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Adaptation behavior in the face of global climate change: Survey responses from experts and decision makers serving the Florida Keys

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ABSTRACT

We conduct a survey to elicit responses from experts and decision makers serving the Florida Keys regarding vulnerability to global climate change. Study findings reveal deep concern among federal, state and local experts and decision makers about adverse impacts at the local level. A large majority of respondents recognize the increasing likelihood of dynamic, potentially irreversible, socioeconomic and ecological repercussions for the Florida Keys. However, very few experts and decision makers report that their respective agencies have developed formal adaptation plans. Respondents identify significant institutional and social barriers to adaptation and convey their support for a host of strategic measures to facilitate adaptation on an urgent basis. The implications of our findings are discussed in the context of enhancing adaptive capacity and resilience in the Florida Keys and beyond. Information generated from this study can provide functional guidance for improving decision-support systems and promoting adaptation policies.

1. Introduction

Global climate change poses unprecedented challenges for the long-term sustainability of the Florida Keys, the third largest barrier reef in the world. The combination of accelerating sea-level rise, extreme hydro-meteorological events, changing oceanic conditions, and other adverse impacts threatens the resilience of this unique socio-ecological system(Bender et al., 2010; Vermeer and Rahmstorf, 2009; Hoegh-Guldberg et al., 2007). Slivers of land amidst some 20 national parks, wildlife refuges and marine sanctuaries, state parks, ecological reserves, botanical sites, aquatic preserves and marine protected areas, the Florida Keys provide unique insights on the emerging challenges associated with climate change adaptation.[1]

Climate change is already impacting the Florida Keys. Over the past 12 years, hard coral cover has declined on average by 44% and populations of reef fish have been largely depleted due to mass coral bleaching (Donahue et al., 2008).[2] Saltwater intrusion from the rising sea and recurring pulse disturbances (e.g., tropical cyclones and fire) have dramatically reduced globally imperiled Pine Rockland communities, including critical freshwater habitat for numerous endemic endangered species (Ross et al., 2008). Accelerating sea-level rise is projected to inundate public lands and private property alike, with potentially severe ecological and economic repercussions (Bigano et al., 2008).

A multibillion dollar, nature-based tourism economy, with average elevations less than 1.5 m above sea-level, the Florida Keys are on the frontline of the climate crisis (Donahue et al., 2008). Frequent threats from tropical cyclones and relative isolation from the mainland add to a host of factors that result in the region's vulnerability to climate change. Conventional adaptation measures will not preclude significant impacts (Adger et al., 2005a). For instance, highly porous limestone geology will limit the effectiveness of widespread use of levees and dikes to wall off the rising sea (MDCATF, 2007). In the face of increasing vulnerability, novel decision-making criteria, regulatory mechanisms and institutional structures must be pursued for coastal communities to adapt (NRC, 2009; Smith et al., 2009).

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[1] The U.S. President Theodore Roosevelt considered the Florida Keys "as valuable as Yellowstone or the Grand Canyon," establishing some of the nation's first preserves here (Brinkley, 2009).

[2] Staghorn coral have declined by 73% and Elkhorn coral by 37%, the major building blocks of reef systems (Bruckner and Hourigan, 2002; Maliao et al., 2008). Bleaching events both in terms of frequency and severity and ocean acidification will likely accelerate the loss of coral reefs (Shinn, 2008; Wooton et al., 2008).

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A major information-action gap has emerged in our understanding of climate change and how to proceed with adaptation (Hansen, 2007). Moving from risk assessments to pragmatic adaptation measures requires cognitive and behavioral changes, at the individual and institutional level, involving the general public and experts and decision makers in various sectors (Berkhout et al., 2006). Our objective is to understand adaptation behavior among experts and decision makers serving coastal communities on the frontline of climate change. Links between on-site experience, risk perceptions, knowledge tied to climate change and sea-level rise, perceived adaptive capacity and willingness to support adaptation measures can provide functional guidance for enhancing local resilience in the Florida Keys and vulnerable coastal communities worldwide. Against this backdrop, we analyze how experts and decision makers serving the Florida Keys (federal, state, regional and local administrative and management personnel, environmental specialists, engineers, policymakers, planners and community leaders) are anticipating and responding to these challenges.

2. Background

The Florida Keys are an archipelago of some 1700 islands, stretching 354 km south-southwest away from the Florida peninsula, terminating at the Dry Tortugas (see Fig. 1). The islands consist of Pleistocene limestone, covering a land area of roughly 355 square kilometers. The islands have a tropical climate, and most rainfall is concentrated between May and October (Lidz et al., 2008). The Florida Keys are adjacent to the third largest barrier reef in the world, extending over 480 km. The reef contains more marine species than any other region in the U.S., including approximately 100 species of corals and 400 species of fish (Donahue et al., 2008).[3] The islands also provide nesting sites for five species of endangered sea turtles, and habitat for over 250 avian species.

The Florida Keys are mostly located in Monroe County, the southernmost county in the continental U.S. The Overseas Highway connects the 42 inhabited islands. Approximately 80,000 residents (35,000 households) live in the Florida Keys, with roughly one-third living on the island of Key West (U.S. Census Bureau Summary Files, 2000). The Florida Keys host four million seasonal visitors and tourists annually (Donahue et al., 2008).

In the absence of improvements in coastal protection, a 15 cm rise in sea level could incur significant damage in the Florida Keys, approximating $1 billion in property values at risk (Harrington and Walton, 2008). Damage estimates as high as $14 billion (48,973 housing units and inundation of 99.6% of land) have been projected for a 0.7 m sea-level rise (Stanton and Ackerman, 2007). The Florida Keys are also located in the prime Atlantic hurricane-forming region where hurricanes present recurrent threats to the ecology and economy. Harrington and Walton (Harrington and Walton, 2008) calculate that a Category 2 hurricane with a sea-level rise of 0.6 m could generate a 60% increase in damages in the Florida Keys.

As greater losses from floods and storms (in Florida and beyond) lead to increases in government spending and insurance premiums, there are significant financial risks to insurance and reinsurance agencies. These risks threaten to cost taxpayers billions of dollars. We are already seeing the withdrawal of coverage by private insurers in Florida, the Gulf Coast and Northeast U.S. (U.S. Government Accountability Office, 2007; Mills, 2009). As a result of a 1-m rise in sea-level and more intense tropical cyclone activity, the U.S. could face annual costs of $123 billion by 2050 and up to $782 billion by 2100, with Florida accounting for 20% of these costs (Ackerman and Stanton, 2008). Titus et al., 2009 calculate that more than 80% of land below 1-m in Florida is developed or intermediate (places with existing low-density development, where land use plans anticipate future development), compared with 45% of land from Georgia to Delaware (Titus et al., 2009).

The vulnerability posed by climate change demands careful risk assessment and anticipatory adaptation policies (Pielke, 2007). Recent climate related observations (e.g., rising temperatures, accelerated melting of glaciers and ice sheets, thermal expansion of the oceans) signal that a decisive shift in Earth's climate is well underway. New greenhouse gas emissions abatement strategies will *not* prevent significant changes in the global climate (Solomon et al., 2009; Rahmstorf et al., 2008). Social and cognitive factors in decision-making under uncertainty may shape how coastal communities adapt, more profoundly than direct physical impacts (Grothmann and Patt, 2005). There is increasing concern that by the time we recognize the need to prepare, on the scale required, the time to act effectively may have passed. Enhancing local capacity-building (through scientific knowledge, resilience, and outreach) must be at the center of adaptation initiatives to reduce vulnerability(Adger et al., 2005b; Vogel et al., 2007). The adverse effects of climate change have the potential to exceed the absorptive capacity of numerous coastal social-ecological systems, negatively affecting public health and the economy, in potentially irreversible ways that reverberate well beyond the coast. Delayed adaptation will reduce the effectiveness of responses (Bigano et al., 2008; Stanton and Ackerman, 2007).

3. Risk perception and adaptation behavior

In this context, the underlying challenge for experts and decision makers is to identify locations with greatest risk exposure and critical thresholds beyond which social-ecological systems collapse (Grothmann and Patt, 2005). However, an individual's sense of risk in the context of place and/or community, concern for local environmental issues, civic involvement and working and living experience can play critical roles in shaping their decisions (Adger et al., 2005b). Earlier studies indicate that willingness to support climate change measures largely depends on people's risk perceptions (Vogel et al., 2007). The stronger one's perception that climate change poses a substantial risk and the stronger their emotional reactions to the risk, the greater is their willingness-to-pay for mitigation (Barnett & Adger, 2003; Hess et al., 2008). However, different psychological and sociological factors trigger concerns and worries for different people, including for experts and decision makers (e.g., personal experience, knowledge, values, morals, culture, and worldviews) (Sundblad et al., 2007).[4]

The vast majority of climate change surveys have focused on concerns of the general public. While these surveys reflect public opinions, they have limitations for guiding policies because of the public's lack of knowledge, experience, and/or limited interests in complex issues like climate change (Cameron, 2005; Sunstein, 2006).[5] Similar surveys have not adequately investigated the

[3] The reef is the foundation of a $6 billion/year revenue stream(Gibson et al., 2008; Palandro et al., 2008). It is the number one scuba diving destination in the U.S. and one of the five most popular in the world. The commercial fishing industry harvests 10 million pounds of seafood and marine products annually (Donahue et al., 2008).

[4] Observations from own experiences and information from other's description can lead to very different choices and decisions (Weber et al., 2002; Leiserowitz, 2006). Beyond scientific information of climate risk, perceptions are influenced by a variety of psychological and social factors (Marx et al., 2007).

[5] Although public perception of global warming and climate change is evolving, the risk continues to be perceived as a spatially and temporally distant and impersonal threat when compared with acts of terrorism or economic crisis (Hertwig et al., 2004). A study by Oak Ridge Center for Advanced Study (Bostrom, 1997) concludes that future climate change research should focus on answering the questions of experts and decision makers at the local and regional scale.

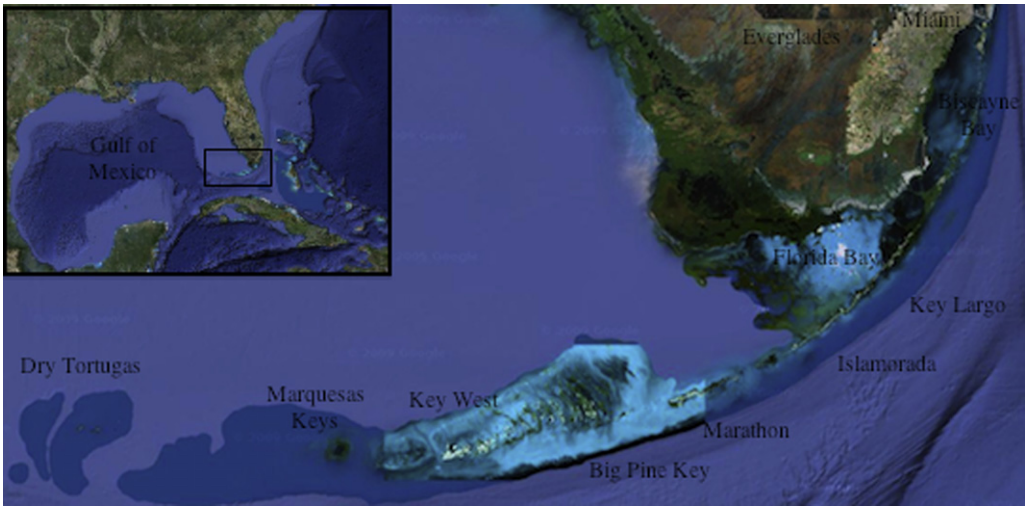

Fig. 1. Map of the Florida Keys and Surrounding Areas

perceptions of local experts and decision makers regarding risk exposure in their jurisdictions, specifically the potential for reducing risk associated with accelerating sea-level rise or adaptation behavior in general. Only a hand-full of expert surveys have been conducted on the links between risk perceptions, experience, and adaptation behavior in the context of climate change (APA, 2009). The limited ability of public surveys to evaluate institutional resource and information needs provides further rationale for collecting responses from experts and decision makers in the current study.

4. Methodology and survey implementation

We designed an online survey addressing the management challenges of the natural and built environments in the Florida Keys (e.g., loss of coral reefs, sea-level rise, more frequent flooding, degraded ecosystems, property loss, impacts on tourism etc.).[6] Experts and decision makers were asked a series of attitudinal, behavioral, and socio-demographic questions. Survey questions consisted of multiple-choice, rating scales, check all, and open-ended formats (a copy of the survey is available upon request). Before implementation, the survey was extensively tested over a four-month period.

Following extensive research and consultations with multiple groups of local stakeholders and key informants, a list of relevant personnel at all levels of government agencies, non-governmental organizations (NGO's) and private research institutions were identified, and mail addresses (where available) were obtained.[7] In total mailing addresses of 807 experts and decision makers from local municipalities, facilities and institutions from 11 unincorporated islands and areas (e.g., Key Largo Wastewater Treatment District), Monroe County, state and federal agencies, private research institutions, and NGO's (e.g., Audubon Society) were compiled. They were contacted by mail beginning in early June (2008), and invited through a brief letter listing the website location to anonymously complete the online survey. A follow-up postcard was mailed after two weeks. In addition, 590 email addresses were obtained (542 email addresses from the original 807 who received mailings as well as 48 email addresses of personnel for whom no mailing address were available). Two email reminders were sent during the first and third weeks of July 2008. Of the 855 invitations, 10 requests were returned with bad addresses. Adjusted for undeliverable solicitations, the overall response rate was 26%, with 225 usable responses received over 56 days.[8]

Experts and decision makers in our sample show substantial variations in their affiliations: 9.6% federal, 17.6% state; 18.1% county; 21.8% municipal; 23.9% NGOs; 9.0% private research labs. In terms of profession types, 26.6% in environmental science, 27.7% in administration and management, 16.3% planning, zoning, permitting and code enforcement, 12.0% emergency management and social services, 8.1% engineering, 9.3% as others. The average number of years of experience in their current profession was nearly 15 years, and the average number of years employed in the Florida Keys was nearly 13 years.

5. Survey results

We present the definitions and descriptive statistics of key variables of survey responses in Table 1. Experts and decision makers participated in the survey were initially presented with four general statements about the reality of climate change, impacts, and potential response options. Respondents expressed strong consensus about the reality of climate change and impacts. However, they were less certain when it came to finding solutions to mitigate or avoid impacts. The climate change impacts question was read as follows:

Please indicate your level of agreement with each of the following statements regarding climate change on a scale from 1 to 5 (where 1 is strongly disagree, 2 is slightly disagree, 3 is slightly agree, 4 is strongly agree, 5 is not well informed).

[6] All of the Florida Keys in Monroe County, including the uninhabited Marquesas Keys (protected under Key West National Wildlife Refuge) and Dry Tortugas were included in the study. The Keys in Miami-Dade County were not included, nor was mainland Monroe County.

[7] These included personnel involved in administration and management, environmental science, planning, zoning, permitting, code enforcement, emergency management, social services, engineering and public works.

[8] Experts and decision makers contacted to complete the survey were from organizations such as the National Oceanographic and Atmospheric Administration, Environmental Protection Agency, National Weather Service, U.S. Fish and Wildlife Service, Army Corps Of Engineers, National Parks Service, Florida Fish and Wildlife Conservation Commission, South Florida Water Management District, Florida Department of Environmental Protection, Florida Keys Aqueduct Authority, Monroe County, City of Key West, Village of Islamorada, The Nature Conservancy, Audubon Society, Reef Relief, Mote Tropical Research Laboratory, Marine Lab.

Table 1
Variable Definitions and Descriptive Statistics.

Variable	Description	N	Mean	SD	Min	Max
Overall Impact	Respondents rate 'climate change is real and impacts are being felt today' (1–4; 1. Strongly disagree, 2. Slightly disagree, 3. Slightly agree, 4. Strongly agree).	210	3.53	0.75	1	4
Economic Impact	Respondents rate the credibility of a significant sea-level rise as an economic threat to the Florida Keys (0–10; 0 is not credible at all and 10 is highly credible).	207	7.55	2.84	0	10
Concern	Respondents concern about climate change in the Florida Keys (0–10; 0 is not concerned at all and 10 is highly concerned).	213	7.65	2.62	0	10
Household Concern	Respondents concern about climate change on household well-being (e.g. health, finances, property), (0–10; 0 is not concerned at all, 10 is highly concerned).	212	6.86	2.74	0	10
Insurance	Respondents rate likelihood of 'higher insurance premiums' in the Florida Keys due to climate change (0–10; 0 is very unlikely, 10 is highly likely).	204	8.75	1.77	0	10
Abandon	Respondents rank the likelihood of 'abandoning parts of the Florida Keys to rising seas by 2050' (0–10; 0 is very unlikely and 10 is highly likely).	206	6.00	2.92	0	10
Reef Loss	Respondents rate likelihood of 'massive loss of coral reefs' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	207	7.86	2.45	0	10
Property Loss	Respondents rate the likelihood of 'private property loss' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	204	7.44	2.57	0	10
Flooding	Respondents rate the likelihood of 'more frequent flooding' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	206	7.34	2.60	0	10
Hurricane Intensity	Respondents rate likelihood of 'more destructive hurricanes' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	207	7.17	2.47	0	10
Land Loss	Respondents rate likelihood of 'permanent loss of public land' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	201	7.09	2.76	0	10
Hurricane Frequency	Respondents rate likelihood of 'more frequent hurricanes' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	203	6.44	2.77	0	10
Tourism Loss	Respondents rate likelihood of 'loss of tourism revenues' in the Florida Keys as a result of climate change (0–10; 0 is very unlikely and 10 is highly likely).	206	6.85	2.77	0	10
Age	Respondent's age (1–6; 1. 18–24, 2. 25–34, 3. 35–44, 4. 45-–54, 5. 55–64, 6. 64+).	187	3.84	1.25	1	6
Gender	Respondent's gender (1 if respondent is male, 0 otherwise).	185	0.59	0.49	0	1
Education	Respondent's highest level of education completed (1–8; 1. Less than 12th grade, no diploma, 2. High school graduate or equivalent, 3. Some college, no degree, 4. Associates 5. Bachelor, 6. Masters 7. Professional degree, 8. Doctorate).	185	5.01	1.49	1	8
Profession	Respondent's profession (1–5; 1. Environmental specialist, 2. Administration, management, 3. Planning, enforcement, public works, engineering, 4. Elected office, community development, social and emergency services 5. Other).	184	2.60	1.33	1	5
Affiliation	Respondent's affiliation (1–6; 1. Federal (e.g., NOAA), 2. State (e.g., FL Dept. of Environmental Protection), 3. County, 4. NGO (e.g., Nature Conservancy), 5. Private research institution (e.g., Mote Lab), 6. Municipalities (e.g., Key West).	188	3.71	1.62	1	6
Experience	Respondent's number of years employed in the current profession.	184	14.90	11.23	0	50

A. Climate change is real and impacts are being felt today.
B. Climate change is real and we will experience impacts within 30 years.
C. Climate change is real and impacts are unavoidable no matter how we respond.
D. Climate change is real but we will find solutions to mitigate the impacts.

Over 91% of experts and decision makers reported their agreement with the statement "climate change is real and impacts are being felt today". Over 90% of respondents agreed that "climate change is real and we will experience impacts within 30 years". Regarding responses and solutions to these issues, experts and decision makers revealed much less of a consensus. Given the statement "climate change is real but we will find solutions to mitigate the impacts," 61.4% of respondents agreed, 37.0% disagreed. Moreover, given the statement "climate change is real and impacts are unavoidable no matter how we respond," 52.0% of experts and decision makers agreed, 45% disagreed. While there is little variation among respondents about the reality of climate change, there is wide variation in finding solutions to reduce impacts.

Survey responses reveal deep concern among experts and decision makers about the local impact of climate change and sea-level rise in the Florida Keys. Approximately 74.0% of respondents reported being highly concerned. Similarly, a large majority (72.5%) regarded a significant rise in sea level as a highly credible economic threat to the Florida Keys. A majority of respondents (60.8%) reported that they were highly concerned about likely impacts on local household well-being (i.e., health, finances and property).[9]

Experts and decision makers were asked to assess probable occurrence of fourteen adverse ecologic and socioeconomic impacts in the Florida Keys as a consequence of climate change and sea-level rise. Approximately 74.4% ranked massive loss of coral reefs in the Florida Keys as the most likely impact. Similarly, large majorities considered degraded ecosystems and habitat loss highly likely (73.0%), species loss and extinction highly likely (71.9%) and beach loss highly likely (71.7%). A large majority of experts and decision makers also considered private property loss highly likely (70.0%), more frequent flooding highly likely (68.4%), more destructive hurricanes highly likely (64.7%), permanent loss of public land highly likely (63.2%), and loss of tourism revenues highly likely (62.2%). A majority of experts and decision makers considered declines in fisheries highly likely (57.6%) and more frequent evacuations during hurricane season highly likely (54.8%). However, less than a majority of respondents (48.0%) think that abandonment of parts of the Florida Keys due to sea-level rise is

[9] Responses for concern were collapsed from a 0 to 10 scale into three categories (0–3 minimally concerned, 4–6 moderately concerned, and 7–10 highly concerned). For descriptive analysis (but not for regression analysis) similar recoding was applied to other variables with a 0–10 scale reported in Table 1. Experts and decision makers were given information from a recent study by Stanton and Ackerman (Harrington and Walton, 2008), which estimated the economic impact of a 0.7 m sea-level rise in the Florida Keys as high as $14 billion with inundation of 99.6% of land.

highly likely and only 40.0% ranked more frequent hurricane activity highly likely. Finally, most experts and decision makers (89.7%) considered higher insurance premiums highly likely in the Florida Keys as a result of climate change.

Survey responses reveal that experts and decision makers in the Florida Keys are currently operating with limited information and they lack a formal institutional framework necessary to shape and execute adaptation measures on an urgent basis. Such a framework should likely comprise (i) a network for monitoring key indicators of specific climate change impacts; (ii) a mechanism for coordinating activities among local, state, regional and federal government agencies with private and non-profit actors and outreach activities with the general public; and (iii) interagency collaboration for planning, evaluation and implementation of strategies to reduce socio-ecological impacts.

Respondents were then asked if their organization or agency had developed an adaptation action-plan (research, planning, and regulatory policies other than greenhouse gas mitigation, energy conservation, etc.) to minimize the immediate adverse impacts of climate change. Only 5% of Florida Keys' experts and decision makers acknowledged that their agency or organization had developed a climate change adaptation-action plan. Less than 5% reported updating documentation of elevations (including infrastructure and roadways) and flood risk maps. Less than 5% reported modeling sea-level rise projections coupled with storm surge risks; strengthening shoreline protection policies and regulations; modifying wetland conservation and restoration policies; or, incorporating climate change impact assessments in the master planning agenda. Less than 1% reported participating in community discussion, outreach activities or participating in broader state or federal climate change policy initiatives. No respondents (0%) reported conducting benefit-cost analyses for adaptation measures compared with the costs of inaction.

The Florida Keys face numerous barriers to adapt to climate change and sea-level rise. Experts and decision makers were presented with fourteen potential constraints to the development of new climate change policies (including social, informational, financial, institutional and legal constraints) and asked to assess their significance as barriers and/or limitations. Most respondents (84.4%) considered insufficient budget as the major constraint to the development of adaptation policies in the Florida Keys. Large majorities ranked lack of direction and leadership (79.5%), insufficient staff time and resources (76.5%), and lack of perceived importance to public officials (76.3%) as major constraints. A large majority of respondents also considered lack of assistance from State or Federal agencies (69.4%), lack of public demand to take action (69.1%), lack of a legal mandate that takes climate change impacts into account (68.4%), and lack of perceived solutions (68.1%) as major constraints to the development of adaptation policy measures. A majority of respondents also reported opposition from stakeholder groups (60.7%) as a major constraint.

Florida Keys experts and decision makers underscored the need for a variety of new types of information, training, organizational and financial inputs to implement adaptation measures. Survey responses indicate that most respondents (85.7%) support preparing now for the most likely scenario of climate change impacts, based on the best available information, and especially in long-term planning decisions. A large majority of respondents (75.3%) considered additional State and Federal funding and assistance highly useful to facilitate adaptation in the Florida Keys. A large majority also considered public workshops and training (71.6%), and better sharing of relevant expertise across departments and levels of government (71.1%) highly useful. A majority of decision makers ranked computational models projecting local and site-specific near term impacts highly useful (65.4%), the creation of a national disaster fund (64.1%), the creation of a Monroe County climate change task force (62.0%), and a database of best management practices and case-studies (60.8%) highly useful to facilitate adaptation in the Florida Keys.

In Tables 2 and 3 further empirical analyses based on ordered logistic regression models are reported. Two sets of models were constructed using multivariate analysis to explore the dominant factors underlying risk perception among Florida Keys decision makers. The first set reports the estimated likelihood of overall impacts (Table 2) and the second set reports the estimated likelihood of economic impacts (Table 3) in the Florida Keys. The objective is to see which group of decision makers is more likely to consider the overall and economic impacts of climate change in the Florida Keys more or less severe.

In Table 2, the dependent variable, *Overall Impact*, is an ordered categorical variable representing experts and decision makers' agreement with the statement 'climate change is real and impacts are being felt today' (1–4; 1 is Strongly Disagree, 2 is Slightly Disagree, 3 is Slightly Agree, 4 is Strongly Agree). The set of explanatory variables included experts and decision makers' concern and awareness of a variety of adverse ecological and socioeconomic impacts (e.g., *Concern*, *Abandon*, *Hurricane Intensity*, *Hurricane Frequency*, *and Land Loss*, see Table 1 for detailed

Table 2
Estimated Likelihood of Overall Impact of Climate Change in the Florida Keys (Ordered Logistic Regression Models).

	Model 1 Dep. Var.: overall impact		Model 2 Dep. Var.: overall impact		Model 3 Dep. Var.: overall impact		Model 4 Dep. Var.: overall impact	
Variable	Coefficient	Marginal effects	Coefficient	Marginal effects	Coefficient	Marginal effects	Coefficient	Marginal effects
Concern	0.499 (0.000)***	0.104 (0.000)***	0.436 (0.000)***	0.092 (0.000)***	0.652 (0.000)***	0.131 (0.000)***	0.538 (0.000)***	0.112 (0.000)***
Abandon	0.248 (0.004)***	0.052 (0.004)***	0.258 (0.002)***	0.054 (0.001)***	0.182 (0.055)*	0.037 (0.060)*	0.203 (0.025)**	0.042 (0.027)**
Hurricane Intensity	0.206 (0.008)***	0.043 (0.010)***			0.264 (0.002)***	0.053 (0.003)***		
Hurricane Frequency			0.237 (0.024)**	0.050 (0.027)**			0.292 (0.006)***	0.061 (0.007)***
Land Loss	0.036 (0.670)	0.007 (0.672)	0.025 (0.754)	0.005 (0.755)	0.029 (0.774)	0.006 (0.775)	0.017 (0.837)	0.004 (0.837)
Age					0.294 (0.147)	0.059 (0.143)	0.145 (0.483)	0.030 (0.479)
Gender					−0.654 (0.187)	−0.126 (0.172)	−0.626 (0.174)	−0.125(0.159)
Education					0.348 (0.033)**	0.070 (0.027)**	0.232 (0.137)	0.048 (0.121)
Experience					0.059 (0.016)**	0.012 (0.019)**	0.061 (0.009)***	0.013 (0.008)***
Profession					−0.207 (0.205)	−0.042 (0.193)	−0.143 (0.372)	−0.030 (0.359)
Affiliation					0.046 (0.732)	−0.009 (0.733)	−0.034 (0.949)	−0.007 (0.791)
N	192		196		169		172	
Wald chi^2	67.17		68.01		82.67		59.68	
Prob. > chi^2	0.0000		0.0000		0.0000		0.0000	
R^2	0.3625		0.3479		0.4185		0.3864	

Notes: ***, **, * imply significance at 1%, 5%, and 10% levels respectively; *p*-values in parentheses; intercept terms are suppressed.

Table 3
Estimated Likelihood of Economic Impact of Climate Change in the Florida Keys (Ordered Logistic Regression Models).

	Model 1 Dep. Var.: economic impact		Model 2 Dep. Var.: economic impact		Model 3 Dep. Var.: economic impact		Model 4 Dep. Var.: economic impact	
Variable	Coefficient	Marginal effects	Coefficient	Marginal effects	Coefficient	Marginal effects	Coefficient	Marginal effects
Concern	0.595 (0.000)***	0.094 (0.000)***	0.585 (0.000)***	0.088 (0.000)***	0.619 (0.000)***	0.089 (0.000)***	0.689 (0.000)***	0.092 (0.000)***
Household concern	0.153 (0.037)**	0.024 (0.048)**			0.172 (0.042)**	0.025 (0.073)*		
Tourism loss	0.146 (0.008)***	0.023 (0.010)***			0.138 (0.013)**	0.021 (0.015)**		
Reef Loss	0.143 (0.029)**	0.023 (0.043)**			0.133 (0.074)*	0.020 (0.090)*		
Property Loss			0.224 (0.023)**	0.034 (0.033)**			0.156 (0.073)*	0.021 (0.089)*
Insurance			0.191 (0.063)*	0.029 (0.078)*			0.270 (0.006)***	0.036 (0.022)**
Flooding			0.145 (0.162)	0.022 (0.161)			0.123 (0.218)	0.016 (0.205)
Age					−0.033 (0.789)	−0.005 (0.789)	−0.069 (0.600)	−0.009 (0.599)
Gender					−0.946 (0.009)***	−0.146 (0.013)**	−0.919 (0.015)**	−0.131 (0.019)**
Education					−0.016 (0.860)	−0.002 (0.860)	−0.016 (0.852)	−0.002 (0.853)
Experience					0.047 (0.004)***	0.007 (0.004)***	0.046 (0.006)***	0.006 (0.005)***
Profession					−0.132 (0.251)	−0.019 (0.274)	−0.139 (0.286)	−0.184 (0.311)
Affiliation					0.034 (0.721)	0.005 (0.720)	0.049 (0.581)	0.006 (0.582)
N	203		198		177		171	
Wald chi^2	128.23		131.86		124.86		120.28	
Prob. > chi^2	0.0000		0.0000		0.0000		0.0000	
R^2	0.2174		0.2319		0.2410		0.2569	

Notes: ***, **, * imply significance at 1%, 5%, and 10% levels respectively; *p*-values in parentheses; intercept terms are suppressed.

definitions of these variables). To check for robustness of findings, baseline models were also run with a number of socio-demographic factors (e.g., *Age*, *Gender*, *Education*, *Experience*, *Profession*, and *Affiliation*).

In Table 2, coefficients of several variables are found statistically significant in predicting agreement with *Overall Impact*. For instance, *Concern* (significant in Models 1 and 2 at 1% levels), is seen to be positively affecting agreement with overall impact. The finding is consistent after controlling for socio-demographic factors in Models 3 and 4. Ranking *Concern* higher by one unit in its scale increased the likelihood that experts and decision makers strongly agreed with the *Overall Impact* by 9–13% (see marginal effects for Models 1, 2 and 3, 4 in Table 2). These findings imply that experts and decisions makers who are more concerned about the impacts of climate change in the Florida Keys are more inclined to agree that climate change is real and impacts are being felt today.

Among related variables, *Abandon* (significant at 1% levels in Models 1, 2 in Table 2), *Hurricane Intensity* (significant at 1% levels in Model 1), and *Hurricane Frequency* (significant at 5% levels in Model 2) seen to be positively affecting agreement with overall impact. Findings are largely consistent after controlling for socio-demographic factors. As marginal effects indicate, ranking these impacts (*Abandon*, *Hurricane Intensity,* and *Hurricane Frequency*) higher by one unit in their corresponding scales increases agreement with overall impact by 4–5% for *Abandon* and Hurricane *Intensity,* and 5–6% for *Hurricane Frequency*. Regarding socio-demographic variables in Table 2, *Experience* is seen to be positive and statistically significant (at 1–5% levels in Model 3, 4). As marginal effects indicate, experts and decision makers with more experience by one year are 1–2% more likely to agree that climate change is real and impacts are being felt today. *Education* is positive and statistically significant in Model 3 (at 5% levels with a marginal effect of 7%). *Gender*, *Profession*, *Affiliation* and *Age* are not found to be statistically significant.

In Table 3, the dependent variable is *Economic Impact*, also an ordered categorical variable representing experts and decision makers' perceptions of a significant rise in sea level as a highly credible economic threat to the Florida Keys (0–10; 0 is not credible at all and 10 is highly credible). The set of explanatory variables included overall concern, household concern and awareness of a variety of adverse ecological and socioeconomic impacts (e.g., *Concern*, *Household Concern*, *Reef Loss*, *Tourism Loss*, *Property Loss*, *Insurance* and *Flooding*, see Table 1 for detailed definitions of these variables). In Table 3, coefficients of several variables are found statistically significant in predicting experts and decision makers' perceptions of sea-level rise as a highly credible economic threat. For instance, *Concern* (significant in Models 1 and 2 at 1% levels) and *Household Concern* (significant at 5% levels in Model 1) positively contribute to decision makers' perceptions of economic impacts of sea-level rise. These findings are consistent when controlling for socio-demographic factors in Models 3, 4. Ranking *Concern* higher by one unit increased the perceived likelihood of adverse *Economic Impact* by 9% (see marginal effects for Models 1–4 in Table 3). Similarly, ranking *Household Concern* higher by one unit increased the perceived likelihood of adverse *Economic Impact* by 2% (see marginal effects for Models 1 and 3 in Table 3).

Among other variables, *Tourism Loss* (significant at 1% levels in Model 1), *Reef Loss* (significant at 5% levels in Model 1), *Property Loss* (significant at 5% levels in Model 2), and *Insurance* (statistically significant at 10% levels in Model 2) all positively affect experts and decision makers' perceptions of sea-level rise as a highly credible economic threat. As marginal effects indicate, ranking these impacts (*Tourism Loss*, *Reef Loss, Property Loss,* and *Insurance*) higher by one unit in their corresponding scales increase the likelihood that experts and decision makers perception of adverse *Economic Impact* by 2% for tourism and reef loss, 3–9% for property loss, and 2–8% for insurance.

Again findings are robust after controlling for socio-demographic factors in Table 3. Consistent with prior risk-related research (e.g. Gustafson, 1998), *Gender* is found to be negative and statistically significant (at 1–5% levels in Models 3, 4) implying male experts and decision makers on average underestimate the impacts compared with their female counterparts. As marginal effects indicate in Table 3, male respondents are 13–15% less likely to perceive the credibility of adverse *Economic Impact*. As seen in Table 2, *Experience* is positive and statistically significant (at 1% levels in Models 3, 4). Experts and decision makers with more experience in their profession are more likely to consider that the economic threat of sea-level rise is a highly credible risk. However, *Age*, *Education, Profession and Affiliation* are not statistically significant.

In Summary, overall concern and risk perception regarding the likely abandonment of parts of the Florida Keys to rising seas, more frequent and intense hurricanes all significantly affected the agreement with *Overall Impact* (experience and education were

also significant). For *Economic Impact*, overall concern about climate change in the Florida Keys, concern about household well-being (regarding health, finances, property) and perceptions regarding loss of tourism revenues, loss of coral reefs, private property loss and higher insurance premiums all significantly affect the credibility of economic impact. Respondent's gender and experience also significantly affect their perception of adverse economic impact of sea-level rise in the Florida Keys.

6. Discussion and conclusions

Experts and decision makers who are involved in coastal resources management on a day-to-day basis learn from their experiences and update their information base through an iterative process (Morgan et al., 2001). Analyzing experts and decision makers' risk perceptions and preferences for response options can provide guidance for facilitating adaptation (Lowe and Lorenzoni, 2007). Given experts and decision makers' capacity to learn with experience (e.g., experimentation, observation, assessment and refinement) and their ability to tap reservoirs of institutional memory (i.e., extrapolating from existing knowledge structures built upon previous learning), their risk perceptions are likely to be more robust to detect climate change signals from noises(ORCAS, 2005). In the presence of uncertainty, relevant experts and decision makers are better equipped to make complex value judgments to evaluate adaptation strategies(Tribbia and Moser, 2008; Moser and Luers, 2008).

Over the next few decades, coastal communities should anticipate substantial changes to ecological, cultural, and socioeconomic systems(Reilly and Schimmelpfennig, 2000; Smith, 2003). Against this backdrop survey-based research can provide systematic information and facilitate risk communication for local planning agencies of vulnerable coastal communities. Analysis of survey responses from experts and decision makers serving the Florida Keys in our case study reveals deep concern about climate change and sea-level rise, including the threat to local household well-being. Experts and decision makers in the Florida Keys are currently operating with limited information, direction and leadership, and they lack an institutional framework necessary to shape and execute adaptation policies and management actions. A large majority of respondents consider additional funding and assistance for climate science and adaptation, better intergovernmental organization and public workshops will be highly effective to support adaptation.

These results underscore the need for a variety of new types of information, training, organizational and financial inputs to implement adaptation measures. Potential information-related adaptation measures include conducting county-wide local vulnerability assessments; updating documentation of elevations (including critical infrastructure, e.g. roadways, water and sewage systems) and flood maps; locally downscaled modeling of sea-level rise projections coupled with storm surge risks; and estimating the costs and benefits of very specific adaptation measures (including the costs of inaction). Organizational measures include exploring effective and well-coordinated strategies for strengthening adaptive capacity, e.g. expanding local professional training, workshops, and participation in broader state and federal climate change initiatives; supporting public education, community discussion forums and targeted outreach activities with affected stakeholder groups; incorporating climate change impact assessments in local and regional planning agendas (land-use change, zoning regulations, density restrictions, building codes, setbacks along shoreline, and elevations standards etc.). Financial and institutional measures may include creating financing mechanisms for adaptation measures, requiring institutional mandates and funding provisions for local agencies to incorporate climate change impact assessments in planning and development, establishing stricter criteria for infrastructure development in vulnerable areas, modifying wetland conservation and restoration policies, adjusting species and habitat protection plans etc.(Bigano et al., 2008; Adger et al., 2005a; Lowe and Lorenzoni, 2007).

Proactive adaptation measures can assist vulnerable communities better cope with adverse environmental and socioeconomic impacts. However, experts and decision makers need an implementation framework to articulate risk evaluations and prioritize responses in rationalizing behavioral changes and justifying the budget (NRC, 2009; Marx et al., 2007). Delayed adaptation by government agencies, communities, and industries can reduce the effectiveness of responses(Klein and Persson, 2008; Burton et al., 2002). It is essential to improve our understanding of adaptation behavior using multidimensional research tools analyzing local vulnerability (Smith et al., 2009; Oppenheimer et al., 2006).[10] Similar studies systematically documenting experts and decision makers' responses and preferences in diverse contexts can be a part of a social science research toolkit to facilitate adaptation measures.

The role of leadership is to link the tools of vulnerability analysis, risk assessment, and risk perception, to develop risk management options for dealing with climate change. Experts and decision makers need to find cost-effective ways that produce optimal ecological and socioeconomic benefits by setting new standards and forging new partnerships (Pfeffer et al., 2008). In the face of increasing vulnerability and complexity, new decision-making criteria, institutional arrangements and funding mechanisms (e.g. vulnerability and resilience information, tax, subsidy and insurance policies, investment in physical and social infrastructure and critical habitat) need to be pursued to secure a more sustainable future for coastal communities (Smith, et al., 2009; McDaniels, 2008; Berkes, 2007). This involves setting new priorities, for governments and society in general, incorporating climate risks and guiding the public and private sectors toward risk reducing measures (Pfeffer et al., 2008). By learning how Florida Keys' experts and decision makers are anticipating and planning for these challenges, we attempt to provide information for enhancing local adaptive capacity. We expect this study will provide useful inputs for understanding the near and long-term challenges relating to adaptation and a greater sense of urgency for translating concern into real-world world action.

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[10] To communicate risk and facilitating adaptive management, some other approaches such as management strategy evaluation (MSE) and systems approach framework (SAF) can also be useful. We thank an anonymous reviewer for pointing out these approaches.

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