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Changes in adaptive capacity of Kenyan fishing communities

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Coastal communities are particularly at risk from the impacts of a changing climate[1]. Building the capacity of coastal communities to cope with and recover from a changing environment is a critical means to reducing their vulnerability[2,3]. Yet, few studies have quantitatively examined adaptive capacity in such communities. Here, we build on an emerging body of research examining adaptive capacity in natural resource-dependent communities in two important ways. We examine how nine indicators of adaptive capacity vary: among segments of Kenyan fishing communities; and over time. Socially disaggregated analyses found that the young, those who had migrated, and those who do not participate in decision-making seemed least prepared for adapting to change in these resource-dependent communities. These results highlight the most vulnerable segments of society when it comes to preparing for and adapting to change in resource-dependent communities. Comparisons through time showed that aspects of adaptive capacity seemed to have increased between 2008 and 2012 owing to higher observed community infrastructure and perceived availability of credit.

Climate change is expected to profoundly impact many tropical coastal communities[1]. For example, increased sea surface temperature is altering the productivity and distribution of marine ecosystems, with potentially cascading impacts on people's livelihoods in areas dependent on fisheries[4,5]. Coral reefs support millions of people through fisheries[6], but are highly susceptible to increases in sea temperatures that can cause coral bleaching (Fig. 1). However, the magnitude and nature of these climate change impacts on people will vary depending not only on the increases in temperature, but also on the social dimensions of vulnerability[7–9]. People's vulnerability to climate change is often conceptualized as being made up of three components: exposure to change (for example, the increases in temperature); sensitivity to change (for example, how much people would be affected by temperature increases); and the capacity to anticipate, respond to, and recover from change (referred to as adaptive capacity)[7]. Although exposure and sensitivity determine the potential impact of a climate-induced change, adaptive capacity can have a major influence on the eventual impact on individuals and society.

Adaptive capacity, which is the focus of this study, is a latent characteristic that reflects people's ability to anticipate and respond to changes, and to minimize, cope with, and recover from the consequences of change[10,11]. Adaptive capacity refers specifically to the preconditions that enable adaptation to change[12]. For example, people with low adaptive capacity may have difficulty adapting to change or taking advantage of the opportunities created by changes in the availability of ecosystem goods and services stimulated by climate change. Those with high adaptive capacity, on the other hand, may be better able to convert human, social, financial, natural or physical resources that exist into successful adaptation outcomes. Consequently, enhancing people's adaptive capacity to reduce their vulnerability is a key element of policy responses to a broad spectrum of uncertain external threats to a fishery[13] that include climate-induced change, as well as impacts of globalization and environmental degradation. Yet, considerable gaps remain in our understanding of where any capacity building efforts should be prioritized and how people's adaptive capacity is likely to change through time.

An emerging body of empirical research explores the capacity of coastal communities to adapt to the impacts of climate change on coral reef fisheries[8,9,14,15]. We build on this work in two key ways. First, we examine whether and how measures of local-scale adaptive capacity vary among different social groups (migrants, the poor, the elderly, and those involved in decision-making). Second, we examine how adaptive capacity changes over time. As a lens though which to explore these issues, we examined indicators of the capacity of marine resource users to adapt to temperature-induced climate change impacts on coral reef fisheries. We interviewed 293 marine resource users from eight communities along the Kenyan coast in 2008 and 2012 (Fig. 2; Methods). Our interviews examined nine indicators of adaptive capacity: human agency; access to credit; occupational mobility; occupational multiplicity; social capital; material style of life; gear diversity; community infrastructure; and trust (Table 1; Methods).

Most vulnerability assessments in tropical coasts focus on how different countries (for example, refs 4,16) or communities (for example, refs 8,9,14) have differing levels of exposure, sensitivity and adaptive capacity. However, vulnerability is often socially disaggregated, whereby social groups such as migrants, the elderly and the poor are expected to have higher levels of vulnerability[17,18]. Critically, disaggregated analyses allow exploration of vulnerable classes or groups of people, which may allow support for climate adaptation to be targeted to those in greatest need. Despite widespread recognition that within-community differences in wealth, power and social position lead to differential vulnerability and resilience, disaggregated analysis is rare in vulnerability studies[19,20]. As a starting point for investigating these issues, we ask 'how do key indicators of adaptive capacity differ among marine resources users on the basis of age, whether they are a migrant, participation in decision-making, and wealth (as indicated by fortnightly expenditures)?'

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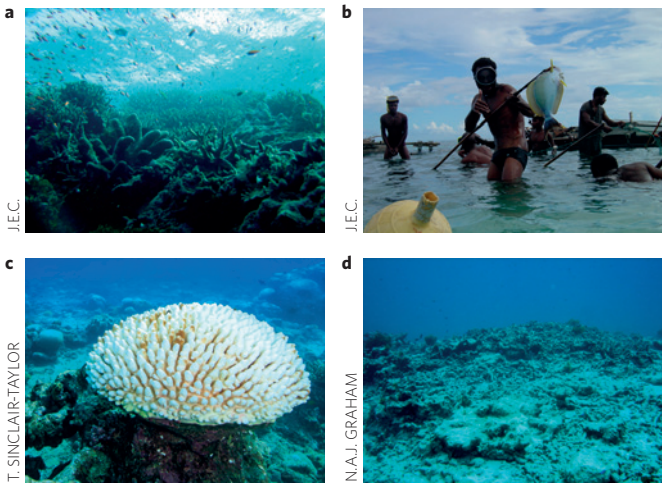

Figure 1 | The impacts of climate change on coral reef fisheries. a, Coral reefs provide critical habitat for a range of fish species. **b**, Coral reef fisheries directly employ over 6 million people, and substantially contribute to food security in many tropical countries[6]. **c**, When exposed to excessive temperatures, corals expel their coloured algal symbiont, leaving the white (that is, bleached) skeleton behind, often resulting in coral mortality[25]. **d**, Over time, the structural complexity of a bleached reef can collapse, meaning the reef can no longer support vibrant fishing-based economics and cultures[25,26].

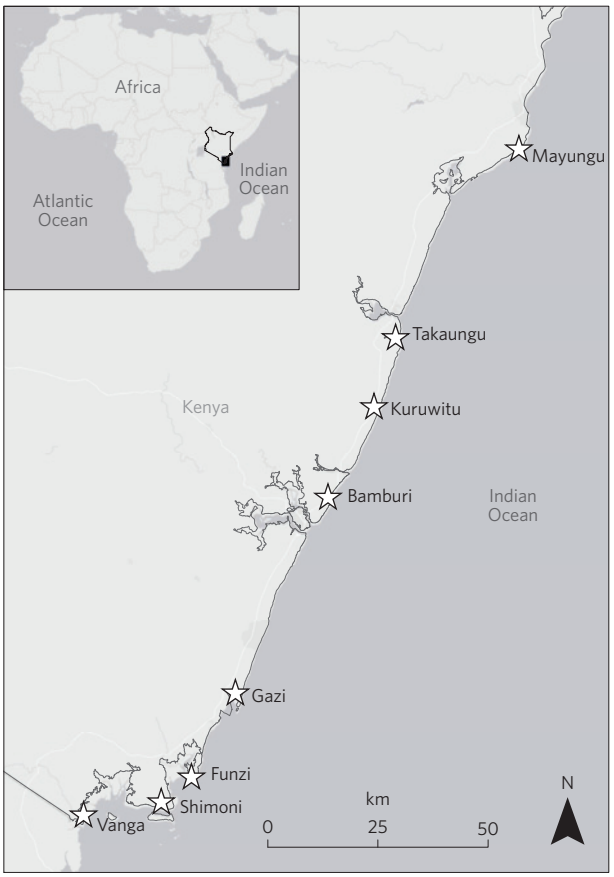

Figure 2 | Map of study sites.

We found that key components of adaptive capacity were socially differentiated among segments of the Kenyan fishers we surveyed (Fig. 3a–d and Supplementary Table 1). Adaptive capacity was differentiated by age; older individuals had greater occupational multiplicity and social capital than the youngest quartile, but, they had lower material wealth (Fig. 3a and Supplementary Table 1). Additionally, migrants had lower adaptive capacity than non-migrants, indicated by significantly lower gear and occupational multiplicity, and understanding of human agency (Fig. 3c). This echoes studies of fishers in Central Africa in which migrants, although not poorer in a material sense were found to have higher vulnerability[18]. A caveat to these findings is that migrants are likely to have greater willingness to be geographically mobile, which may contribute to their adaptive capacity in a way that is not captured in this analysis.

People with least participation in local decision-making had significantly lower occupational multiplicity and gear diversity, trust, and social capital (Fig. 3d). This result importantly identifies political marginalization of a section of society who also has the lowest adaptive capacity. These people do not participate in decision-making and have limited agency to influence resource governance and how it affects them, and are also least able to respond to negative effects. This impacts their vulnerability in two ways: not only is their adaptive capacity low, but also decisions are unlikely to consider their interests or protect their livelihoods (which may increase their exposure). Interestingly, low participation was not related to material wealth (Fig. 3e), suggesting that such political and social marginalization would go undetected by a simple uni-dimensional monetary analysis of poverty. Wealth (as indicated by expenditure) was significantly related to community infrastructure (Fig. 3b).

Adaptation processes are, by nature, dynamic. Yet, the ways in which people's capacity to adapt changes over time are poorly understood. Most assessments of adaptive capacity are static and the temporal dynamics of vulnerability are rarely studied explicitly[21]. Here, we ask 'how do key indicators of adaptive capacity in coastal communities change over a four-year period?'. We found that two key indicators of adaptive capacity (availability of credit and community infrastructure) seemed to rise slightly but significantly in our study sites between 2008 and 2012 (Fig. 3e and Supplementary Tables 1 and 2). Increases in community infrastructure were apparent in six of the eight communities (with one other remaining constant and another decreasing slightly). The types of infrastructure change were broad-based (13 of the 20 indicators had changed in at least one community), with multiple communities seeing increases in water, electricity, Internet, transportation and/or emergency services. Our analytical approach does not allow us to make statistical inferences about causation; however, it is plausible that these changes can be understood in the context of development processes and state support for infrastructure. Likewise, access to credit increased in every community (Supplementary Table 2), though no other indicators changed significantly over time across the study sites (Fig. 3 and Supplementary Tables 1 and 2). Although we cannot demonstrate causality, this increase in credit could plausibly be explained by the establishment of microfinance institutions in many of our study communities (for example, Bamburi, Kuruwitu, Mayungu), which seem to have had a measurable effect on people's reported access to credit. All of our study sites received some form of development assistance over this four-year period, which includes involvement of non-governmental organizations (such as Act, Change, Transform (ACT!)), International donor assistance (for example, Global Environmental Fund- and World Bank-funded Kenya Coastal Development Projects, and the European Union-funded Community Development Trust Fund), and/or government initiatives (such as the county-level decentralization, and Beach Management Units). In our example of Kenyan marine resource users, some adaptive capacity components (infrastructure and credit) seem to have been enhanced as a result of

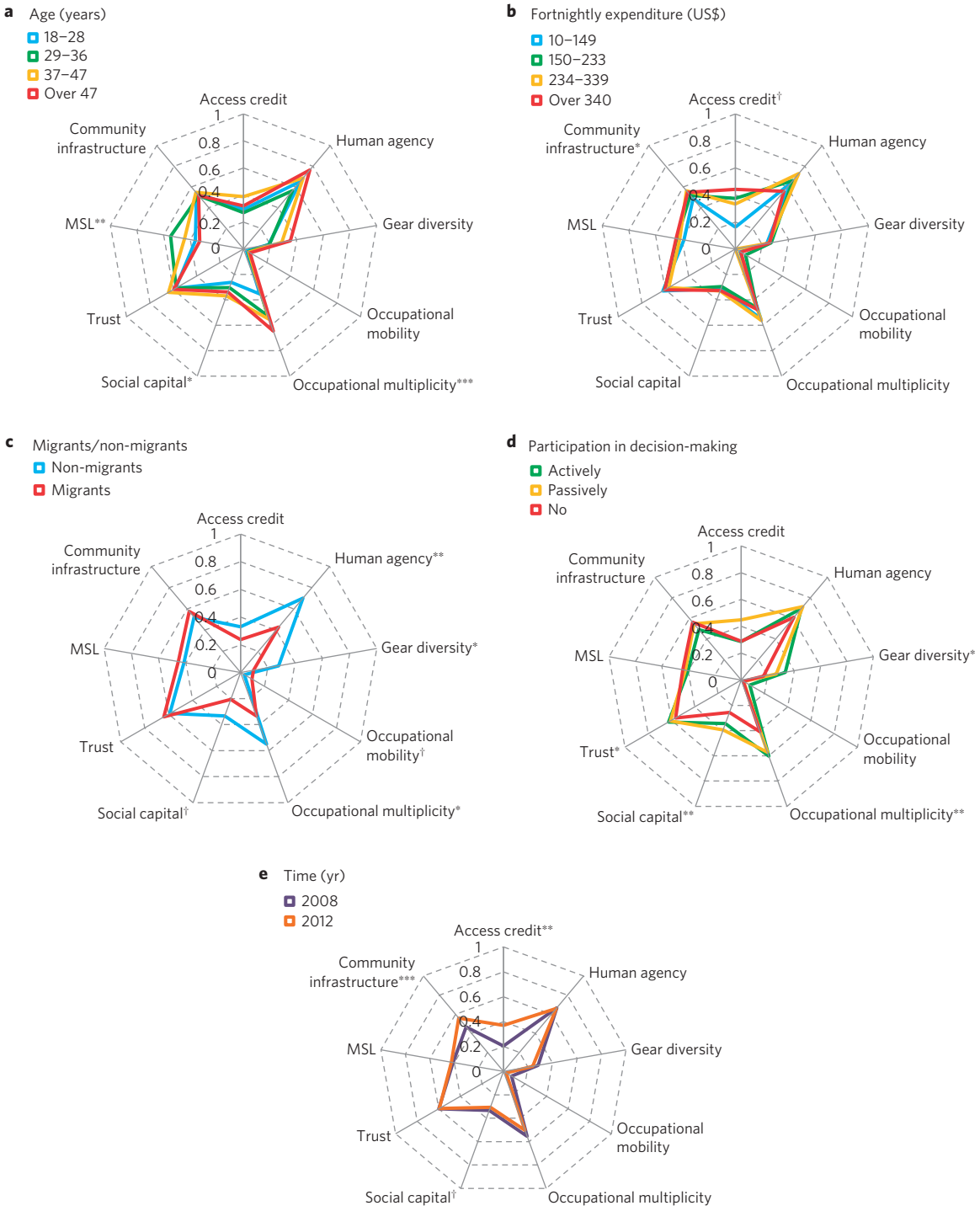

Figure 3 | Differences in adaptive capacity over time and among different segments of Kenyan fishing communities. a–e, Spider plots to look at the variation of adaptive capacity indicators among factors aggregated across all sites by age (**a**), by household expenditure (**b**), between migrants and non-migrants (**c**), among those with different levels of participation in community decision-making (**d**) and over time (**e**). ***$p=0.001$; **$p=0.01$; *$p=0.05$; †$p=0.1$. MSL, material style of life.

specific interventions to establish infrastructure and provide credit potentially contributing to higher adaptive capacity. Meanwhile, other adaptive capacity indicators have not shown a consistent directional change over a four-year period.

It is very important to emphasize the fact that we have used theoretically informed indicators of adaptive capacity, but there are limitations to this approach and further work is needed to empirically test the relationship between these indicators and actual adaptive behaviour in response to gradual change (for example, ref. 22) or extreme events (for example, ref. 23). Further research into adaptation in action is also needed to understand the mechanisms by which these different components support adaptive action and interact with one another. This type of mechanistic investigation would be best informed by panel data (that is, tracking individuals over time) collected before and after a disturbance (such as a coral bleaching event). Similarly, attempts to build adaptive capacity could be evaluated by randomized field experiments, with control and treatment groups monitored over time[24].

Table 1 | Indicators of social adaptive capacity*.

Indicator	Description	Data type
Human agency	Recognition of humans as causal agents impacting marine resources (measured by content-organizing responses to open-ended questions about what could impact the number of fish in the sea).	Binary
Access to credit	Measured as whether the respondent felt he or she could access credit through formal institutions or informal means (for example, family, friends, middlemen/dealers).	Binary
Occupational mobility	Previously experienced vertical occupational mobility (that is, moved to a better job)[27] (measured as whether the respondent had experienced a change in jobs in the past five years, to an occupation they preferred).	Binary
Occupational multiplicity	The total number of person-jobs in the household.	Ordinal (3 categories)
Social capital	Measured as the total number of community groups the respondent belonged to.	Ordinal (4 categories)
Material style of life	A material style of life indicator measured by factor analysing whether respondents had 15 household material possessions such as vehicle, electricity and the type of walls, roof and floor.	Continuous
Gear diversity	Whether the respondent used more than one type of fishing gear.	Binary
Community infrastructure	Infrastructure measured by summing the number of community-scale infrastructure items present. These were: banking, daily food market, daily newspaper, dentist, doctor, electricity, emergency services (fire/ ambulance/ search/ rescue), fish freezer (community or private), gas station, paved road, hospital, hotel/inn, ice machine, Internet facilities, jetty/wharf, mechanic/garage, medical clinic, pharmacy, piped water, police station/booth, primary school, public transportation, restaurant, secondary school, stand pipe, weekly food market.	Continuous
Trust	Measured as an average of Likert scale responses to questions about how much respondents trusted: community members, local leaders, police and local government. Community trust was an average of these four Likert scale scores.	Continuous

*Table adapted from refs 9,10,15.

This study shows how indicators of adaptive capacity within a particular livelihood group are socially differentiated by age, migrant status and participation, and whether they have changed amongst the sampled population over time. We found that certain aspects of adaptive capacity (access to credit and community infrastructure) seemed to increase in our study sites between 2008 and 2012. Additionally, our analysis underscores that vulnerability can be socially differentiated. Specifically, we found that youth, migrants, and those who did not participate in decision-making had specific aspects of adaptive capacity that were relatively low (Fig. 3). Although we could not demonstrate causality, our results suggest that community-level interventions such as provision of infrastructure or services such as credit facilities may help to increase aspects of adaptive capacity over time. However, they also underscore that there may be different needs between (for example) younger and older people; migrants and non-migrants; and those already involved in decision-making and those that are not.

Methods

Methods and any associated references are available in the online version of the paper.

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Author contributions

J.E.C. designed the research in consultation with T.M.D. and E.H.A. J.E.C. and A.W. conducted the fieldwork. C.H. conducted the analyses. J.E.C., C.H., C.C.H., T.M.D., N.M., A.W. and E.H.A. participated in a workshop and wrote the manuscript.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to J.E.C.

Competing financial interests

The authors declare no competing financial interests.

Methods

Study sites. We conducted social vulnerability assessments of 10 communities along the Kenyan coast in 2008, which were randomly sampled from a list of pilot sites undergoing changing coastal governance arrangements[8,28]. In 2012, we revisited eight of these communities (pirate and terrorist activity prevented us from re-visiting the other two sites).

Sampling. We employed a combination of surveys targeted at resource users' (fishermen and fish traders) households and semi-structured interviews with community leaders and fishermen. We conducted a total of 293 household surveys, and at least two key informant interviews per site. All interviews were conducted in Swahili by trained interviewers. We employed a simple random sampling strategy within a defined group (for example, resource users) for the household surveys, whereby respondents were randomly selected from lists of resource users provided by local leaders. Lists were cross-referenced with other fishermen and fish traders for accuracy.

Data collection. On the basis of these surveys, we generated 9 socioeconomic indicators of social adaptive capacity (Table 1), which are adapted from previous studies[8,9,14]. In addition, we used our household survey to examine four covariates: age of respondent, measured in years; fortnightly expenditures (converted to US$, and adjusted for inflation); migration status, measured as a binary metric of whether the respondent was born in the village (0) or somewhere else (1); and whether the respondent was actively involved in local decision-making (that is, attended meetings regularly and spoke), passively involved (attended but did not voice opinions), or not involved.

Analysis. We conducted two types of analysis. First, we examined whether there were statistical differences in adaptive capacity indicators between groups based on: age; fortnightly expenditure; migrant/non-migrant status; and those who were actively, passively, or not involved in local decision-making processes. We fitted linear mixed models for our continuous response variables, binary logistic mixed models with a logit link for our binary response variables, and multinomial logistic mixed models with a cumulative logit link for our ordinal response variables (Table 1 and Supplementary Table 1). We generally included year as a fixed effect and community as a random effect (except when community was a fixed factor; Supplementary Table 1). We used spider plots to visualize these relationships.

Second, we examined whether each adaptive capacity indicator had changed over time in the eight communities where we had data from both 2008 and 2012. Our study examined data from independently drawn cross-sections of a population sampled at two points in time, in what are referred to as pseudo-panel data (as opposed to panel data, which track individuals over time). Pseudo-panel data are generally analysed by comparing the mean or median between the time periods, or between 'cohorts' of individuals within each time period[29,30]. Drawing on the former, we used linear mixed models for continuous adaptive capacity indicators, and generalized (binomial family) linear mixed models for binary or ordinal indicators: each adaptive capacity indicator was the dependent variable, with year as the independent variable, and 'community' as a random factor (Supplementary Table 1). This tested whether the mean of each indicator varied significantly over time, while explicitly accounting for the differences between communities.

Our research was an initial attempt to use applied field data to inform key debates about adaptive capacity, but the applied nature of the data and research design means that there are several caveats that should be considered: our design does not allow us to infer causation, which would require a proper experimental design, and/or the use of instrumental variables; there is potential for biased and inconsistent estimates because some of our indicators relied on recall data by respondents.

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