Executive summary. http://africatalksclimate.com/sites/default/files/01-Executive%20Summary.pdf. Accessed 23 February 2011.

Xue, C. (2001). Coastal Erosion and Management of Majuro Atoll, Marshall Islands. Journal of Coastal Research 17(4): 909–918.